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Economic and climate effects of low-carbon agricultural and bioenergy practices in the rice value chain in Gagnoa, Côte d'Ivoire

FAO AGRICULTURAL DEVELOPMENT ECONOMICS TECHNICAL STUDY



Economic and climate effects of low-carbon agricultural and bioenergy practices in the rice value chain in Gagnoa, Côte d'Ivoire

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Preface

Climate-smart agriculture (CSA) is a comprehensive theoretical and practical approach that helps guide actions needed to transform and reorient agricultural systems, in order to effectively support development and ensure food security in a changing climate. CSA aims to simultaneously tackle three main objectives: sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change and reducing and/or removing greenhouse gas (GHG) emissions where possible.

The Food and Agriculture Organization of the United Nations (FAO), as a specialised technical agency serving its Member States, holds a valuable expertise regarding agricultural challenges. The organization acts at different governance levels, both through technical assistance and the implementation of projects. A technical cooperation project with the Republic of Côte d'Ivoire entitled "*Contribution à l'atteinte des objectifs liés au changement climatique et à la sécurité alimentaire via l'agriculture intelligente face au climat en Côte d'Ivoire – cas de la filière riz*" has lead FAO to work with its governmental partners from the agriculture, energy, environment and forestry sectors to sustainably increase rice productivity, promote low carbon agriculture and use rice by-products to replace charcoal.

Rice has become a staple food over the past years in Côte d'Ivoire but production remains low. This has led to an inadequacy between supply and demand. The approach adopted by this FAO project harnesses expertise from a range of technical areas related to FAO's core mandate and helps to fill the gap caused by years of overlooking the crucial importance of the domestic energy sector. This FAO project aims at achieving three objectives, namely (i) sustainably enhance productivity of both flooded and rainfed rice, as well as stakeholders' incomes acting along the value chain (ii) strengthen resilience of small-scale farmers against climate change thanks to the Farmers Field Schools training method and (iii) improve the carbon footprints of the two value chains in order to highlight the potential of rice husk briquettes as a replacement for charcoal, thus decreasing GHG emissions from charcoal production.

This technical study presents the results of the carbon footprint of two rice value chains and the use of by-products for domestic energy. FAO remains fully committed to support efforts that sustainably increase staple food productivity while decreasing GHG emissions and improve access to energy so that communities can cook their food in a sustainable way.

Acknowledgements

This publication documents the changes in GHG emissions of the rice value chain in Gagnoa in Côte d'Ivoire following a technical cooperation programme (TCP/IVC/3601). The programme has established key CSA practices such as the system of rice intensification and the production of bioenergy from rice by-products to replace charcoal. This is a joint publication of FAO's Agricultural Development Economics (ESA) and Climate and Environment (CBC) Divisions with crucial support from the team working on FAO's Strategic Programme 4 – Enable inclusive and efficient agricultural and food systems.

The technical study was written by Florent Eveillé (CBC), Laure-Sophie Schiettecatte (ESA) and Anass Toudert (ESA) under the overall supervision of Germain Dasylyva, FAO representative in Côte d'Ivoire, Olivier Dubois (CBC), David Neven (ESA), Louis Bockel (FAO Regional Office for Africa [FAORAF]) and Adriana Ignaciuk (ESA).

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The authors would also like to thank the staff of the *Agence Nationale d'Appui au Développement Rural* (National Agency to Support Rural Development [ANADER]), the *Office National pour le Développement de la Riziculture* (National Office for the Development of Rice Cultivation [ONDR]), the *Ministère de l'Agriculture et du Développement Rural* (Ministry of Agriculture and Rural Development [MADR]) and the *Ministère de l'Environnement et du Développement Durable* (Ministry of Environment and Sustainable Development [MINEDD]) of Côte d'Ivoire, and the Gagnoa rice platform for their very valuable support in the data collection process.

The final version of this technical study was copyedited by Nilar Chit Tun (ESA) and benefitted from the support of Daniela Verona (ESA) for the design and publishing coordination.

Acronyms

ADERIZ	<i>Agence pour le Développement de la filière Riz en Côte d'Ivoire</i> (Agency for the Development of the Rice Value Chain in Côte d'Ivoire)
ANADER	<i>Agence Nationale d'Appui au Développement Rural</i> (National Agency to Support Rural Development)
CARD	Coalition for African Rice Development
CGIAR	Consultative Group on International Agricultural Research
CNRA	<i>Centre National de Recherche Agronomique</i> (National Center for Agronomic Research)
CSA	Climate-smart agriculture
DSDI	<i>Direction des Statistiques, de la Documentation et de l'Informatique du Ministère de l'Agriculture et de l'Institut Nationale de la Statistique</i> (Directorate of Statistics, Documentation and Information)
EX-ACT	EX-Ante Carbon-balance Tool
EX-ACT VC	EX-Ante Carbon-balance Tool for value chain
FAC	<i>Fédération des Associations des Consommateurs Actifs</i> (National Federation of Consumer Association)
FAO	Food and Agriculture Organization of the United Nations
FIRCA	<i>Fonds Interprofessionnel pour la Recherche et le Conseil Agricole</i> (Inter Professional Fund for Agricultural Research and Extension)
GHG	Greenhouse gas
GWP	Global Warming Potential
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
ITC	International Trade Center
JICA	Japan International Cooperation Agency
MADR	<i>Ministère de l'Agriculture et du Développement Rural</i> (Ministry of Agriculture and Rural Development)
MEF	<i>Ministère des Eaux et Forêts</i> (Ministry of Water and Forestry)
MINEDD	<i>Ministère de l'Environnement et du Développement Durable</i> (Ministry of Environment and Sustainable Development)
MPEDER	<i>Ministère du Pétrole, de l'Energie et du Développement des Energies Renouvelables</i> (Ministry of Oil, Energy and the Development of Renewable Energies)
NGOs	Non-governmental organizations
NPK	Nitrogen, phosphorus and potassium
ONDR	<i>Office National pour le Développement de la Riziculture</i> (National Office for the Development of Rice Cultivation)

SNDR	<i>Stratégie Nationale de Développement de la filière Riz</i> (National Rice Strategy)
UNFCCC	United Nations Framework Convention Climate Change
XOF	CFA franc (<i>Banque Centrale des États de l'Afrique de l'Ouest</i> [BCEAO])

Units and chemical formulae

CH₄	Methane
CO₂	Carbon dioxide
CO₂-e	Carbon dioxide equivalent
N₂O	Nitrous oxide
tCO₂-e	Tonne of CO ₂ equivalent
tCO₂-e/ha/yr	Tonne of CO ₂ equivalent per hectare per year
tCO₂-e/tonne/km	Tonne of CO ₂ equivalent per tonne per kilometre

Executive summary

The present technical study provides the results and a summary of the most important lessons learned from implementation of a series of climate-smart agriculture (CSA) practices in the rice supply chains of Gagnoa in Côte d'Ivoire. The aim of the CSA practices was to enhance the adaptive capacity of the rice sector against climate change, as erratic rainfall patterns and droughts events have, historically, significantly impacted production. This study relies on data collected at farm and processing levels during two field missions to two pilot sites in August 2017 and September 2018 under the project *“Contribution à l'atteinte des objectifs liés au changement climatique et à la sécurité alimentaire via l'agriculture intelligente face au climat en Côte d'Ivoire – cas de la filière riz”*. This project is a Technical Cooperation Project implemented by the Food and Agriculture Organization of the United Nations (FAO) from 2016 and 2018.

The objective of this FAO project was to disseminate CSA techniques at production level and encourage the production of bioenergy from residues and by products in the rice sector. This FAO project revolved around (i) taking into consideration potential opportunities for climate change mitigation and adaptation; (ii) the implementation of a pilot study on appropriate CSA practices and bioenergy production; (iii) the capacity building of stakeholders on CSA; and (iv) encouraging the development of CSA and bioenergy policy and regulatory framework.

The first comprehensive issue tackled was the reduction of greenhouse gas (GHG) emissions from rice production while increasing productivity, thus reducing the rice carbon footprint, through the adoption of CSA practices on two pilot sites. The analysis focused on the implementation of the CSA practices in the rainfed rice pilot site increased both productivity and soil carbon sequestration rates, with the white rice carbon footprint changing from 0.89 tonnes of CO₂ equivalent (tCO₂-e) to -0.70 tCO₂-e per tonne of white rice. The change in the sign indicates that the production of rainfed rice shifted from being a net source of emissions to a net sink of emissions. In the irrigated rice pilot site, increases in yields compensated for a rise in GHG emissions from the CSA practice of additional manure application. The irrigated white rice carbon footprint decreased by 1.08 tCO₂-e per tonne of white rice with implementation of CSA practices.

The second issue addressed the adoption of traditional bioenergy sources (rice husks) as the primary source of energy for cooking. Currently 82 percent of the population of Côte d'Ivoire relies on wood or charcoal as the primary source of energy for cooking. This FAO project supported the transformation of available rice husk into carbonized briquettes to replace charcoal. The results of the analysis showed that together, the two pilot sites were able to produce 165 tonnes of briquettes per year. This is equivalent to 4 percent of the available rice husk feedstock in Gagnoa, and from an energy perspective, is equal to 1 414 tonnes of woody biomass or 5.4 ha of naturally regenerated forest.

The results demonstrated that existing policies support rice production and marginally, its residues transformation. While the benefits of agricultural residues management practices are generally understood, incentives for the development of a modern bioenergy sector in Côte d'Ivoire are scattered. Other areas of the value chain such as post-harvest and storage practices received little attention. Stable and predictable policies should encompass all steps of the agricultural value chains (including residue management) could highlight areas for economic growth. These policies should also consider the carbon footprint of the commodities together with the overall greenhouse gas emissions. These policy schemes would also support Côte d'Ivoire's national “zero deforestation policy in agriculture” through the energy recovery of agriculture by-products, ecosystem restoration, certification of “zero deforestation” products on markets and the involvement of all commodity stakeholders (coffee, cocoa, palm oil, rubber and subsistence crops).



1 Introduction

The Ivorian government recognized rice as a strategic and priority commodity in its latest national agricultural development plan. Once a rice exporter, the progressive disengagement of the government from the rice sector exposed the country to rice price instability and spend about USD 500 million a year to meet its own requirement importing rice from mainly Asia. To put an end at this situation the government adopted a national rice development strategy, 2012–2020, led by the National Rice Development Office (ONDR) to target an increase of the national rice production.

This technical study is based on a project implemented by FAO (Technical Cooperation Project 3601: *“Contribution à l’atteinte des objectifs liés au changement climatique et à la sécurité alimentaire via l’agriculture intelligente face au climat en Côte d’Ivoire – cas de la filière riz”*) over an 18-month period between 2016 and 2018. This FAO project aimed at enhancing the adaptive capacity of Côte d’Ivoire against climate change, in particular in the rice value chain, where erratic rainfall patterns and drought events affect its production. It sought to disseminate CSA techniques, including the production of bioenergy from residues and by products in the rice sector. The project revolved around (i) taking into consideration potential opportunities for climate change mitigation and adaptation; (ii) the implementation of a pilot study on appropriate CSA practices and bioenergy production; (iii) the capacity building of stakeholders on CSA; and (iv) encouraging the development of CSA and bioenergy policy and regulatory framework.

The findings of this study are the result of the implementation of a series of CSA practices throughout the project, including the production of bioenergy from residues and by products in the rice sector, their impact on yields, system resilience and GHG emissions at production and processing.

The first chapter of this document focuses on the different challenges within the rice sector in the country. It relates with the different policies, in particular the national rice strategy running from 2012 to 2020, the national institutions framework of the rice sector including non-state actors, their roles and the different linkages of the rice supply chain. Since 2008, the production of milled rice has slowly increased, but is still below the targets of the national rice development strategy. Rice imports increased in parallel to consumption trends, driven by a rapid urbanization and high poverty level (46 percent in 2015), which, together with the cooking advantages of the rice, made it the ideal staple food.

The national rice strategy aims to significantly reduce rice imports by making the country auto sufficient with its own production, while at the same time increasing employment in the rice value chains and improving producers’ revenue. Two pillars define this strategy: (i) the technical support for the rice production to provide certified seeds and good management practices on fertilizers and intercropping; and (ii) valorisation of the national rice by the rehabilitation of irrigation systems, increase of rice areas and extension services to support farmers in terms of seeds, machinery and technical support. Within this strategy, the Agency for the Development of the Rice Value Chain in Côte d’Ivoire (ADERIZ) is in charge of the development of the national rice production of Côte d’Ivoire through the coordination of the different actors involved in the rice value chain, and aims to support the production and the profitability of the national rice sector. In parallel, the National Agency to Support Rural Development (ANADER), a semi-public company with a 35 percent stake by the Republic of Côte d’Ivoire and other shares owned by agricultural trade unions and private companies, works at the development of extension services for farmers and other infrastructures.

The second chapter covers the rice sector, from governance to actors, production and its by-products highlighting the potential in bioenergy from the rice husks briquettes. Côte d'Ivoire holds significant rice areas, mainly as rainfed rice. The production is organized by groups of one to three departments. Those pools are themselves organized around the mills. Most of the production and mills are concentrated within Centre-West and Northern-West part of the country, where the different actors of the sector are interacting within the “rice platform” to ensure local governance and agree on price and standards. Data from rice production indicate that about 20 percent of it is rice husks mainly used as bedding for poultry while a remained part could be used as bioenergy in the form of carbonized rice husks briquettes. In Gagnoa, the region of the project's implementation, about 6 112 tonnes per year of husks could be used to produce 4 276 tonnes of carbonized briquettes, which is equivalent to almost 5 500 tonnes of charcoal, the equivalent of 37 000 tonnes of woody biomass or 142 ha of a tropical moist deciduous forest. These results indicate the potential of energy recovery from agricultural by-products if not also ecosystems preservation.

The last chapter presents the results and analysis of implementation of CSA practices through the Technical Cooperation Project at two production sites (rainfed and irrigated) and deployment of briquette lines in three mills in Gagnoa. Climate mitigation, system resilience and economic analysis from producers to milling centres was performed along both value chains using the FAO's EX-Ante Carbon-balance Tool for Value Chain (EX-ACT VC). The implementation of CSA practices included soil conservation, efficient fertilization practices, use of by-products to produce energy and adoption of drought tolerant rice seeds positively impact the rice value chain, from producers and, to a lesser extent, processors. Results showed that the reduction of carbon footprint is only achieved on a per crop unit basis through significant increase in yields in the case of irrigated rice. This highlights the importance of ensuring that all good farming practices are implemented in synergy, as a key factor to achieve sufficient yield improvement in this case. The results also show the sharp increase in household income is mainly due to the increased yield, as targeted by the National Rice Strategy. Although rainfed rice farmers are the most vulnerable to climate change (the annual production barely covers their self-consumption), this analysis highlights the potential of simple agricultural practices and adaptation to climate change on incomes and food security. Furthermore, the results of this analysis demonstrated the importance of using by-products of the rice value chain to produce energy. The replacement of charcoal by rice husk briquettes implies co-benefits for the forestry sector and increased profits for rice millers. Indeed, they have the opportunity to shift from a costly waste management process to improved profits and replacing charcoal use in the area.

This technical study provides a series of recommendations for policymakers, including incentives for the development of a modern bioenergy sector in Côte d'Ivoire which are still nascent. Other areas of the value chain such as storage and post-harvest practices need further attention to reduce food loss and waste, as seen in the rainfed rice case study. Stable and predictable policies should encompass all steps of the agricultural value chains (including residue management) could highlight areas for economic growth. These policies should also consider the carbon footprint of the commodities together with the overall greenhouse gas emissions. These policy schemes would support the national “zero deforestation policy in agriculture” through energy recovery of agricultural by-products, ecosystem restoration, and certification of “zero deforestation” products on markets and the involvement of all commodity stakeholders (coffee, cocoa, palm oil, rubber and subsistence crops).

2 The rice sector in Côte d'Ivoire

KEY MESSAGES

- ◆ The rice value chain in Côte d'Ivoire is economically sustainable and could contribute to inclusive growth. Currently the country is heavily dependent on rice imports (up to 60 percent). As the rice production is also confronted with risks linked to water management and international market price fluctuation, this set of elements heightens the risk for food security.
- ◆ The national rice strategy of 2012–2020 aims to reduce rice imports by increasing the rice production at a national level while granting a profitable and stable income to rice producers.

2.1 Status and importance of the rice sector

Côte d'Ivoire's economy is predominantly based on agriculture. Notably natural resource potential such as high availability fertile lands, cultivable lands, and hydrological resources among others have made it possible to exploit a varied range of vegetable productions including coffee, cocoa, cashew nuts, pineapple and rice among others (FAO, 2009). Agriculture supports 38 percent of the population and produces 23 percent of the gross domestic production in Côte d'Ivoire (UNFCCC, 2015). About 2 565 500 persons are employed in the rice value chain in the country, of which about 2 million are rainfed rice producers (CARD, 2012). Rice is also the principal food crop grown in many areas and is one of the most important staple foods for the country's urban population (Ricepedia, 2019).

In 2008, rice represented 17 percent of the food budget and accounted for more than half of the population's cereal intake (Coulibaly, Tebila and Diagne, 2015). Annual consumption ranges between 60 to 70 kg per habitant per year since 1980, as compared to around 40 kg in the sixties. Rice has become an important food source for the majority of the population as a rapid urbanization along with a high poverty rate (38 percent in 2002, 49 percent in 2008 and 46 percent in 2015 (WFP, 2018)) has encouraged the consumption of this affordable and easy to prepare dish (JICA and JAICAF, 2013). Its domestic production slowly increased over the past decade to amount about 1.3 million tonnes by 2013–2015 (see Table 1) (CARD, 2012; ONDR, 2019a, 2019b, 2019c).

While a small percentage of the national production is exported to adjacent countries, mainly Mali and Burkina Faso, representing a volume of USD 14 million (Ricepedia, 2019), the national production covered only between 40 to 60 percent of the domestic consumption until 2012 (see Table 1). The country therefore relies on imports of milled rice from Asia to compensate for this deficit, making Côte d'Ivoire the Africa's third largest rice-importing country after Nigeria and Senegal (Coulibaly, Tebila and Diagne, 2015). Imports amount to about USD 480 million per year (ITC, 2017). This foreign dependence is a major challenge for food security because of international rice price market fluctuations, and additional complications resulting from a past military crisis and population displacement (FAO, 2011). The flow of imported and locally produced rice within the country is schematized in Figure A1 in the Annex.

◆ **TABLE 1** Rice production, imports and consumption, in tonne per year, from 2008 to 2014

Year	National milled rice production	Rice consumption	Rice import for national consumption
2008	604 024	1 360 704	756 680
2009	628 184	1 547 265	919 081
2010	784 000	1 640 101	986 790
2011	550 000	1 695 660	1 084 516
2012	984 000	1 697 230	1 167 233
2013	1 218 000	1 753 231	830 831
2014	1 343 000	1 586 993	952 600

Source: CARD 2012 for data until 2010; ONDR, 2019b, 2019c, 2019d for data from 2010–2014.

To bring this precarious situation to an end, the government is setting up structures to achieve rice self-sufficiency. The country already possesses significant suitable land area for rice cultivation, producers with ample know how, high yielding rice varieties with good organoleptic qualities, an existing market potential and a satisfactory economic and institutional environment (ONDR, 2019a). The critical review of past rice policies (see Table A1 in the Annex) has led to the development and adoption by the government of the National Strategy for the Development of the Revised Rice Sector for the period 2012–2020 (CARD, 2012).

2.2 Relevant institutions and their roles in the rice subsectors

Several agencies are involved in the implementation and or leading the development of the rice supply chain. The major actors include:

THE MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT (MADR)

The role of the MADR is to provide the strategy and the framework for the development of the rice sector, coordinate the different public and private actors of the rice value chain, as well as control and certify the varieties of rice seeds produced (MADR, 2019).

THE AGENCY FOR THE DEVELOPMENT OF THE RICE VALUE CHAIN IN CÔTE D'IVOIRE (ADERIZ)

Established in January 2018 to replace ONDR, ADERIZ is a public agency with a private administrative and financial management. The agency is in charge of the development of the national rice production of Côte d'Ivoire through the coordination of the different actors involved in the rice value chain. The change in the management mode aims to support the production and the profitability of the national rice sector (ONDR, 2019e).

THE NATIONAL AGENCY TO SUPPORT RURAL DEVELOPMENT (ANADER)

A semi-public company, the government of Côte d'Ivoire holds a 35 percent share of ANADER, with the remaining shares owned by agricultural trade unions and private companies (ANADER, 2019). The role of the company is to develop extension services for farmers and to create agricultural infrastructures such as irrigation schemes, dams, and pumping stations. ANADER is predominantly focus on helping to develop the irrigated and rainfed rice sector in Côte d'Ivoire. Of the 600 000 ha dedicated to rice production in the

country, only 5 percent is irrigated. In 2013, the stimulus for national irrigated production associated with favourable agro climatic conditions has led to a reduction of imports of about 38 percent compared to 2011 (*Ministère de l'agriculture de l'agroalimentaire et de forêt de la République Française*, 2015).

THE INTER PROFESSIONAL FUND FOR RESEARCH AND AGRICULTURAL EXTENSION (FIRCA)

Created in December 2002, FIRCA finances agronomic and forestry research, the diffusion of knowledge and technologies, supports projects building the sustainable profitability of farmers, and capacity building of the different trade unions (FIRCA, 2019). FIRCA is co-financed by the state and the different crop boards and unions: ADERIZ, cacao board, cotton board or coffee board (FIRCA, 2019).

AFRICARICE

A pan-African research organization created in 1971, AfricaRice is one of the 15 research centres of the Consultative Group on International Agricultural Research (CGIAR). Its mission is to contribute to food security, poverty alleviation through research activities and the development of partnerships in order to increase the productivity and the profitability of the rice value chain to ensure the sustainability of the production environment. Based in Abidjan, the centre works closely with the National Centre for Agronomic Research (CNRA) which is in charge of the production, conservation and development of the rice seeds sector.

THE MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT (MINEDD)

MINEDD was created in 1981, elaborates and implements the national climate action policy. It works in line with the Ministry of Energy to promote renewable energy policy and the development of green technologies to reduce impacts on water, air and soils.

In parallel the rice sector involves other stakeholders and actors (ONDR, 2019f) among which include:

- ♦ the National Federation of Consumer Associations (FAC);
- ♦ non-governmental organizations (NGOs) which provide technical support;
- ♦ input providers (machinery, irrigation system, fertilizer and herbicide);
- ♦ two millions producers gathered in informal groups and 44 cooperatives;
- ♦ workers and managers of the 2 152 rice mills;
- ♦ transporters; and
- ♦ wholesalers and dealers.

In brief, the categorization of these actors gives us: (i) the producers grouped together for the most of them in co-operatives, which are grouped into Associations or Federations, (ii) processors, (iii) importers and traders and (iv) consumers, (v) the support structures of which the State and the structures of support (CARD, 2012).

2.3 The national rice strategy 2012–2020

Economic and trade policies for rice in Côte d'Ivoire have gone through several development periods. Briefly, between 1960–1977, the nation's rice policy was essentially producer-oriented. The government made large public investments to boost the rice sector in an effort to achieve self-sufficient production, with the creation of two parastatal companies to lead the development of the rice supply chain. Between 1978 and 1994, the private sector began to be involved in the processing and marketing activities, in parallel to a progressive

disengagement of the government intervention. The period from 1995–2008 is the one of with full liberalization of the rice sector, from production, processing to marketing, and extension of imports from Asia to other rice products such as brown and broken rice. In 2008, the food crisis prompted the government to reduce the heavy reliance on imports by increasing the domestic production. The Emergency Rice Program, developed in this context, focused on the supply side of the production, i.e. seeds distribution, agricultural inputs and equipment. The programme failed because of lack of funding (see Table A1 in the Annex) (Coulibaly, Tebila and Diagne, 2015).

The National Rice Strategy 2012–2020 is the most recent, adopted and published in January 2012 by ONDR. It is based on the Emergency Rice Program of 2008, still focused at reducing imports, and with the following objectives (CARD, 2012):

- ◆ Satisfy 100 percent of rice needs with the national production.
- ◆ Guarantee a profitable and stable income to rice producers.
- ◆ Reduce import and outflow of foreign currency.
- ◆ Increase the value of national rice production for national and regional consumers.

Beyond these objectives, ONDR has further integrated the following elements into the strategy:

- ◆ Define and take into account all actors of the rice value chain including private actors.
- ◆ Extend the support to the rainfed production.
- ◆ Give priority to the rehabilitation of existing and most cost-effective infrastructures.
- ◆ Improve the coordination of the different initiatives and create a piloting structure (ONDR).
- ◆ Simplify the procedures to mobilize funds rapidly and align resource mobilization with the agronomic calendar.

Established in 2011, the targets of the strategy were:

- ◆ By 2018, the national paddy rice production will reach 2 100 000 tonnes¹ and a security stock of 200 000 tonnes will be created.
- ◆ 500 000 direct jobs are created in the irrigated rice value chain.
- ◆ 1 500 000 direct jobs are created in the rainfed rice value chain.
- ◆ 500 000 direct jobs are created in the transformation and associated services of the rice sector.
- ◆ The capacities for community savings of producers will be strengthened and their well-being improved.

In order to fulfil these requirements, the government defined two strategic pillars, (i) the technical support to the production, and (ii) the support to the valorisation of the national rice by mean of extension services.

To achieve this, the strategy foresaw the creation of six new centres for the preparation and packaging of the R2 rice seeds (higher yields) produced by a network of seed producers, as well as agronomic research to develop new varieties and associated crop protocols. These seeds are controlled and certified by competent services of the MADR and the centres are managed by ADERIZ. The CNRA defines on his side the most efficient fertilization dosage for each production zone according to the soil properties and develop innovative intercropping practices.

¹ About 1.3 million tonnes of white rice at the assumed transformation rate of 65 percent.

On the field, currently 35 000 ha are equipped for irrigated rice production out of a potential 200 000 ha. The national strategy intends to rehabilitate 35 000 ha of irrigation infrastructures, equip an additional 10 000 ha for a two-cycle production scheme and convert 25 000 ha of flooded plains into irrigated rice (with two-crop cycles). Extension services will provide support to farmers in terms of seeds, machinery and advice on performant techniques through the support of FIRCA. Once implemented the rainfed rice production is expected to increase by 30 percent, while in the irrigated and flooded rice areas, the yield is expected to double reach up to 5 tonnes/ha per cycle. Finally the strategy aims at increasing the use of organic manure, introduce technologies to reduce post harvest losses and train actors in the finance, fertilization and machinery sectors.

2.4 Economic description of the rice value chain

The rice market represents about USD 2 billion per year with imports reaching a value of USD 480 million. The sector employs 2 million rainfed rice producers, 164 000 producers of irrigated rice and 50 000 producers of flooded rice (CARD, 2012). About 350 000 persons are employed in the rice transformation, transport, retail and trade. Around 1 500 persons are employed in the support to rice producers. In total 2 565 500 persons are employed in the rice value chain in the country (CARD, 2012). At national level, the rice value chain involved six type of actors with different roles:

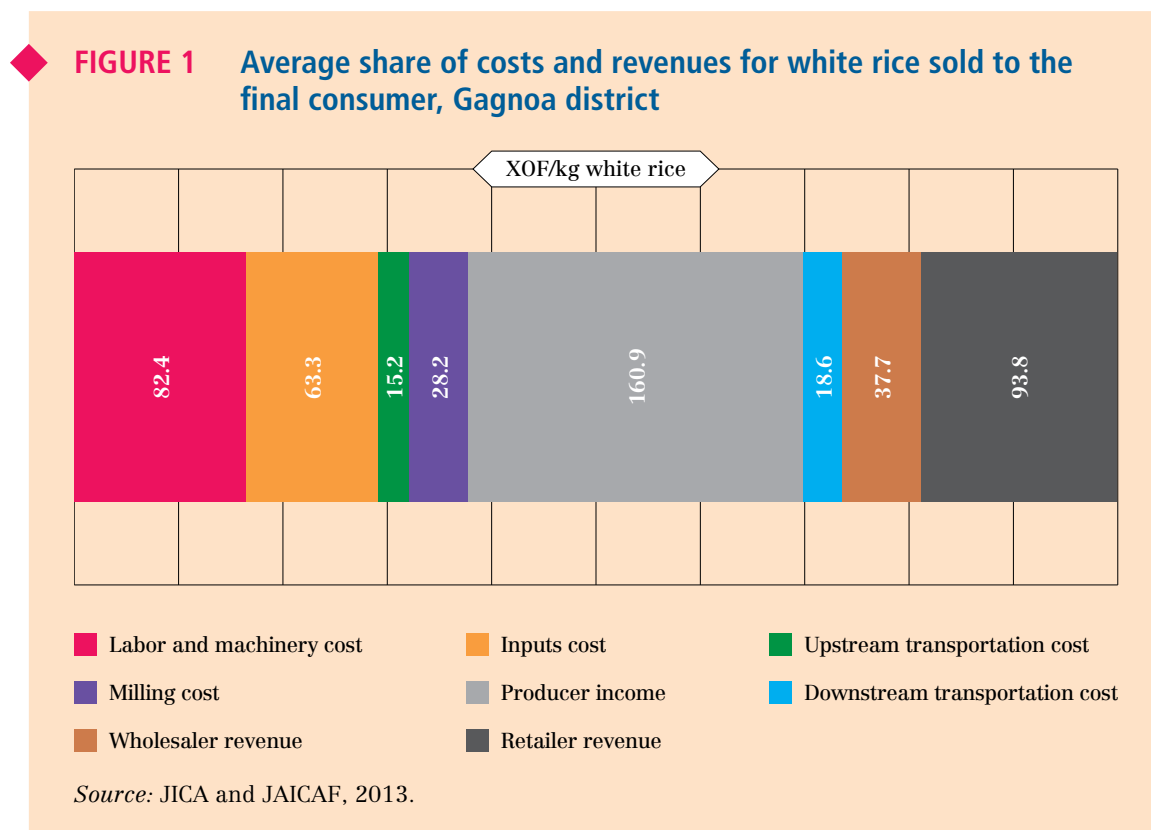
- ♦ **Farmers and associated workers²** prepare the soil, plant the seeds, manage inputs, harvest the crop, thresh the rice to separate the paddy from the straw, and transport all their production or only a portion to the mill. In the majority of cases (and in the entire rainfed rice sector) they store a portion of paddy rice to be milled at a later period.
- ♦ **Input providers** are involved into the production, trade and transport of inputs. The main inputs used in rice production are fertilizers, herbicides, machinery and water. A water user committee usually manages water of the irrigation scheme.
- ♦ **Millers and parboilers** perform the necessary operations for the crop to become edible such as drying when necessary, hulling, milling and parboiling.
- ♦ **Transporters** are involved in the transport of the paddy rice to the mill. They are also responsible for all transport operations between the mill and the final consumer (direct sale, storage, wholesaling and regional markets).
- ♦ **Wholesalers** are responsible for trade operations locally, nationally and internationally (both import and export).
- ♦ **Retailers** are responsible for selling the rice product to the consumers in Côte d'Ivoire.

Gender dimension: The majority of rice farmers are women (55 percent) working in family farms. They have a strong presence in the rice supply chain, at both production and retail ends. They are traditionally involved in post-harvest operations (threshing, winnowing) and hold a virtual monopoly for local rice retail sales in the markets in most production zones. They are also very present in the organization of school canteens with about 1 200 groups of women producing rice to supply 5 230 school canteens across the whole country. The other activities such as milling, transport and wholesale are generally male dominated (CARD, 2012).

In 2013, a study commissioned by the Japan International Cooperation Agency (JICA) assessed the cost and revenues of rice of different actors along the value chains in eight

² Associated workers include family members and hired labour.

regions (JICA and JAICAF, 2013). The simplified results³ of this assessment are adapted in Figure 1 and shows that for a kg of white rice sold in the capital, producers are the ones supporting highest costs (mainly from labor, machinery and inputs) but also receive the highest revenues, i.e. about XOF 160 per kg of white rice. In average, production costs average 42 percent of the price per kilo and revenues 58 percent. These figures vary at regional level with highest revenue for producer, i.e. about XOF 260 per kg of white rice, in Gagnoa which is one of the most important rice production region and the region of project implementation, against XOF 74 per kg of white rice in Korhogo (data not shown) (see JICA and JAICAF [2013] for detailed analysis).



³ This assessment does not necessarily take into account several risks endured by retailers and traders, opportunity costs and the different systems related to the internalization of transport costs. Farmers, millers, traders and retailers can bear these costs depending on the selected commercialization model.

3 Characteristics of the rice supply chain in Côte d'Ivoire

KEY MESSAGES

- ◆ The Centre-West and North-West part of the country are the major centres of production of paddy rice. The production of rice is the most important with an equivalent of 1.4 million tonnes of paddy rice.
- ◆ Carbonized rice husks briquettes have a high potential of use as bioenergy and substitute charcoal, which offer new opportunities of development and economic growth for the country as rice husks represents 20 percent of the paddy production.

3.1 Geographical distribution of the rice production systems and mills

Paddy rice production

In Côte d'Ivoire, rice is grown throughout the country in both rainfed and irrigated systems, although rainfed or upland is by far the most common. Planting and harvesting can vary widely throughout the country's different zones and according to the rice cultivation system. For instance, non-irrigated upland rice is typically planted between April and June, and then harvested between October and December. Further south, planting and harvesting occur about a month earlier than in the north. These periods will fluctuate on an inter-annual basis according to rainfall patterns. The largest producing areas are concentrated primarily in the country's western regions, around Man, Daloa, and Gagnoa which account for nearly half of national production. Areas in the North and East Centre around Bouaké, Korhogo, Odienne, and Yamassoukro account for about a third of national production (CARD, 2012).

There are three rice production systems: (i) rainfed rice grown throughout the country with a dominance in the West, North and Central West, (ii) flooded rice that is cultivated mainly in the great plains of North-West and North and (iii) irrigated rice which is cultivated in the lowlands developed or dams at the Centre, to West, Central West and North (CARD, 2012).

The location of rice mills

Rice production is usually distributed around the mills, in the Centre-West and Centre-North (see Figure 2). In 2018, about 2 153 mills were established categorized in five different typology, with a majority of mills (1672) of a capacity of 0.5 tonnes per hour. These mills ensure the transformation of 40 percent of the total paddy production (ONDR, 2019h). The capacities of the different mills and their contribution to the transformation of national paddy production is reported in Table 2.

◆ **TABLE 2** Share of the transformation of the national paddy production per mills capacity

Mills		Share of the transformation of the national paddy production (in percentage)
Number	Capacity in tonnes per hour	
2	>5	0.23
98	1-5	16.3
380	<1	35.57
1672	0.5	40

Source: ONDR, 2019h.

The national rice strategy foresees the creation of 10 mills with a transformation capacity between 15 000 to 24 000 tonnes per year through the establishment of public-private partnerships (CARD, 2012).

◆ **FIGURE 2** Localization of rice mills at national level

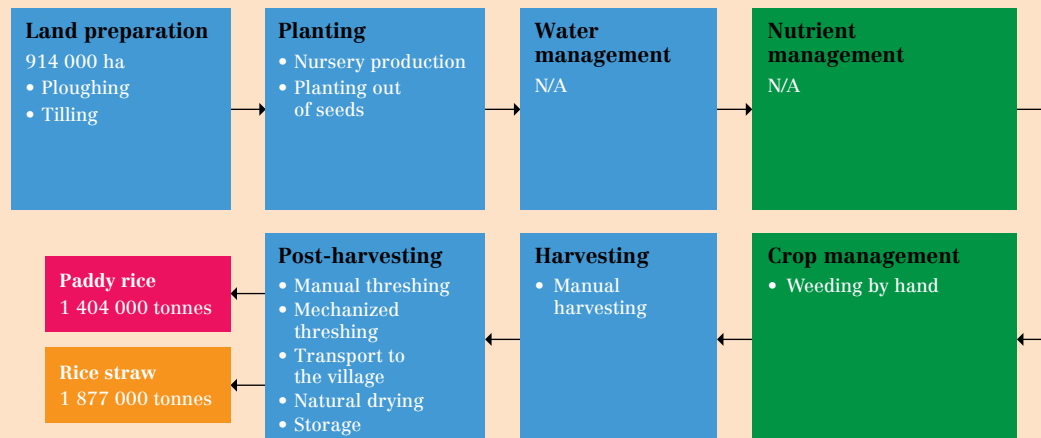


3.2 Rice production systems

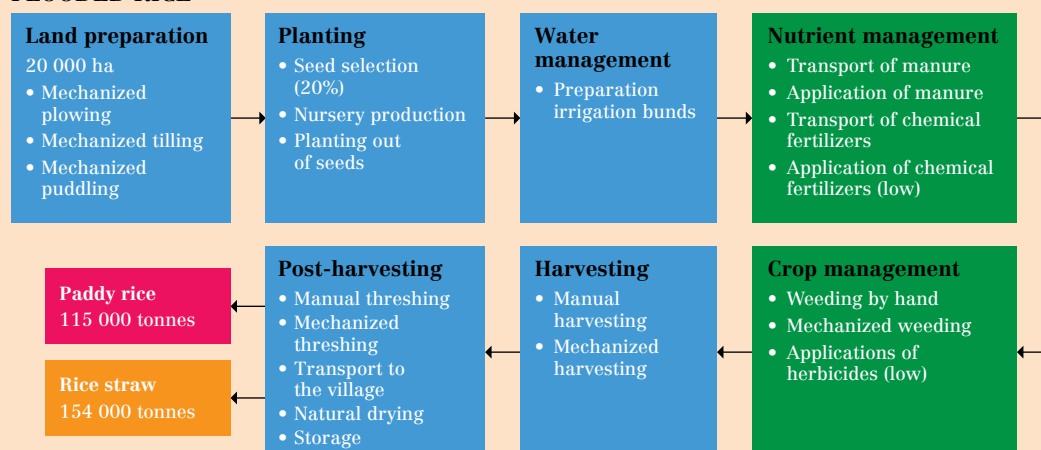
Rice production is dominated by three systems (see Figure 3) producing five rice products (CARD, 2012; Boansi, 2013) as described below.

◆ **FIGURE 3** Rice production systems

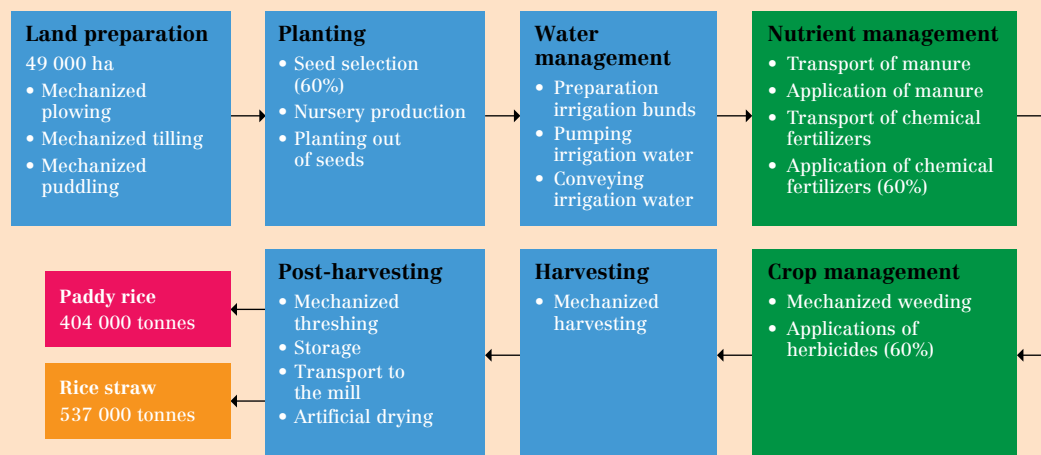
RAINFED RICE



FLOODED RICE



IRRIGATED RICE



Note: N/A stands for not applicable.

Source: Authors' own elaboration from CARD, 2012 and Boansi, 2013.

Rice production

- ◆ **Rainfed rice** is the dominant production, with an **average yield of 1.5 tonnes/ha** and one harvest per year. The production was equivalent to **1 800 000 million tonnes of paddy rice** in 2013. Selected seedlings are used in **7 percent of the planted area** only. The use of herbicide and fertilizers is very low. All the production operations are carried out by hand.
- ◆ **Irrigated rice** production has an average yield up to **10 tonnes/ha** in two harvesting season per year. The production was equivalent to **385 000 tonnes of paddy rice** in 2013. Selected seedlings are used in around 60 percent of the planted area. Herbicides and fertilizers are used in **60 percent of the planted area**. Machinery such as tractors, tillers and threshers are common.

Flooded rice schemes have an average yield of **5.9 tonnes/ha** in two harvests per year. The production is equivalent to **52 500 tonnes of paddy rice** in 2011. Selected seedlings are used in around **20 percent of the planted area**. The use of herbicide and fertilizers is very low. Machinery such as tractors, tillers and threshers is common.

Rice processing

Once harvested, the rice is usually transformed into five different products (JICA and JAICAF, 2013):

1. **Paddy rice**: rice after threshing. It keeps its husk. It can be stored for milling when the farmer's household needs it (for cash or food). The rate of self-consumption is between 5 to 20 percent of the total production.
2. **White rice**: milled rice where the husk, bran and germ are detached.
3. **Broken rice**: rice grains fragmented at different stages of the transformation (threshing, drying, transport or milling). Farmers usually do not discard the broken rice, as it can be used for household consumption, unless it has to be sold.
4. **Brown rice or "cargo" rice**: rice where only the husk is removed. It keeps its bran and germ. This type of rice is used for long-distance transport as its processing increases storage time and reduces the rice weight by about 20 to 30 percent because of the husk removal (Abé, 2017).
5. **The parboiled rice**: rice that has been boiled in its husk. The rice is soaked, steamed and dried before being milled. This process makes the hulling process by hand easier and increases the nutrient value of the rice.

Rice by-products

- ◆ **The straw residue to crop** ratio is around 1.14 (FAO, 2018a). As reports usually mention that straw is discarded after threshing, the assumption is that the total amount of straw available is around 2 415 215 tonnes in 2017 for a production of 2 118 610 tonnes of paddy (ONDR, 2019b).
- ◆ **The husk** is separated from the endosperm during the hulling process. The residue to crop ratio is 0.21 (FAO, 2018a). The husk is used for poultry bedding and bioenergy. The rice husk production is almost 444 908 tonnes in 2017 for a production of 2 118 610 tonnes of paddy (ONDR, 2019b).
- ◆ **The bran** is partially separated from the endosperm during the milling process. The residue to crop ratio is 0.08 (Abé 2017). The bran is used for poultry feed. The bran production is about 233 047 tonnes in 2017 for a production of 2 118 610 tonnes of paddy (ONDR, 2019b).

3.3 Regional production information of the rice sector

Actors

At the regional level, all actors of the rice value chain together form the “rice platform”, chaired by a president with different agencies and actors (see Section 2.2), such as ANADER, ADERIZ, producers, millers, input providers, traders and transporters. This platform helps with identifying and connecting all actors, such as input and product suppliers. The platform ensures the local governance where the different actors can agree on prices and standards. For instance, producers, millers and traders agreed on a “no-stone standard”, which is reflected in equipment, prices and packaging.

Rice flow within the supply chain

The main actors of the rice value chain are farmers and cooperatives on one side, and collectors and processors on the other. Generally, farmers send their production to processing units for milling. This processing unit is commonly located close to the village. Once processed, farmers use milled rice for their own consumption and or sell it on local markets according to their economic needs, for instance to afford school fees. They also save part of the dry paddy as seeds for the next cycle. Women have an important role in subsistence farming as they are directly involved in milling and marketing of rice.

There are three different business models after production:

- ♦ In the **co-operative model**, farmers have their own mill and sell their production under the same brand. The cooperative is responsible for finding wholesalers. Farmers receive payment based on the quality of their rice and quantity at an agreed tariff. The farmer can ask to have part of the payment in nature (white rice) for self-consumption and dry paddy as seeds for the next cycle.
- ♦ In the **wholesale model**, the miller buys the paddy rice from the farmer and finds wholesalers or retailers to buy the white rice. After the transaction, the miller pays the farmer. The farmer can ask to have part of the payment in nature (white rice) for household consumption and dry paddy as seeds for the next cycle.
- ♦ In the **service model**, the miller asks the farmer to pay for a milling fee.

Private millers use either the wholesale or the service model. The wholesale model includes more risks, better revenues and a profound knowledge of the local value chain as millers place orders to farmers after solicitation from wholesalers. Alternatively, the service model is used by either farmers for household consumption (low production) or farmers or wholesalers, which have already identified a specific market and contract.

The Ivorian rice market is characterized by several ways of marketing depending on the distance between the production location and the consumption centres. Over the years, the commercial system has shown its ability to adapt to market demands through a regular supply of urban centres. The main market constraint is the availability of sufficient quantities of rice to be milled and transported from one producer or from a group of producer at any point of time during the year.

3.4 Rice production in Gagnoa and bioenergy potential

Rice production is typically organized in pools grouping one to three departments. The pools are then organized around mills with a range of up to 75 km. For instance, the Gagnoa pool includes the two departments of Gagnoa and Oume (North East of the department of Gagnoa). In 2016, paddy production of the Gagnoa pool accounted for 3.2 percent, 66 466 tonnes of paddy, of the national production (2 054 535 tonnes of paddy). Once collected, the paddy is transformed in the milling units. The milling produces white rice and broken rice consumed at a regional level but is also exported. Additionally, several by-products are produced from the milling as illustrated in Table 3.

◆ **TABLE 3** Products and by-products of the rice production in Gagnoa district

Products	By products
White rice and broken rice (local consumption)	Straw burned on the field.
White rice (extra regional consumption)	Straw used for animal feed:
	◆ reincorporation of straw for soil stabilization
	◆ husks wasted and decomposing through aerobic digestion
	◆ husks used in briquette production
	◆ rice bran used for poultry feed.

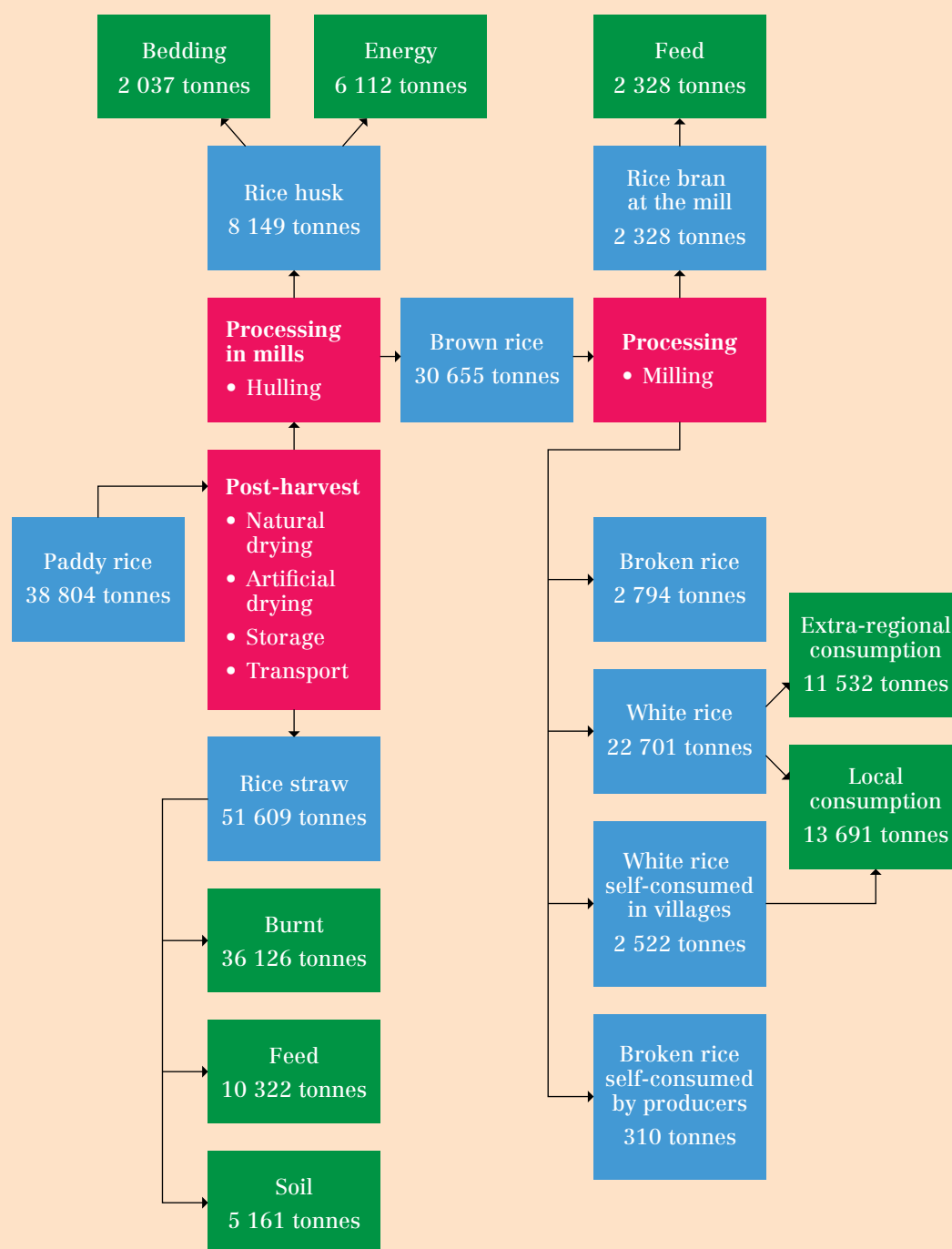
Source: ANADER technician, personal communication.

In Gagnoa, the region of project implementation, paddy's production was 38 804 tonnes in 2016. It is estimated that around 8 149 tonnes of husk, 2 328 tonnes of bran, 28 327 tonnes of milled rice or white rice are produced in Gagnoa (see Figure 4). Assuming the national food supply quantity of milled rice is about 64 kg per capita per year (kg/capita/yr) (FAO, 2019a for year 2013), a population of 213 918 inhabitants would consume 13 597 tonnes of milled rice. The local production covers the majority of local needs and 50 percent of the production could be exported at regional and or national level (see Figure 4).

The quantity of rice straw produced per year in the district is more than 44 236 tonnes. According to Romasanta *et al.*, 2017, the burning of 1 kg of dry weight of rice straw can produce 4.51 gram (g) of methane (CH₄) and 0.069 g of nitrous oxide (N₂O). Based on this study, the burning of rice straw in Gagnoa could emit up to 5.9 million tCO₂-e per year (tCO₂-e/yr).⁴ Finally about 25 percent of the rice husk is currently used for poultry bedding, i.e. 6 112 tonnes per year that could be used to produce 4 276 tonnes of carbonized briquettes, which is equivalent to almost 5 500 tonnes of charcoal (FAO, 2018b).

⁴ The CO₂ emitted from biomass burning is not considered a net GHG emission because it is assumed that the carbon emitted will be reabsorbed by the vegetation during the next growing season (IPCC, 2006). The two other gases emitted have a 100-year Global Warming Potential (GWP) of 25 for CH₄ and 298 for N₂O (IPCC, 2006).

◆ **FIGURE 4** Rice products and by-products flow in Gagnoa for 2016



Source: Authors' own elaboration from Agbri Lako and ONDR technician, personal communication.



4 Analysis of the rice value chain

KEY MESSAGES

- ◆ Implementation of climate-smart agriculture practices, including soil conservation, efficient fertilization practices, use of by-products to produce energy and adoption of drought tolerant rice seeds positively impact the rice value chain, from producers and, to a lesser extent, processors
- ◆ The reduction of the carbon footprint of milled rice is only achieved on a per crop unit basis through significant increase in yields in the case of irrigated rice. Good farming practices must be implemented concurrently to achieve sufficient yield improvement and reduce rice carbon footprint in irrigated rice.
- ◆ The replacement of charcoal with rice husk briquettes implies co-benefits for the forestry sector and the opportunity to shift from a costly waste management process to improve profits.

4.1 Context

The FAO project “*Contribution à l’atteinte des objectifs liés au changement climatique et à la sécurité alimentaire via l’agriculture intelligente face au climat en Côte d’Ivoire – cas de la filière riz*” (TCP/IVC/3601), aims at enhancing country’s capacity against climate change negative impacts, in particular, the rice value chain, where erratic rainfall patterns and drought events affect its production. The impact of this FAO project is to contribute to the adaptation of the food sector to climate change and food security through the promotion of CSA practices in the country including sustainable bioenergy in the rice value chain. This FAO project is also fully in line with the Paris agreement roadmap and the National Development Plan of the *République de Côte d’Ivoire Groupe Consultatif* for 2016–2020.

This FAO project seeks to create experimental rice fields with CSA practices included in an integrated system for recovering residues from their exploitation and rice processing. The rice production will be used in the production process or sold in market. The sought synergies include the identification of key stakeholders and the availability of data on the rice sector. The results from CSA implementation will provide the policy with key information on the applicability of such a practice in the rice sector.

4.2 Materials and methodologies

Agro-ecological variables of pilot sites

Gagnoa was selected as it is one of the major rice production area. This region is characterized by a tropical moisture regime, marked by four seasons including two rainy seasons and two dry seasons, with a rainfall annual average of 1 459 mm. A heavier rainy season stretches

from March to July and a small rainy season ranges from September to October. The two dry seasons are divided into a long dry season from November to February and a short dry season in August.

According to the Intergovernmental Panel on Climate Change (IPCC) classification of agro-ecological variables, the FAO project area is characterized by a tropical moisture regime with a low activity clay (LAC) soil type. The analysis was run over two years to consider the progressive shift from traditional rice management practices to CSA ones, and a capitalization phase of 18 years to reach a 20-years analysis.⁵

Data collection

The data collection was organized in two phases: from 3 to 7 August 2017 and from 9 to 13 September 2018. Both missions covered two communities: Godelilé in August 2017 and September 2018 for the rainfed rice, and Guessihio in August 2017 and Demidougou in September 2018 for the irrigated rice. In January 2018, the irrigated rice site was changed from Guessihio to Demidougou due to a low participation rate of farmers in planned extension activities. The data collection aims to provide co-benefits appraisal of the rice value chain on GHG emissions, resilience and income generation from the rice value chain.

More than 70 persons involved in the rice value chain in the region were interviewed, including:

- ◆ 42 rainfed rice producers (site of Godelilé)
- ◆ 27 irrigated rice producers (Guessihio and Demidougou sites)
- ◆ three processors
- ◆ one rice trader
- ◆ three agricultural inputs suppliers
- ◆ different officers from ADERIZ, ANADER, MINSEDD, MADR, the Ministry of Oil, Energy and the Development of Renewable Energy (MPEDER), the Ministry of Water and Forestry (MEF) and local authorities.

The data collection process followed seven steps:

1. The data was collected by the national consultant involved .
2. The data was then reviewed by the authors.
3. The authors collected primary data on site in August 2017.
4. The consultants on the project as well as different stakeholders were trained on the EX-ACT tools, i.e. EX-ACT and EX-ACT VC in August 2017.
5. The collected data was reviewed to establish the baseline.
6. The authors collected primary data on site in September 2018 following the implementation of the climate-smart agriculture and bioenergy measures.
7. Data revision before analysis with EX-ACT VC.

The analysis run with EX-ACT VC is based on data collected in September 2018.

⁵ The 20-year period (accounting duration) is in line with the idea that even after the point at which a new equilibrium in land use and practices is reached at the end of the implementation phase, further changes may occur as the result of the preceding interventions. For instance, for the soil C estimates, the default values are based on default references for soil organic C (SOC) stocks for mineral soils to a depth of 30 cm (Table 2.3 of IPCC, 2006). When SOC changes over time (land use change or management change), it is assumed a default time period for transition between an equilibrium of 20 years. These values are used either in IPCC 1996 or 2006 Guidelines and are gathered from a large compilation of observations and long-term monitoring.

EX-Ante Carbon-balance Tool (EX-ACT)

EX-ACT is an appraisal system developed by FAO providing ex-ante estimates of the impact of agriculture and forestry development projects, programmes and policies on the carbon-balance (Bernoux *et al.*, 2010; FAO, 2017b). The carbon-balance is defined as the net balance from all GHGs expressed in carbon dioxide equivalents (CO₂-e) that were emitted or sequestered due to project implementation as compared to a business-as-usual scenario.

EX-ACT is a land-based accounting system, estimating carbon stock changes and GHG emissions per unit of land, expressed in equivalent tonne of CO₂ per hectare and year (tCO₂-e/ha/yr). The tool helps project designers to estimate and prioritize project activities with high benefits in economic and climate change mitigation terms. The amount of GHG mitigation may also be used as part of economic analysis as well as for the application for funding additional project components.

EX-ACT has been developed using mostly the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) that furnishes EX-ACT with recognized default values for emission factors and carbon values, the determined Tier 1 level of precision. EX-ACT is based upon chapter 8 of the Fourth Assessment Report from working group III of the IPCC (Smith *et al.*, 2007) for specific mitigation options not covered in (IPCC, 2006). Other required coefficients are from published reviews or international databases. For instance, embodied GHG emissions for farm operations, production and transport of agricultural inputs, and irrigation systems implementation come from Lal (2004) and electricity emission factors are based on data from the International Energy Agency (IEA, 2013).

EX-Ante Carbon-balance Tool for value chain (EX-ACT VC)

EX-ACT VC is a tool derived from EX-ACT and allows to access agricultural value chains from cradle to shelf. It can be used for the assessment of (i) GHG impacts (carbon footprint); (ii) climate resilience; and (iii) socio-economic performance (value added, income, and employment generated) along all stages of food value chains. The approach is based on a specifically designed system of indicators, including environmental indicators such as water use and energy use (FAO, 2017a). Therefore, the methodology used in EX-ACT VC is based on the one described above, complemented at the processing and transport levels with the following inputs:

At the processing and transportation level:

- ♦ GHG emissions are mainly associated with energy use, such as fuel consumption and electricity, and the type of conditioning. The standard approach to estimating CO₂-e emissions involves multiplying the quantity of input per tonne of production by an ad hoc emissions factor defined in the scientific literature. For energy use at the processing level, the emission factor is the same as those used in EX-ACT.
- ♦ The transportation emissions factors are expressed in tCO₂-e per tonne per kilometre (tCO₂-e/tonne/km), according to the following categories: truck, air, rail, inland water and international water container (Weber and Matthews, 2008).

4.3 Environmental, climate mitigation and social-economic analysis

Profile of the different actors before implementation of climate-smart agriculture practices

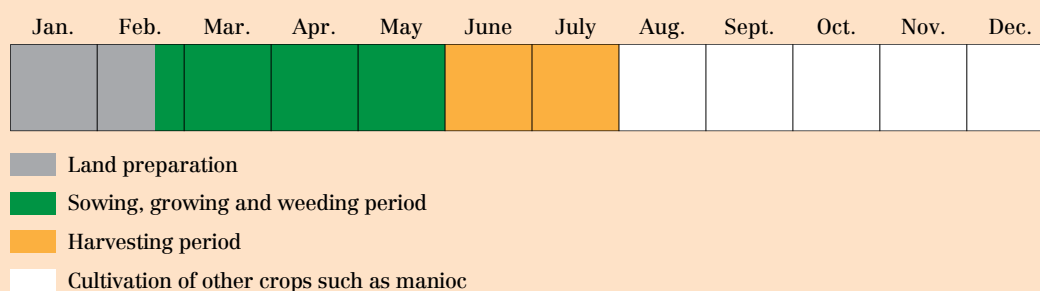
FARMERS

The present analysis covered a sample of farmers interviewed at two sites: Godelilé with rainfed rice fields and Demidougou with irrigated rice schemes.

GODELILÉ – RAINFED RICE PRODUCTION

The total area of rainfed rice covers 19 ha for 38 households, i.e. 0.5 ha per households. Among the farmers, 14 are women and 24 are males. 28 farmers own their land, whereas the remaining ones pay the land lease with rice. There is only one cycle of rice production per year (see Figure 5), and tasks between women and men for rice cultivation are well defined. Men are mainly in charge of sowing and harvesting while women are in charge of clearing land before sowing, weeding, field monitoring against birds and pests, transport of the rice from the field to the village and threshing. Men also cultivate latex, cacao and coffee, which are sold to afford school fees and other expenses. The community is located about 5 to 6 km from the main road connecting to Gagnoa. They have no means of transportation. Therefore, when buyers come to the village they impose the selling price to farmers. At present, the annual rice production, 3 tonnes of paddy rice for 19 ha, barely covers household consumption. The paddy rice is kept in granaries and threshed when needed. Production and post-harvest losses are high (about 50 percent). These losses are linked to several factors, such as: weather, pests, rain, transport from the field to the village (the farthest field is 4 km away from the village), and storage.

◆ **FIGURE 5 Rainfed rice calendar (Godelilé, Gagnoa)**



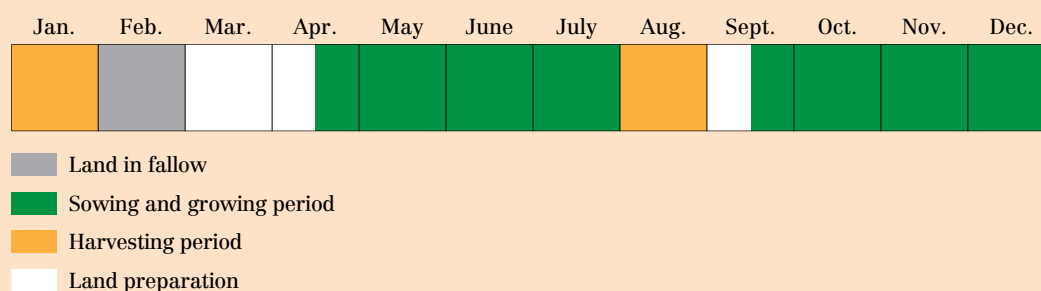
Source: Authors' own elaboration based on data collected from interviews at country level.

DEMIDOUGOU – IRRIGATED RICE PRODUCTION

This community is composed of 17 households holding 17 ha of irrigated rice area, exclusively exploited by men. Farmers produce rice all year through two cultivations periods, of about 120 days each. They seed in April and mid September and harvest in August September and early January. Land is fallowed in February (see Figure 6).

Once harvested, paddy rice is kept at home in a granary and transported to be processed when households are short of milled rice for their own consumption and sold. On average, about 94 percent of the production is sold at market, at a market price between XOF 375 to 400. Farmers have to cover the costs of transportation and threshing (XOF 25 per kg of white rice).

◆ **FIGURE 6** Irrigated rice calendar (Demidougou, Gagnoa)



Source: Authors' own elaboration based on data collected from interviews at country level.

FROM PRODUCERS TO PROCESSORS

In the case of the rainfed rice community, the threshing is manual and exclusively performed by women. Their rice is currently not sold but kept for household consumption. On the contrary, the **irrigated rice community is part of the service model of supply chain**.

Motorized tricycles are the preferred mode of transportation between the producers and the millers. The average distance from the field to the milling house is around 10 km, with a transport costs of XOF 10 per kg of paddy rice.

Rice is processed with milling machines, at a service cost of XOF 25 per kg of white rice. The energy consumption at processing level is about 42 kWh for every tonne of white rice (i.e. 27 kWh per tonne of paddy rice). The average milling rate for rice ranges between 60 to 66 percent of white rice per quantity of paddy rice. After the milling process, farmers can either sell the white rice to wholesalers and or consume it. Millers do not store white rice. Paddy rice can be dried by electrical drying or sun dried in a specific area. The drying cost ranges from XOF 10 to 15 per kg of white rice depending on the moisture percentage.⁶ The ideal moisture percentage for milling should be no more than 14 percent. In this study most of the paddy rice is sun-dried.

Finally, millers are in charge of by-products management (husk and bran). Husk management is a cost for the milling company since the local authority charges mills for discarding. Therefore, local poultry farms use the available husk bearing the cost of management and transport. The rice bran used for poultry feed ranges between XOF 25 to 30 per kg.

Adoption of climate-smart agriculture practices

Based on a review of existing CSA practices in the rice value chain in Western Africa (FAO, 2017c) and existing bioenergy end use options for Côte d'Ivoire (FAO, 2016), different practices were implemented the two pilot study sites, and are summarized in Table 4.

◆ **TABLE 4** Summary of implemented climate-smart agriculture practices

Site	Practices
Irrigated rice 17 ha and 17 farmers	<ul style="list-style-type: none"> ◆ Agro-ecosystem analysis ◆ Row planting with one strand instead of four ◆ Improved seeds (JT11) ◆ Use of 150 kg/ha of NPK (14/18/18) after tiling and 100 kg/ha of urea after the first weeding instead of mixing higher quantities of NPK and urea ◆ Two manual weeding instead of chemical weeding ◆ Integrated pest management
Rainfed rice 19 ha and 38 farmers	<ul style="list-style-type: none"> ◆ End of slash and burn ◆ End of residues burning ◆ Dibble seeding instead of broadcasting ◆ 100 kg/ha of urea after the first weeding and no NPK ◆ Three manual weeding instead of chemical weeding
Rice mill (3)	Installation of a briquette process from unused rice husk: pyrolysis kiln, mixer, press and drying area

Source: Authors' own elaboration based on data collected from interviews at country level.

THE RAINFED RICE CULTIVATION

Before the implementation of CSA practices, farmers were not using any agricultural inputs and residues were burned. During this FAO project implementation, several CSA practices were applied (see Table 4), including exporting residues for composts used as organic amendment on crops, e.g. coffee and cacao. The dibble seeding instead of broadcasting and the use of 100 kg/ha of urea after the first weeding, helped to increase the rice yield from 300 to 701 kg/ha/year (see Table 5).

THE IRRIGATED RICE CULTIVATION

Before this FAO project, farmers bought local rice varieties, e.g. *Nerica*, *Sohou*, *Youkinmin*, *Ziankagui*, *Tangomani*. The germination rate was about 80 percent. This FAO project proposed to use different seeds varieties, e.g. J11, with a higher rate of germination, i.e. 95 percent. The new seeds varieties have a shorter life cycle and are drought resistant: 120 days of cultivation.

Water regime management. The water regime is based on the use of channels and bunds. The soil is flooded two weeks before the cropping season and intermittently flooded during the cropping period. This FAO project did not plan to change the water regime management. However, the fields were levelled after tiling to improve drainage.

Organic amendment. While before the project farmers used to burn rice straw, the rice straw will be exported to be used as organic amendment on cropland (rice, cacao and coffee for instance). Agricultural inputs used in both situation include nitrogen, phosphorus and potassium (NPK 14/18/18) fertilizers and urea (see Table 5).

♦ **TABLE 5** Main production characteristics of rice cultivation systems

	Rainfed rice 1 cycle of production		Irrigated rice 2 cycles of production	
	Without CSA	With CSA	Without CSA	With CSA
Total hectare (ha)	19	19	17	17
Total yield (tonnes/ha/yr)	0.3	0.7	5	10
Production loss at farm gate in percent*	50	50	15	15
Auto-consumption (percent)	100		6	
Agricultural inputs				
NPK (kg/ha/yr)	–	–	300	300
Urea (kg/ha/yr)	–	100	200	200
Seeds from previous year (kg/ha/yr)	100	50	N/A	N/A

Note: * Includes loss during the cultivation period, transport from the field to the village, threshing and storage.

Source: Authors' own elaboration based on data collected from interviews at country level.

Loss of production from field to farm-gate. It amounts to 15 percent of the production, from the collection of the rice after harvest, threshing and drying phase.

Before the implementation of CSA practices, the average yield was approximately 5 tonnes/ha/year. The implementation of this FAO project allowed farmers to use improved varieties together with implementation of CSA practices (see Table 4) and this resulted in an increase of the yield to 10 tonnes/ha/yr. Farmers sell 96 percent of the production, at prices ranging between XOF 375 to 400 per kg of white rice.

Potential production cost from field, transport and processing

Based on the different interviews, costs vary according to community's needs and location. Production, transportation and processing costs (see Table 6) are described hereafter, and include:

- ♦ agricultural inputs (seeds, fertilizers and eventually herbicides);
- ♦ fuel consumption associated to threshing of irrigated rice;
- ♦ labour cost, for example, on the field (in man-days per hectare);
- ♦ transportation of paddy rice to the processors; and
- ♦ land rental (in hard cash or in nature such as rice).

Most of the fieldwork is completed by farmers and their families, but is occasionally supported by operators for some particular tasks such as weeding, application of herbicides and threshing. Production costs for the producers of irrigated rice interviewed in September 2018 are reported in Table 6. The land rental costs are excluded from the analysis, as usually paid with a part of the production. Rainfed rice producers are not presented in the table as they do not sell their rice production. The assumption in place for this analysis is that the landowners belong to the same community. The economic analysis rather reflects an average profile for all households, even though land owners may receive higher incomes than other households.

◆ **TABLE 6** Annual production costs and value of the gross and net production at farm gate for irrigated rice producers (without and with climate-smart agriculture practices)

	Without CSA	With CSA
Yield (tonne per hectare per year)	5	10
Loss at farm-gate (%)	15	15
Total paddy produced (tonnes)	46	136
Total white production	29	92
Gross white rice production value (XOF)	9 595 000	28 437 000
Agricultural inputs (XOF per year)		
NPK	(1 836 000)	(1 836 000)
Urea	(1 020 000)	(1 020 000)
Seeds	(425 000)	(255 000)
Agricultural inputs cost (XOF per year)	(3 281 000)	(3 111 000)
Transportation cost	(49 635)	(1 644 558)
Processing cost	(1 087 796)	(2 571 760)
Total annual cost production (XOF)	(5 212 583)	(7 327 318)
Cost production per kg of white rice	(120)	(71)

Note: Numbers in brackets indicate costs in XOF.

Source: Authors' own elaboration based on data collected from interviews at country level.

4.4 Results

In the two rice production systems (rainfed and irrigated), several CSA practices were implemented such as better water management practices, nutrient management, compost application, improved seed varieties (resistant to drought and higher yield) and ultimately reuse of by-products (see Table 4, Figures 7 and 8). All these management options help to double the yield (0.7 and 10 t of paddy/ha/yr for respectively the rainfed and irrigated production) and contribute to soil carbon sequestration in the case of rainfed rice. At the time of data collection, none of the farmers was yet applying the CSA practices. Therefore the EX-ACT analysis compares the GHG emissions or removals from the conventional practices, e.g. residues burning, against the implemented CSA practices.

♦ **FIGURE 7** Management practices for the rainfed rice

PRODUCTION PRACTICES - ANNUAL SYSTEMS													
		Management options					? Definition mngt option					Areas concerned (ha)	
		Improved agronomic practices	Nutrient management	NoTill./ residues management	Water management	Manure application	Residue management	Yield (t/ha/yr)				Current	Upgrading
Annual systems from other LU	Type of crop							Current	Upgrading				
Annual after deforestation (current)	Default	?	?	?	?	?	Please select	-	-	0	-		
Annual after deforestation (upgrading)	Default	?	?	?	?	?	Please select	-	-	0	0		
Annual after non-forest LU (current)	Default	?	?	?	?	?	Please select	-	-	0	-		
Annual after non-forest LU (upgrading)	Default	?	?	?	?	?	Please select	-	-	0	0		
Annual crop staying as annual:								Yield (t/ha/yr)					
Riz pluvial traditionnel	Grains	?	?	?	?	?	Burned	0.3	0.7	19	0		
Riz pluvial amelioré	Grains	?	?	Yes	?	?				0	19		
Description#3	Default	?	?	?	?	?	Please select			0	0		
Description#4	Default	?	?	?	?	?	Please select			0	0		
Description#5	Default	?	?	?	?	?	Please select			0	0		
								Total (ha)		19	19		
Percentage of production loss								50%	50%				

Source: FAO, 2019b.

♦ **FIGURE 8** Management practices for the irrigated rice

Rice systems staying as rice system							Yield (t/ha/yr)		
Riz conventionel	240	Irrigated - Intermittently flooded	Non flooded preseason <180 days	Straw exported	5	17	0		
Riz amélioré	240	Irrigated - Intermittently flooded	Non flooded preseason <180 days	Straw exported	10	0	17		
Description#3	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment		0	0		
Description#4	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment		0	0		
Description#5	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment		0	0		
Description#6	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment		0	0		
					Total (ha)	17	17		
Percentage of production loss					15%	15%			

Source: FAO, 2019b.

Climate mitigation impact

The change of management practices brought about several benefits in terms of climate mitigation and for household economics.

RAINFED RICE PRODUCTION

While GHG emissions increase from the application of urea, about 9 tCO₂-e/yr, they are largely compensated by the new management practices adopted on rice field, i.e. stopping residues burning, 14 tCO₂-e/yr. Climate-smart agriculture practices (see Table 4), here contribute to a decrease in GHG emissions at production level, from 0.09 to -0.15 tCO₂-e/ha/yr, which are mainly driven by shifting to residue burning and retaining them (see Table 7).

IRRIGATED RICE PRODUCTION

Climate-smart agriculture practices for this FAO project involve different approaches for seeding and weeding which do not have any impact on GHG emissions. Since there is no changes in agricultural inputs, GHG emissions without and with implementation of CSA practices are equivalent, at 5.9 tCO₂-e/ha/yr. Over the whole value chain, GHG emissions increase at processing level proportionally to the increase of production (see Table 8).

In this case, agricultural inputs have a small share of the total GHG emissions when considering the whole value chain. Their associated GHG emissions remain steady in the irrigated rice since there is no change in fertilizers consumption and the straw is exported for composting in other productions. GHG emissions are reduced by stopping the residues

burning whereas applying compost does slightly increase GHG emissions (see additional scenario for more information). The adoption of CSA practices implemented within this FAO project have a positive impact on the carbon footprint from production to processing. The carbon footprint is here defined as tCO₂-e per tonne of white rice. In rainfed rice although the production loss is consequent, i.e. 50 percent, the carbon footprint is 0.7 tCO₂-e per tonne of white rice as compared to 0.89 tCO₂-e per tonne of white rice in the initial situation, so a decrease of 1.58 tCO₂-e per tonne of white rice at production level (see Figure 9). In the case of irrigated rice increased yield, i.e. 101 tonnes of white rice are produced per year with implementation of CSA practices as compared to 66 tonnes in the original situation. Thus, significantly decreases the carbon footprint, 1.08 tCO₂-e per tonne of white rice with the project scenario, as compared to 2.16 in the situation without the project (see Table 8).

◆ **TABLE 7** Details of the rainfed rice carbon footprint

	Without CSA	With CSA
GHG impact (tCO₂-e/yr)	1.62	-2.88
GHG impact (tCO₂-e/ha/yr)	0.09	-0.15
Carbon footprint (tCO₂-e per tonne of milled rice)		
Production	0.89	-0.70
Processing	–	–
Transport	–	–
Total carbon footprint for the milled rice	0.89	-0.70

Source: FAO, 2019b.

◆ **TABLE 8** Details of the irrigated rice GHG emissions and carbon footprint

	Without CSA	With CSA
GHG impact (tCO₂-e/yr)	101	102
GHG impact (tCO₂-e/ha/yr)	5.86	5.86
Carbon footprint (tCO₂-e per tonne of milled rice)		
Production	2.16	1.08
Processing	0.02	0.02
Transport	0.01	0.01
Total carbon footprint for the milled rice	2.19	1.11

Source: FAO, 2019b.

At the processing level, GHG emissions are linked to the electricity consumption (27 kWh per kg of paddy rice processed), and are relatively low, i.e. about 25 tCO₂-e/yr (data not shown) which translated per tonne of white rice of about 0.02 tCO₂-e per tonne of white rice.

Sensitivity analysis of the mitigation impact

In the near future, applying compost for the production of irrigated rice will be considered. An additional scenario has been run to take into account the impact of compost application on GHG emissions. Such a practice fuels the organic carbon pool, which results in higher CH₄ emissions as compared to the business as usual situation when straw is exported. Indeed, as explained by the IPCC “organic material incorporated into rice soils increases CH₄ emissions. The impact of organic amendments on CH₄ emissions depends on the type and amount of the applied material which can be described by a dose response curve. Organic material incorporated into the soil can either be of endogenous (straw, green manure, etc.) or exogenous origin (compost, farmyard manure, etc.)”. The emission factor for compost is 1.15 kg CH₄/ha/day, while for green manure and farm-yard manure it is respectively 1.4 and 2.18 kg CH₄/ha/day (IPCC, 2006).

The impact of compost applied as organic amendment is consequently reflected in the GHG emissions, with an increase of GHG emissions, from 5.86 tCO₂-e/ha/yr without application of compost to 6.54 tCO₂-e/ha/yr when applying compost (see Table 9). Therefore, some practices deemed sustainable such as the application of compost in lieu of synthetic fertilizers can potentially generate more GHG emissions. This analysis demonstrates that the implementation of such practices needs to go along with an increase of the crop productivity. By doing so, it helps to decrease commodity's carbon footprint avoiding land use changes and land reclamation to provide for the consumer demand, in this case being rice.

♦ **TABLE 9** Details of the irrigated rice GHG emissions and carbon footprint

	Without compost	With compost
GHG impact (tCO₂-e/yr)	101	114
GHG impact (tCO₂-e/ha/yr)	5.86	6.54
Carbon footprint (tCO₂-e per tonne of milled rice)		
Production	2.16	1.20
Processing	0.02	0.02
Transport	0.01	0.01
Total carbon footprint for the milled rice	2.19	1.23

Source: FAO, 2019b.

Economic analysis

The economic analysis was run for the Demidougou community as the rainfed rice community does not sell the rice but consumes it. The economic analysis assume that applied CSA practices and yields are uniform for each household. Data from Table 6 was used to populate EX-ACT VC. While it has been demonstrated in the section above that a shift to sustainable practices significantly contribute to climate mitigation, this shift also helps to double the yield, and hence to improve the economic conditions this community.

While the production cost was about XOF 120 per kg of white rice, it decreased to XOF 71 per kg of white rice with the project, as the production doubled. Post-production costs, i.e. transport and processing, are inherently linked to the volume of production and therefore increased with the project.

The value added is defined as the gross production value minus the cost at production level. In the present analysis the annual value added is estimated to reach XOF 12 192 000 in the current situation increasing to XOF 33 821 000 with the project. This is linked to the increase of both yield and expenses from transport and milling level. The annual value added (two cycles) after the project is estimated to increase by 44 percent compared to before the project. This also potentially represents a sharp increase for the gross income for the farmers, from XOF 717 185 per year in the current situation, to about XOF 2 million with the project (see Table 10).

◆ **TABLE 10** Economic analysis at production level of the producers of irrigated rice

	Without project	With project
Area covered for crop (ha)	17	17
Annual net rice production (tonnes)	72	141
Gross processed production value (XOF)	17 405 000	41 148 000
Value added (XOF)	12 192 000	33 821 000
Gross income (XOF)	12 192	33 821
Value added per tonne of product (XOF)	168 750	240 056
Value added per hectare (XOF)	717 185	1 989 461
Gross income per household	717 185	1 989 461

Source: FAO, 2019b.

Climate resilience analysis

The aim is to specify a score between 0 and 4 for every questions asked in this module based on project experts' judgement (0 being the lowest and 4 the highest). It is a qualitative appraisal of the extent of the upgrading scenario on the buffer capacity of the rice value chain to natural shocks, of the households in relation to food security. It also analyses the resilience and the self organization of households and the market resilience and the adaptation capacity of the value chain. An assumption for every sub-index was done in this case, but is open to debate. The questionnaire on climate resilience is in Figure A2 in the Annex.

In terms of system resilience, both types of cultivations are managed under a medium climate resilience (see Table 11).

♦ **TABLE 11** Impact on system resilience with implementation of climate-smart agriculture practices for rainfed rice and irrigated rice producers

Resilience index of the system	Rainfed rice producers	Irrigated rice producers
Buffer capacity of project area	Medium	Medium
Buffer capacity of rice production	Low	Low
Buffer capacity of household in relation to food security	Low	Low
Self-organization of households	Medium	Medium
Learning capacity of households	High	High
Resilience generated by project implementation	Medium	Medium

Source: FAO, 2019b.

The global medium resilience index is explained by a low buffer capacity of the project area. Climate-smart agriculture practices improves efficiency in the use of water and soil conditions, and at the production level, reduces crop failure and disease. The project benefits mostly at the household level with a medium buffer capacity in relation to food security by increasing income, food availability and agricultural skills. The active participation of the households in the project implementation increased the linkages between agriculture value chains and capacity building on local knowledge. It also suggests it could benefit the system resilience, such as the self-organization of the households. The project also improves, though to a lesser extent, market resilience and adaptation capacity to value chains through farmers' knowledge of threats and opportunities to agricultural production.

Briquette production and potential of bioenergy

Briquette production lines were installed in three mills. Each line has a capacity to process 250 kg of husk per day to produce 175 kg of briquettes per day from 115 kg of carbonized material (FAO, 2018c). The calorific value of the briquette is the equivalent to 225 kg of charcoal (FAO, 2018c). The three lines have a capacity to produce 165 tonnes per year which represent only 4 percent of the available rice husk feedstock in the area. This is the equivalent of 212 tonnes of charcoal per year or 1 414 tonnes of woody biomass assuming a traditional conversion rate from wood to charcoal of 15 percent (FAO, 2014). This aboveground biomass represents the equivalent of 5.4 ha of naturally regenerated forest (IPCC, 2006), or about 55 tCO₂ sequestered per year in the case of reforestation of tropical moist deciduous forest, according the following breakdown: 7.35 tCO₂/yr sequestered in the soil and 47.5 tCO₂/yr sequestered in biomass (FAO, 2019b).



5 Conclusion and policy recommendations

The results of this analysis show that the implementation of CSA practices, including soil conservation, efficient fertilization practices, use of by-products to produce energy and adoption of drought tolerant rice seeds positively impact the rice value chain, from producers and, to a lesser extent, processors. The main impact concerns the reduction of the carbon footprint of milled rice for both irrigated and rainfed cultivations. However, this reduction is only achieved on a per crop unit basis through significant increase in yields in the case of irrigated rice. This shows the importance of ensuring that all good farming practices are implemented in synergy, as a key factor to achieve sufficient yield improvement in this case. The sharp increase in household income is mainly due to the increased yields. Although rainfed farmers are the most vulnerable to climate change (one rice crop and a production which barely cover their self-consumption), this analysis highlights the potential of simple agricultural practices and adaptation to climate change on incomes and food security.

This analysis demonstrated the importance of using by-products of the rice value chain to produce energy. The replacement of charcoal by rice husk briquettes implies co-benefits for the forestry sector and increased profits for rice millers. They have the opportunity to shift from a costly waste management process to improved profits and replacing the use of charcoal in the area.

The results from this analysis demonstrates that existing policies support rice production and marginally support its transformation. Despite the potential in agri-residues management, incentives for the development of a modern bioenergy sector in Côte d'Ivoire are scattered. Other areas of the value chain such as storage and post-harvest still receive low attention. Stable and predictable policies related to all steps of the agricultural value chains and residue management that take into account the carbon footprint of commodities would then be conducive to economic growth. These policy schemes would also support the national “zero deforestation policy in agriculture” through the energy recovery of agriculture by-products, ecosystem restauration, certification of zero deforestation products on markets and the involvement of all commodity stakeholders (coffee, cocoa, palm oil, rubber and subsistence crops). The threshing (manual) and the loss of production at storage level within a community should be addressed if observed at a regional level (Figure 7). This loss was reported to be associated with a lack of hermetic containers and stored production consumed by pests. Such marginalized communities (rainfed rice) do not have the sufficient technical and or financial means to preserve their production, putting at risk their food security.

Finally, if CSA practices are widely applied at regional scale, it will generate meaningful multiple benefits, both in term of climate mitigation and adaptation, and socio-economic aspects. For instance, transporters and millers will have to face an increase of throughput. This is expected to create numerous jobs. It is recommended to test the different CSA practices in synergy in a larger project area and GHG emissions to be monitored along the value chain. For instance the activities related to rice value chain development within the *Programme d'Appui de la Relance des Filières Agricoles en Côte d'Ivoire* (PADFA) could benefit from CSA practices including bioenergy and an EX-ACT VC tool analysis.

The use of rice husk briquettes can contribute to reduce the dependence on charcoal and therefore benefits natural forests. Cooking tests have shown that briquettes have a higher energy content than charcoal but produce a higher quantity of ashes. The production of ashes could be reduced by decreasing the amount of clay used in the process of briquette production.



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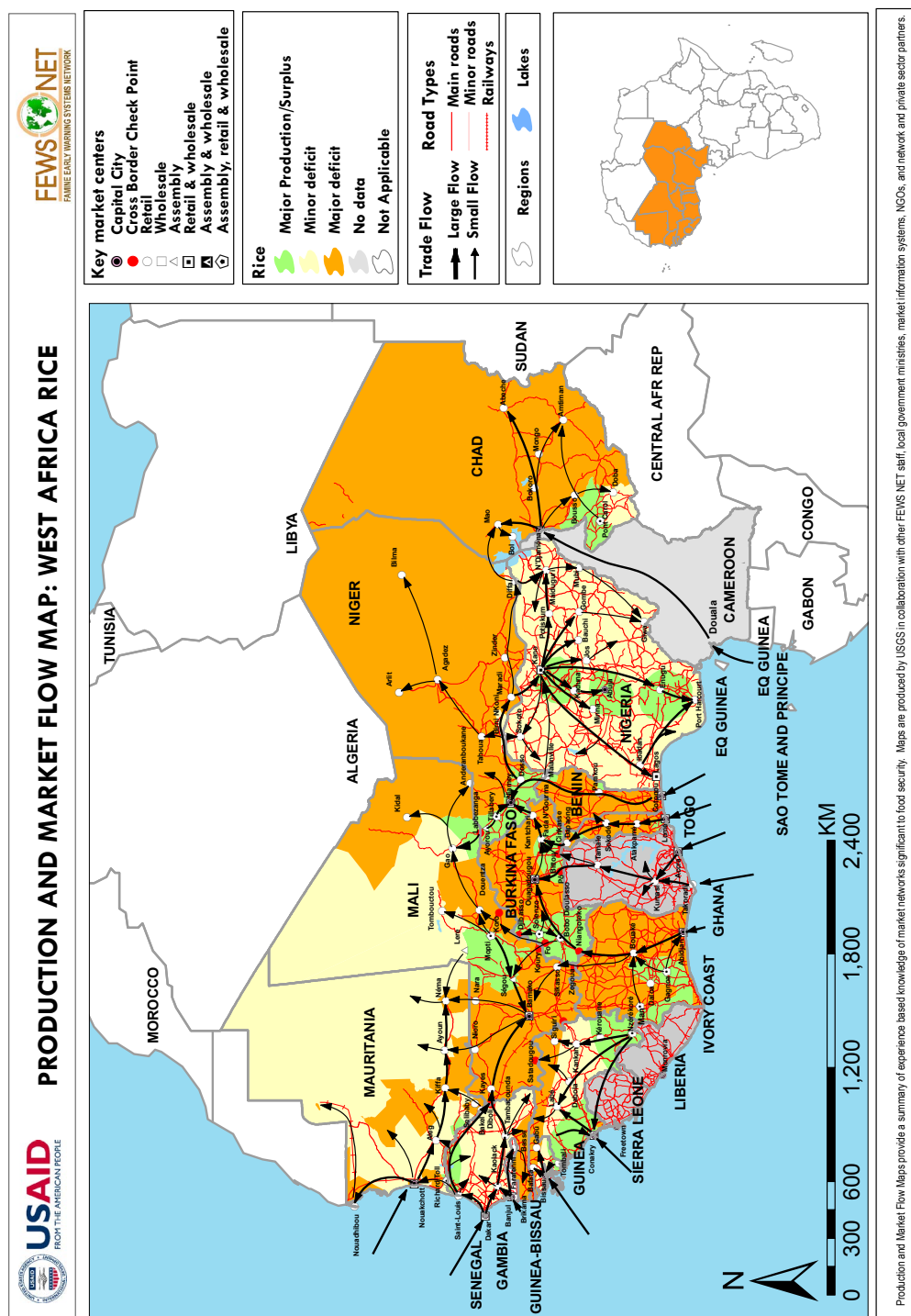
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Annex

FIGURE A1 Production and market flow rice in West Africa



Note: Conforms to UN Map No. 4045 Rev. 8.1, July 2018.

Source: FEWS, 2009.

◆ **TABLE A1** Rice policies in Côte d'Ivoire from 1960 to nowadays

<p>1960–1977 Larges public investments leads the supply value chain</p>	<p>Rice policy was essentially producer-oriented. The government made large public investments to boost the rice sector and achieve self-sufficiency in rice. Parastatal companies, e.g. Soderiz, were in charge of leading development of the rice supply chain. At the upstream level, they were involved in distributing inputs (improved seeds, herbicide and fertilizer) to increase rice productivity and facilitate access to mechanization to modernize rice production systems. At the downstream level, Soderiz implemented institutional purchase of rice at a floor price designed to provide incentives to producers to invest in rice production. Soderiz was also controlling rice processing with modern mills. Rice imports declined to 2 000 tonnes per year compared to 48 000 tonnes per year prior to 1970 (mainly from the Kingdom of Thailand, Taiwan Province of China and the Republic of Italy). The effectiveness and success of the rice development programs enabled Côte d'Ivoire to export 32 000 tonnes of rice in 1976. In 1977, Soderiz was dismantled because of managerial difficulties.</p>
<p>1978–1994 Public investments decrease, imports increase</p>	<p>The government progressively retrieved from the rice sector and allowed for more private investment (mainly in processing and marketing activities). This coincided with a decline in the international market price of rice, which encouraged Côte d'Ivoire to start rice imports to meet national demand, imports rose up to 350 000 tonnes per year in the 1980s and 1990s (United States of America, Thailand, the Socialist Republic of Viet Nam and the Islamic Republic of Pakistan).</p>
<p>1995–2008 Suppression of annual quotas on imports</p>	<p>Liberalization and privatization were phased in during the ensuing period starting from 1995 until 2008. Production, processing and marketing activities were privatized. Rice imports were also liberalized and extended to brown rice and broken rice. In 1997, annual quotas on rice imports were suppressed. Rice imports reached 616 530 tonnes/year, mostly as broken rice. Thailand, the Republic of India, Pakistan, Viet Nam and in a lesser share the United States of Americas were the main importers.</p>
<p>After 2008</p>	<p>The food crisis due to the civil war (2002–2011), prompted the Ivorian government to reduce its heavy reliance on rice imports and undertake to provide a significant boost to domestic production. An emergency plan for development of the rice sector was drafted in 2008 to emphasize the production side of the value chain through (seeds, fertilizer and agricultural equipment), but failed because of funding issues. Imports represented 64 percent of rice consumption in 2011.</p> <p>In 2012, the original 2008 rice sector development program was revisited to formulate more realistic objectives achievable within a specific time frame and to address the main challenges across the different nodes of the rice value chain. This resulted in a national rice development strategy 2012–2020 led by the ONDR. It targeted the production of milled rice to 1 900 000 tonnes by 2016, and up to 2.1 million tonnes by 2018. Rice import still remains a challenge, i.e. 950 000 tonnes per year in average since 2008 (mainly from Asia) (see Table 1).</p>

Source: Coulibaly, Tebila and Diagne, 2015; Boansi 2013.

FIGURE A2 Analysis of the system resilience

Data entry for qualitative appraisal of climate resilience induced by project to be done here		Expert group assessment (0-4)	Indicator weighting (0-3)	
Buffer capacity of watershed, landscape and project area				
1	To what extent does upgrading the value chain <u>improve land cover</u> ? (e.g. agroforestry, cover crops etc.)	0	0	
2	To what extent does upgrading the value chain <u>reduce soil erosion</u> ?	0	0	
3	To what extent does upgrading the value chain <u>improve soil conditions</u> (e.g. soil moisture, soil structure etc.)?	3	3	
4	To what extent does upgrading the value chain <u>improve efficient use of water</u> ?	2	3	
5	To what extent does upgrading the value chain <u>save water</u> ?	0	0	
6	To what extent the value chain area upgraded <u>is protected from climate shocks</u> ?	1	2	
7	To what extent the value chain <u>infrastructure - building investments are climate-proof</u> ?	0	0	
Sub-Result		17	medium	16
Buffer capacity of systems production		(0-4)	(0-3)	
8	To what extent does upgrading the value chain <u>reduce crop failure</u> ?	1	1	
9	To what extent does upgrading the value chain <u>improve resistance of crops to pests and diseases</u> ?	2	2	
10	To what extent does upgrading the value chain <u>improve resistance of livestock to pests and diseases</u> ? (e.g. through	0	0	
11	To what extent does the project reduce post-harvest losses?	1	2	
12	To what extent does upgrading the value chain <u>increase practice of mixed cropping/intercropping</u> ?	0	0	
13	To what extent does upgrading the value chain <u>promote on-farm diversity</u> (annuals/perennials, mixed cropping, mixed farm enterprise e.g. livestock-crop)?	0	0	
14	To what extent does upgrading the value chain <u>reduce (crop/livestock) yield variability</u> ?	1	2	
Sub-Result		9	low	14
Buffer capacity of households in relation to food security		(0-4)	(0-3)	
15	To what extent does upgrading the value chain <u>improve household food availability</u> (e.g. through increased household food production or improved household access to food)?	2	3	
16	To what extent does upgrading the value chain <u>improve household food storage</u> ?	1	3	
17	To what extent does upgrading the value chain <u>improve household income</u> ?	2	3	
18	To what extent does upgrading the value chain <u>increase agricultural production physical assets</u> ?	0	0	
19	To what extent does upgrading the value chain <u>improve access of households to agricultural inputs</u> ?	1	3	
20	To what extent does upgrading the value chain <u>support (existing or new) farmer groups and networks</u> ?	1	3	
21	To what extent does upgrading the value chain <u>increase agricultural skills</u> ?	2	3	
22	To what extent does upgrading the value chain <u>improve access of households to climate-related social safety nets</u> (e.g. climate-index agriculture insurance, cash, vouchers, warehouse receipt systems etc.)?	1	2	
Sub-Result		29	low	40
Resilience and self-organisation of households		(0-4)	(0-3)	
23	To what extent does upgrading the value chain <u>improve cooperation and networks of farmers</u> (e.g. farmer groups, farmer field schools, farmer organisations etc.)?	2	2	
24	To what extent does the value chain upgraded <u>collaborate with national/sub-national farmer/pastoralist organisations</u> (capacity of farmers/pastoralists to influence decisions)?	1	1	
25	To what extent does upgrading the value chain <u>support farmer-networks across scales</u> (e.g. local farmer groups being connected to national farmer organisations; bridging/linking social capital)?	0	0	
26	To what extent <u>are farmers actively participating in the upgrading project</u> ?	3	3	
27	To what extent does upgrading the value chain <u>foster good governance</u> (keeping of records; accounting for exclusion, elite capture and corruption) in farmer cooperation and networks?	0	0	
28	To what extent does upgrading the value chain <u>improve farmer skills to manage groups</u> ?	0	0	
29	To what extent does upgrading the value chain <u>link with other actors</u> ?	0	0	
30	On-farm reliance: To what extent does upgrading the value chain <u>build on local knowledge</u> ?	2	2	
Sub-Result		18	medium	16
Market resilience and adaptation capacity of value chain		(0-4)	(0-3)	
31	To what extent does upgrading the value chain <u>improve farmer knowledge of threats and opportunities to agricultural production</u> (e.g. climate specific awareness programmes)?	4	3	
32	To what extent does upgrading the value chain <u>improve access to extension services</u> ?	2	2	
33	To what extent does upgrading the value chain <u>improve farmer/pastoralist experimentation</u> (e.g. through farmer/pastoralists field schools, climate field schools, exchange visits)?	4	3	
34	To what extent does upgrading the value chain <u>improve access to climate information</u> (e.g. seasonal forecasts adapted for agriculture, workshops)?	4	3	
35	To what extent does upgrading the value chain <u>improve access to market information</u> ?	0	0	
36	To what extent does upgrading the value chain <u>improve access to communication networks</u> (e.g. mobile networking, radio programmes)?	0	0	
Sub-Result		40	high	22
TOTAL RESILIENCE INDEX		113	medium	108

Source: FAO, 2019b.

The present technical study provides the results and a summary of the most important lessons learned from implementation of a series of climate-smart agriculture (CSA) practices in the rice supply chains of Gagnoa in Côte d'Ivoire. The aim of the CSA practices was to enhance the adaptive capacity of the rice sector against climate change, as erratic rainfall patterns and droughts events have, historically, significantly impacted production. This study relies on data collected at farm and processing levels during two field missions to two pilot sites in August 2017 and September 2018 under the project “*Contribution à l'atteinte des objectifs liés au changement climatique et à la sécurité alimentaire via l'agriculture intelligente face au climat en Côte d'Ivoire – cas de la filière riz*”. This project is a technical cooperation project implemented by the Food and Agriculture Organization of the United Nations (FAO) from 2016 and 2018. The study provides a series of recommendations for policymakers, including incentives for the development of a modern bioenergy sector in Côte d'Ivoire which are still nascent.

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