Enhancing Sustainable Land Management and Climate-Resilient Agri-food Systems in Côte d'Ivoire (LARACI) Funding Proposal

Annex 23a: Adaptation benefits - narrative

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Contents

1 Introduction and overview of adaptation impact

This annex (23a) includes a narrative elaboration of the methodology used and assumptions applied for the calculation of the adaptation benefits (Core indicator 2) of the LARACI project. This narrative is accompanied by an Excel spreadsheet (Annex 23b) comprising the calculations of the number of direct and indirect beneficiaries adopting the climate-smart innovations promoted by the LARACI project, and a quantification of the adaptation benefits achieved by the beneficiaries whether through enhanced soil organic carbon, water saving, or production and income increase in a climate vulnerability context.

1.1 Project objectives

Côte d'Ivoire is facing increasing climate-related challenges that threaten agricultural productivity, food security, and livelihoods, especially in the central regions. Farmers are already contending with reduced crop yields, soil degradation, and decreased ecosystem productivity, which are only expected to increase moving forward.

Despite being relatively climate-resilient, the combination of high exposure to climate risk with the low adaptive capacity associated with current practices still makes rice, cassava, and yam-based value chains highly vulnerable to climate risk. The rice, cassava, and yam-based value chains face significant exposure to climate change, especially from increased temperatures, changing rainfall patterns, drought and floods, and pests and diseases (see Annex 2). Poor management practices used by farmers, particularly the use of obsolete non-climate resilient varieties, blanket fertilizer application, poor water control, limited use of organic fertilizers, crop residue removal, and limited crop diversification result in low adaptive capacity.

The adaptation objective of the LARACI project is to improve the production and profitability of rice, cassava, and yam value chains in the face of climate change, thereby contributing to enhanced food security.

The innovations that will be promoted by the LARACI project have been prioritized during stakeholder consultation workshops based on their potential to enhance climate change resilience, land productivity, and reduce greenhouse gas emissions, and their alignment with farmers' biophysical and socio-economic conditions.

1.2 Overview of results

Based on the calculations presented in Annex 23b, the project is expected to result in positive adaptation impacts on a total of 588,000 individuals, consisting of 147,000 direct beneficiaries and 441,000 indirect beneficiaries by the end of the project (Core indicator 1). The number of direct beneficiaries represents 5% of the total population of the target region, whereas the number of indirect beneficiaries represents 14% of the total population in the target region. The intervention will bring 110,600 hectares of land under improved low-emission and climate-resilient management practices by the end of the project (Core indicator 4).

At an aggregate level, the adaptation outcomes from these innovations include an increase of 65,100 tons in rice production per year by the end of the project, 21,972 tons per year in cassava production, and 113,643 tons per year in yam production despite projected climate stress risks It is expected that by the end of the project, the beneficiary farmers' net income will be raised by a total of USD 122.2 million per year. Moreover, total soil organic carbon will be boosted by 61,100 tons per year and water usage in rice cultivation will decrease by 5.76 million m^3 per year.

2 Assumptions used in calculations

Because smallholders in the target regions commonly manage mixed cropping systems and as experience shows that scaling is often achieved through integrated packages rather than single technologies (e.g., integrated soil fertility management packages, agronomic advice plus climate information advisory in combination), we apply a conservative 30% overlap adjustment when aggregating beneficiaries across technologies and value chains in order to avoid double-counting. This means that total direct and indirect beneficiaries are computed as 70% of the simple sum of technology-specific beneficiary counts.

Direct beneficiaries are defined as farmers and producer organization members who receive targeted project interventions and whose adoption of at least one promoted CSA practice is verified through panel surveys, extension agent records, or using minimum adoption criteria as will be defined in the Project Operations Manual. Indirect beneficiaries are defined as individuals who benefit from project outcomes through peer diffusion and social learning effects without directly receiving project inputs, training, or extension services. They include neighboring farmers who adopt promoted CSA practices after observing the results achieved by direct beneficiaries. All beneficiary figures are detailed in calculations in Annex 23b. The projection for indirect beneficiaries assumes that for each direct beneficiary who adopts the innovations, three indirect beneficiaries who are not targeted by the project will adopt the innovations after having observed the benefits experienced by a peer direct beneficiary. Empirical evidence from similar smallholder contexts and diffusion of innovation theory indicates that each directly targeted farmer can influence multiple peers through social learning and demonstration effects. The 3:1 indirect-to-direct diffusion ratio is conservative within the range documented in comparable contexts. Takahashi et al.[1], reviewing technology adoption in developing-country agriculture, document farmer-to-farmer spillover effects ranging from 2:1 to 5:1 depending on technology observability and extension support intensity. The CGIAR ACAI project in Nigeria and Tanzania demonstrated adoption diffusion beyond direct participants exceeding 3:1.

Annex 23b also shows that the direct beneficiaries will experience a number of adaptation outcomes through the application of climate-smart agriculture technologies and practices that significantly improve agricultural yield, farmers' income, and, where possible, increase soil organic carbon and reduce water consumption.

[1] Takahashi et al., 2019: Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature. *Agricultural Economics, vol.51, issues 1.*

The calculations in Annex 23b reflect the number of beneficiaries at the end of the project (i.e. end of Year 5 after project start-up). In terms of number of beneficiaries reached, we have used the assumption that 33% of total beneficiaries will be reached in Year 1, 50% by Year 2, 66.7% by Year 3, 83.3% by Year 4, and 100% by Year 5 (end of project). It is assumed that the same number of beneficiaries will continue to experience adaptation benefits for 20 years from project start.

3 Project Scenario

3.1 Description of improved technologies and their adaptation outcomes in a climate vulnerability context

3.1.1 Rice-based systems

In rice-based systems, enhanced resilience to climate change will be pursued through the adoption of RiceAdvice; Smart-Valleys; the system of rice intensification (SRI); combined application of biochar and nitrogen fertilizer; mid-season drainage; and dissemination of climate information services and early warning systems.

- **RiceAdvice:** a digital application offering location-specific recommendations. This application aims to address challenges associated with changing growing seasons and unsuitable varieties. Compared to blanket recommended rice management practices, RiceAdvice increases rice yield by 0.9 t/ha and farmers' income by 306 USD/ha (Arouna et al., 2020). By the end of the project, a total of 50,000 farmers (direct and indirect beneficiaries) are expected to use RiceAdvice recommendations. With 12,500 direct beneficiaries at the end of the project, rice production will increase by a total of 6,750 t per year and farmers' net income by USD 2.3 million yearly (Table 1).
- **Smart-Valleys approach:** focuses on participatory land and water development for improved water control in inland valleys to overcome issues such as drought and soil erosion. Smart-Valleys is a low-cost, participatory, and sustainable approach for small-scale irrigation development in inland valleys. The implementation of the Smart-Valleys approach increases rice yield by 2.2 t/ha and farmers' net income by 748 USD/ha (Dossou-Yovo et al., 2022). By the end of the project, a total of 70,000 farmers (direct and indirect beneficiaries) are expected to use the Smart-Valleys approach. With 17,500 direct beneficiaries by the end of the project, rice production will increase by 23,100 t and farmers' net income by USD 7.9 million per year.
- **System of Rice Intensification (SRI):** a package of technologies that combines the use of younger seedlings, organic matter, intermittent irrigation, and larger spacing (Uphoff, 2003). SRI addresses climate-related stresses such as water scarcity, drought tolerance, changes in rainfall patterns, soil fertility degradation, and biotic stresses such as pests and diseases. Compared to farmers' practices, SRI increases rice yield by 2.4 t/ha, farmers' income by 816 USD/ha, soil organic carbon by 2.66 t/ha and reduces water use by 330 m^3/ha (Sharma et al., 2019). By the end of the project, a total of 50,000 farmers (direct and indirect beneficiaries) are expected to implement the system of rice intensification. With 12,500 direct beneficiaries by the end of the project, rice

production will increase by 18,000 t and farmers' net income by USD 6.1 million per year. Soil organic carbon will increase by 18,000 t and water use will be reduced by 2.5 million m^3 yearly.

- **Combined application of biochar and nitrogen fertilizer:** addresses climate-related stresses such as drought, water scarcity, and soil fertility. Use of the combined application of biochar and nitrogen fertilizer will increase rice yield by 1.0 t/ha, farmers' net income by 340 USD/ha, soil organic carbon by 5.4 t/ha, and reduce water use by 350 m^3/ha (Iboko et al., 2023). By the end of the project, a total of 50,000 farmers (direct and indirect beneficiaries) are expected to switch to the combined application of biochar and nitrogen fertilizer. With 12,500 direct beneficiaries by the end of the project, rice production will increase by 7,500 t and farmers' net income by USD 2.6 million per year. Soil organic carbon will increase by 40,500 t and water saved by 2.6 million m^3 yearly.
- **Mid-season drainage:** a water management technology in which all surface water is removed from the rice field between the mid- and late-tillering stage, allowing the soil to dry and re-aerate before being flooded again for improved field drainage and reduced iron toxicity effects. Compared to continuous flooding, mid-season drainage increases rice yield by 0.6 t/ha, farmers' net income by 204 USD/ha, and reduces water use by 89 m^3/ha (Dossou-Yovo et al., 202**3**). By the end of the project, a total of 50,000 farmers (direct and indirect beneficiaries) are expected to use mid-season drainage. With 12,500 direct beneficiaries by the end of the project, rice production will increase by 4,500 t and farmers' net income by USD 1.5 million per year. Water use will be reduced by 668,000m^3 yearly.
- **Climate information services and early warning systems:** these include information about onset and cessation of growing seasons, dry spells, and daily forecast and establishment of an early warning system to inform rice farmers about the occurrence of drought, flooding, pests, and diseases and enable them to make climate-informed agricultural decisions to enhance resilience to climate change. Farmers who receive and use climate information services and early warning systems have a 0.7 t/ha and 238 USD/ha higher yield than those who do not (Diallo and Dossou-Yovo, 2023). By the end of the project, a total of 50,000 farmers (direct and indirect beneficiaries) are expected to use the climate information services and an early warning system. With 12,500 direct beneficiaries by the end of the project, rice production will increase by 5,250 t per year and farmers' income by USD 1.8 million.

3.1.2 Cassava-based systems

In cassava-based systems, enhanced farmers' resilience to climate change will be achieved through cassava-legume intercropping; tailored agronomic advice via the AKILIMO agronomic advisory service (for site-specific recommendations as well as optimum planting and harvesting time); and cassava seed systems.

- **Cassava-legume intercropping**: Intercropping of cassava and legumes addresses climate-related stresses such as drought, soil erosion, and soil fertility depletion while diversifying farmers' income. It allows for more efficient use of the land cleared or prepared for the cultivation of cassava. In addition, cassava may use some of the nitrogen fixed by the legume crop. Although cassava yields are often reduced in intercropping systems (estimated -1.16t/ha), the land equivalent ratio (LER) is often larger than 1. Moreover, the legume intercrop contributes to reduction in soil erosion (Delaquis et al., 2018). The spatial arrangement of cassava and legumes can be modified to make the management of the companion crop more convenient or to allow for two subsequent companion crops (Pypers et al., 2011). Whether a second intercrop is possible depends on the vigor, growth habit, and size of the cassava crop during the period of the second legume crop (Kreye et al., 2020). For farmers, intercropping also provides an additional, early available source of cash generation until the cassava crop is ready for harvest after about 12 months, leading to an expected income increase of USD 899 per ha. By the end of the project, a total of 30,000 producers (direct and indirect beneficiaries) are expected to have replaced sole cropping with cassava-legume intercropping. With 7,500 direct beneficiaries by the end of the project, farmers' net income will increase by about USD 6.7 million per year.

- **AKILIMO - tailored agronomic and site-specific advisory service/site-specific recommendations:** Site-specific tailored and appropriate quantity levels of fertilizer recommendations based on crop model simulations for cassava support in sustainable intensification. This helps address climate change-related depletion of soil fertility, leading to yield increase of 1.38 t/ha and an income increase of USD 166 per ha. By the end of the project, a total of 30,000 farmers (direct and indirect beneficiaries) are expected to use the tailored agronomic and site-specific advisory service. With 7,500 direct beneficiaries by the end of the project, cassava production will increase by 10,380 t per year and increase net income by USD 1.24 million yearly.
- **AKILIMO (https://akilimo.org) tailored agronomic advisory service – optimum planting and harvesting time:** Provision of site-specific agronomic recommendations for fertilizer application and optimal planting and harvest time, using the AgWise framework of CGIAR's Sustainable Farming Science Program. This supports farmers to adjust planting and harvest times according to (changing) seasonal patterns. By incorporating El Niño–Southern Oscillation (ENSO) phase specific insights, forecasting of agronomic recommendations improves as they relate to wet, dry, and intermediate rainfall seasons. This tool, currently available for Nigeria, will be adapted and introduced to Côte d'Ivoire through LARACI. If there are limitations in the availability of soil libraries, optimal planting recommendations will be adjusted, and alternative fertilizer recommendations will be estimated. Based on results from Nigeria and Tanzania[2], a 21% increase in cassava root yield can be expected through the use of the AKILIMO advisory, bringing the yield increase to 1.4 t/ha with an increase in income estimated to 235 USD/ha. By the end of the project, a total of 30,000 producers (direct and indirect

[2] Based on results from the ACAI project implemented by IITA (ACAI project report Dec. 2022

beneficiaries) are expected to use the optimum planting and harvesting time advisory. With 7,500 direct beneficiaries by the end of the project, cassava production will increase by 10,380 t per year and increase net income by USD 1.8 million yearly.

- **Cassava seed systems:** The ability of cassava to withstand difficult growing conditions and long-term storability of roots underground makes it an ideal candidate crop to address food insecurity and economic vulnerability that many countries in sub-Saharan Africa face due to climate change. Cassava production can only be raised sustainably if farmers have access to climate-smart/resilient improved varieties and production technologies are made available. The availability of improved planting material will strengthen the planting material supply system. Climate-resilient and high yielding cassava varieties are more resilient to changing temperature and precipitation patterns resulting in drought occurrences, making them more adaptable to changing climate conditions. They are also more resilient to drought, pests, and diseases. Promising widely adaptable and high-yielding genotypes varieties from IITA's cassava breeding program will be released and recommended to support climate change adaptation strategies. The recommended genotypes have been thoroughly evaluated for their climate resilience and alignment with different product profiles well suited to food security and are estimated to lead to a yield increase of 20% or 1.3 t/ha and an income increase of 224 USD/ha. By the end of the project, a total of 30,000 producers (direct and indirect beneficiaries) are expected to have adopted the recommended genotypes. With 7,500 direct beneficiaries by the end of the project, cassava production will increase by 9,887 t per year and farmers' net income by USD 1.68 million per year.

3.1.3 Yam-based systems

Enhanced resilience to climate change in yam-based systems will be achieved through plant arrangements that use the available space, and thus resources, more efficiently; climate-smart staking; nutrient uptake and/or nutrient use efficient yam varieties; and yam seed systems.

- **Efficient plant arrangements for improved use of resources**: Replacing mounds by ridges makes crop management more efficient and allows for the use of appropriate planting densities, i.e. an increase to between 10,000 to 10,416 plants ha^{-1} on ridges from 4,000 to 6,000 plants ha^{-1} on mounds (Osei et al., 2015; Owusu Danquah et al., 2018a; Frimpong et al., 2020 as cited in Danquah et al., 2022). By using ridges, farmers will use water resources more efficiently and decrease soil erosion. Yam tubers harvested from ridges tend to be smaller than those harvested from mounds, but this may be an advantage for the export market (Owusu Danquah et al., 2018b as cited in Danquah et al., 2022). The direct benefit for farmers is harvesting a higher number of yam tubers from the same area, reducing the pressure to plant on less suitable or virgin land. Based on evidence from testing in Ghana, combined planting on ridges with seed-tuber treatment and inorganic fertilizer application, use of the trellis system for staking and weed management leading to improve cost benefit ratios compared to conventional practice (mounding, no fertilizer, no seed-tuber treatment, conventional vertical staking) by a factor of 1.3 to 1.9 at three test sites in Ghana (Frimpong et al.

2020). In the project areas, it is expected that farmers will realize a yield increase of about 1 t/ha and increase income by 780 USD/ha. By the end of the project, a total of 100,000 producers (direct and indirect beneficiaries) are expected to benefit from this technology. With 25,000 direct beneficiaries by the end of the project, yam yields will increase by 20,000 t per year and farmers' net income by USD 15.6 million yearly.

- **Climate-smart staking - climate smart soil health and fertility improvement:** Yam requires fertile soil and performs best when staked to support climbing. While tree-based systems for annual cropping failed to be adopted, the introduction of *Gliricidia sepium* as fallow species in yam systems has potential to furnish improved soil properties and stakes during the fallow phase. The leguminous tree contributes to improved soil fertility via nitrogen fixation and reduces the risk of climate-related soil erosion via mulch application from pruning in a crop that is usually characterized by low planting densities. *Gliricidia* is easily established from stem cuttings, it grows quickly, fixes N_2, and is easy to manage (Elevitch and Francis, 2006). Its growth habit of forming long, unbranched shoots, yet allowing for light to reach the soil surface (Carsky et al., 2010), makes it the perfect species to produce yam stakes. Two similar systems will be available for farmer adoption: *Gliricidia* live stakes and *Gliricidia* stakes to cut and carry (Otu and Agboola, 1994). The *Gliricidia* live stake system is based on a high density of *Gliricidia* stakes being planted as fallow. These stakes grow into a bush and are retained for 3 to 4 years. The fallow is then cleared such that 2 to 3 *Gliricidia* stakes are retained but stripped of their leaves. Excess shoots are cut off and either used as stakes in other fields (cut and carry) used as fuel wood or simply left to rot along with the foliage. The yam is planted around the *Gliricidia* and trailed to the *Gliricidia shoots* that are used as climbing support. After the yam harvest, the site is left to regrow the *Gliricidia*. Compared to using bamboo or other non-leguminous/live staking material, the use of *Gliricidia* stakes is estimated to lead to a 16% yield increase or an increase of 1.05 t/ha, and an increased income of 815 USD/ha. By the end of the project, a total of 100,000 producers (direct and indirect beneficiaries) are expected to use *Gliricidia* stakes. With 25,000 direct beneficiaries by the end of the project, yam yields will increase by 20,900 t per year and net farmers' income by USD 16.3 million per year, while soil organic carbon will increase by 2,600 t yearly.
- **Nutrient uptake and nutrient use efficient yam varieties:** Selection of responsive genotypes available from IITA based on evaluation of their performance under the conditions of the target regions. Varieties/genotypes will be assessed through gender integrated participatory, citizen science-based variety selection methods such as tricot to facilitate and enhance uptake of improved varieties and accelerate realization of their climate change adaptation and mitigation potential. It is expected that these varieties will realize a yield increase of up to 2.2 t/ha and an income increase of 1,716 USD/ha. By the end of the project, 100,000 producers (direct and indirect beneficiaries) will have adopted nutrient uptake and nutrient use-efficient yam varieties. With 25,000 direct beneficiaries by the end of the project, yam yields will increase by 44,000 t per year, and farmers' net income will increase by USD 34.3 million yearly.

- **Yam seed systems:** Work on yam seed systems will support the adoption of technologies of high ratio propagation of quality seeds and the establishment of a formal system to get genetic gains faster to farmers. There are no specialized seed yam producers in the traditional yam production systems. Techniques that can be applied for rapid multiplication include Semi Autotrophic Hydroponics (SAH), minisetts, and leaf bud cuttings (LBC). LBCs of disease-free mother plants are used by seed entrepreneurs to produce seeds, increasing the multiplication rate of yam from 1:3 to 1:300. This will make planting materials more readily available. Adoption of quality seeds of climate-resilient yam varieties is expected to lead to a yield increase of 1.44 t/ha and an income increase of 1,120 USD/ha. By the end of the project, a total of 100,000 producers (direct and indirect beneficiaries) are expected to have adopted quality seeds of climate-resilient yam varieties. With 25,000 direct beneficiaries by the end of the project, yam yields will increase by 28,741 t per year and farmers' net income by USD 22.4 million yearly.