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Employment Impacts of Deploying Climate-Smart Agriculture Practices

A Value Chain Input-Output Analysis Approach

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ACRONYMS AND ABBREVIATIONS

BAU	Business-as-Usual
CSA	Climate Smart Agriculture
ESCO	European Skills, Competences, Qualifications, and Occupations
EX-ACT-VC	Ex- Ante Carbon balance Tool for Value Chains
FAO	Food and Agriculture Organization of the United Nations
FTE	Full-time equivalent jobs
GDP	Gross Domestic Product
GGGI	Global Green Growth Institute
ILO	International Labour Organization
IPCC	Intergovernmental Panel of Climate Change
ISCO	International Standard Classification of Occupations
ISIC	International Standard Industrial Classification of All Economic Activities
IO	Input-Output
LT-LEDS	Long-Term Low Emission Development Strategies
NDCs	Nationally Determined Contributions
SDGs	Sustainable Development Goals
TTT	Traditional Territorial Practices and Technique

CONTENTS

Executive summary

Climate-smart agricultural (CSA) practices are actively promoted in developing countries due to their proven impact on reducing climate change risks, enhancing climate resilience, allowing climate change mitigation, and improving welfare, including increasing employment opportunities and household income (World Bank, 2019d). However, few studies quantify the employment impacts of deploying CSA practices. This study contributes to closing this knowledge gap and assumes that contributing to an in-depth understanding of the socio-economic benefits of deploying CSA practices over conventional agricultural practices[1] could help accelerate their adoption, ultimately resulting in employment maintenance or creation in the agricultural sector.

This study quantifies the economy-wide employment impacts of achieving the Nationally Determined Contribution (NDC) targets of Colombia and Ethiopia linked to utilizing CSA practices. It estimates the total gross number of full-time equivalent (FTE) jobs that can be supported through the use of selected CSA practices along the agricultural value chain of selected crops over a period of 10 years (2024 to 2034)[2]. The study compares employment impacts across two scenarios: a business-as-usual (BAU) scenario, which assumes the use of conventional agricultural practices, and an NDC scenario, which assumes the achievement of CSA NDC targets for the same crops and modeling period. Table 1 specifies the crops, CSA practices, and NDC targets assessed per country[3].

Table 1. Crops, CSA practices, and NDC targets assessed.

Colombia	**Crops**	**Cocoa**	**Forest Plantations for Commercial Purposes**	**Irrigated Rice**	**Panela Sugar**
	CSA practice assessed	Agroforestry; Cross-slope barriers	Agroforestry	Cross-slope barriers; Straw mulching; Alternative wet and dry irrigation	Agroforestry; Cross-slope barriers; Solar powered irrigation
	Total current land used for production (baseline, circa 2023)	194,428.0	528,000.0	596,000.0	215,000.0

1 Conventional farming (also known as traditional farming or industrial agriculture) refers to high input o high-yield agriculture systems that include the frequent use of synthetic chemical fertilizers, fungicides, insecticides, herbicides, high yielding cultivars, monoculture, GMO, heavy machinery, intensive tillage, and irrigation (Antonin Le Campion, Francois-Xavier Oury, Emmanuel Heumez, Bernard Rolland, 2020)

2 This 10-year simulation begins with a baseline for the 2022–2023 period, using the most recent data available by country and crop.

3 The estimation of direct employment is based on employment intensities per sub-activities within a crop. Employment intensities refers to the number of workers needed per day at each stage of the value chain. These figures are sourced from existing literature, including value chain assessments by the FAO that utilize the EX-ACT suite of tools. To estimate indirect and induced employment, input-output (IO) modeling is applied. This method uses IO tables to analyze how changes in one sector impact others, helping to determine the additional labor needs across the economy. The IO tables for both countries were obtained from their respective national economic accounts.

	NDC Target [Cumulative area planted under CSA intervention in hectares by 2030]	230,000 (150, 000 under agroforestry, 80,000 for rehabilitation)[4]	368,836[5]	462,046 (255,000 for irrigated rice cultivation and 207,046 for rainfed rice cultivation)[6]	From 165,980 to 200,000[7]
Ethiopia	**Crops**	**Barley**	**Corn**	**Teff**	**Wheat**
	CSA practice assessed	Integrated Soil Fertility Management (ISFM); Agroforestry; Furrow irrigation with Solar PVsystems	ISFM; Agroforestry; Furrow irrigation with Solar PVsystems	ISFM; Agroforestry; Furrow irrigation with Solar PVsystems	ISFM*; Agroforestry; Furrow irrigation with Solar PVsystems
	Total current land used for production (baseline, circa 2023)	926,107.0	2,526,212.0	2,928,206.0	1,897,405.0
	NDC Target **[Cumulative area planted under any CSA intervention in hectares by 2030]**	225,913 (957.61 Smallholder farmers at main rainy season)	225,913 (2,733.32 Smallholder farmers at main rainy season)	225,913 (3,172.12 Smallholder farmers at main rainy season)	225,913 (2049.31 Smallholder farmers at main rainy season)

Source: Authors' development. Notes: Most of the crops included in the study are represented as individual products within the social accounting matrices. However, when a specific crop was not available as a standalone entry, we used closely related crop products as proxies for their IO structure. For example, in the case of Colombia, DANE classifies cocoa under industrial code 2303, forest plantations under 03, and panela under 2302. For rice, however, we approximated its structure using the category "Agricultural products (except coffee) and related services [0101]." In the case of Ethiopia, within the IO matrices, corn is classified under the category "maiz", which corresponds to maize; barley and wheat are grouped together in a single category labeled "whea"; while the structure of teff is approximated using the category "sorg," which corresponds to sorghum and millet.

The study further links the importance of achieving NDC targets with agricultural employment by estimating the impact of increasingly high temperatures caused by climate change on agricultural labor productivity; thus, the number of jobs supported using CSA.

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4 Retrieved from NDC Annex M1. Portafolio de medidas de mitigación de GEI de la NDC, page XI. Project name: Estrategias de reducción de emisiones de GEI en el ciclo de vida de la producción de cacao: Aumento en el área dedicada al cultivo de cacao bajo sistemas agroforestales, así como su renovación y rehabilitación, para incrementar el stock de carbono. Target: 80,000 hectares for renovation and rehabilitation; 150,000 hectares in agroforestry systems with timber species, with a potential mitigation scenario equivalent to 0.16 Mt CO_2e.

5 Retrieved from NDC Annex M1. Portafolio de medidas de mitigación de GEI de la NDC, page XI. Project name: Desarrollo y consolidación de la cadena productiva de las plantaciones forestales con fines comerciales: Articulación técnica y económica para la producción de madera de plantaciones forestales con fines comerciales con el plan de acción de la cadena. Target: Plantation of 27,282 hectares (300,000 hectares from 2015 to 2030). An increase in ambition is anticipated for the year 2030, based on an annual increase in plantations to 34,165 ha (46,000 ha including the reference scenario), which would amount to 368,836 ha of commercial forest plantations under the mitigation scenario by 2030, with a potential mitigation equivalent to 10.37 Mt CO_2e.

6 Retrieved from NDC Annex M1. Portafolio de medidas de mitigación de GEI de la NDC, page XI. Project name: Adopción masiva de tecnología (AMTEC 2.0) para la producción de arroz: Implementación de un modelo de transferencia de tecnología basado en la sostenibilidad y la responsabilidad social, que propende por la organización, la competitividad y la rentabilidad del productor, implementando tecnologías en forma integral masiva para aumentar los rendimientos y reducir los costos de producción en el cultivo del arroz. Incluye pronósticos del tiempo - modelamiento de cultivo, agricultura de precisión y el sistema de riego MIRI. Target: 255,000 hectares of irrigated rice, 207,046 hectares of rainfed rice, with a potential mitigation scenario equivalent to 0.08 Mt CO_2e (only from N_2O emission reductions due to lower fertilizer use).

7 Colombia's NDC does not specify the number of hectares allocated to this strategy. The study assumes an annual target of hectares equivalent to 5% of the current total production area, approximately 200,000 hectares for the modeling period (i.e., 10,000 hectares per year). (Bolaños- Benavideș. et. al. 2023). The NDCs do mention a plan to improve the technology of panela mills, including the substitution of diesel for electric engines, and reforesting 800 hectares of land.

In addition, the study qualitatively assesses employment by reviewing the human capital skills necessary to accelerate the adoption of CSA practices in Colombia and Ethiopia. Finally, it briefly discusses the impact of deploying CSA practices on gender equity and employment informality in the agricultural sector of the assessed countries.

The study recognizes that CSA practices are not a one-size-fits-all solution but rather an adaptable approach contingent upon local circumstances. CSA practices involve managing various aspects of agriculture and landscape management to balance food security and livelihood needs with long-term adaptation and mitigation goals (FAO, 2013). In line with this, the study assesses CSA practices suitable for either increasing smallholder farmers' participation, mitigating GHG emissions, or increasing the climate resilience of the selected crops. These practices are mainly focused on the production stage of the agricultural value chain. In addition, assumptions on the increase or decrease of inputs—such as fuel—were considered to account for more sustainable production practices along the different value chain stages, i.e., aggregation, processing, and distribution.

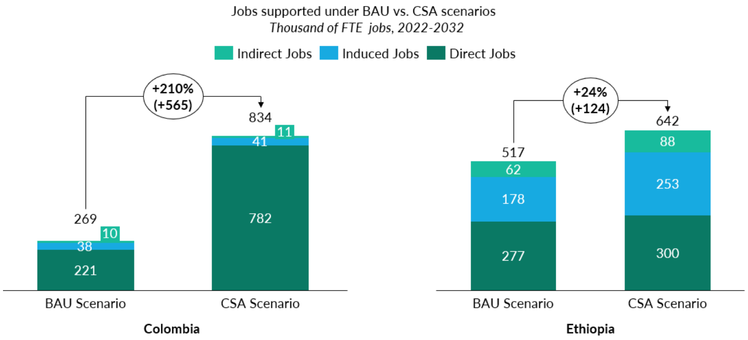
The study links the findings on employment impacts and skills requirements to policy recommendations aimed at increasing employment in the agricultural sector. Thus, the modeling results are presented in the form of five action areas that can facilitate the operationalization of initiatives to accelerate the deployment of CSA practices.

Area 1. Bridging the gap between national and local level climate targets and agricultural development strategies to accelerate CSA deployment through an improved enabling environment

Findings on employment impacts:

The model estimates suggest that utilizing CSA practices on the selected crops to achieve NDC targets could support more jobs than conventional agricultural practices. In Colombia, it is estimated that an average of 83,000 total jobs per year for a period of ten years could be supported when reaching the NDC targets linked to the utilization of CSA practices for the assessed crops. This represents a 210% increase in the number of total jobs—direct, indirect, and induced jobs—supported compared to a BAU scenario, which assumes only the utilization of conventional agricultural practices. In Ethiopia, an average of 110,000 new jobs per year for ten years could be supported. This represents a 24% increase in job numbers compared to the BAU scenario.

Figure 1. Total jobs supported BAU vs. CSA scenarios



Source: Authors' development.

The increase in direct agricultural employment is partially due to the need for additional labor for CSA installation and annual maintenance, as well as some CSA practices being more labor-intensive than conventional ones. Moreover, the increase in indirect jobs is partially due to the extensive investment required in infrastructure to enhance productive potential and resilience to climate change (e.g., irrigation, roads, transportation, storage, as well as extension services and research, development, and access to improved seed varieties. Finally, the increase in induced jobs is linked to the restructuring and consolidation of the food system, which impacts labor markets and re-shapes business activities in towns and cities.

A loss of agricultural employment results from exposure to increasingly high temperatures caused by climate change.[8] In Colombia, between 59,000 and 137,000 FTE jobs are expected to be lost in the sector due to exposure to high temperatures, compared to the total estimated 834,000 new jobs under the CSA scenario. In Ethiopia, exposure to negative climate change impacts would result in a loss of 4,000 to 21,000 FTE jobs from the total estimated new jobs of 641,000.[9]

Policy Recommendations (Detailed in Section 7):

- Ensure the implementation of coordinated climate and agricultural development policies at the local level through increased involvement of local governments, rural communities, and inter-ministerial coordination. This would, in turn, ensure

8 The impacts on labor productivity were derived from considering the shift in the percentage of total work hours lost under intense labor conditions without sun protection under a high work intensity corresponding to a metabolic rate of 400W, adequate to represent typical agriculture labor. These computed hours are then extrapolated to equivalent full-time positions, assuming a standard 8-hour workday over 250 days per full-time employment. The percentage of total work hours lost forecast is based on a scenario with policy measures intended to keep global temperatures on the trajectory of a 2°C increase from 2021 to 2040.

9 Under the BAU scenario, the exposure to negative climate change would result in a loss of 19,000 and 44,000 FTE jobs in Colombia; and a loss of 4,000 to 18,000 in Ethiopia.

the achievement of employment modeling results under a CSA Scenario. The implementation of policies in an articulated manner—climate and economic development policies—takes into account the characteristics of the territories to apply production approaches such as CSA, sustainable, regenerative, agroecological, etc, resulting in increased investments in CSA practices in response to a positive enabling environment. Investments create employment, and integrated development policies minimize employment losses.[Colombia]

- Recognize and address trade-offs between agricultural and climate policies in targets that might lead to future unintended consequences. While Ethiopia's policies demonstrate considerable integration, conflicts between policy objectives could impede progress toward overarching national development goals—notably, efforts to enhance agricultural production clash with environmental objectives and commitments. [Ethiopia]

Area 2. Financing CSA practices at scale.

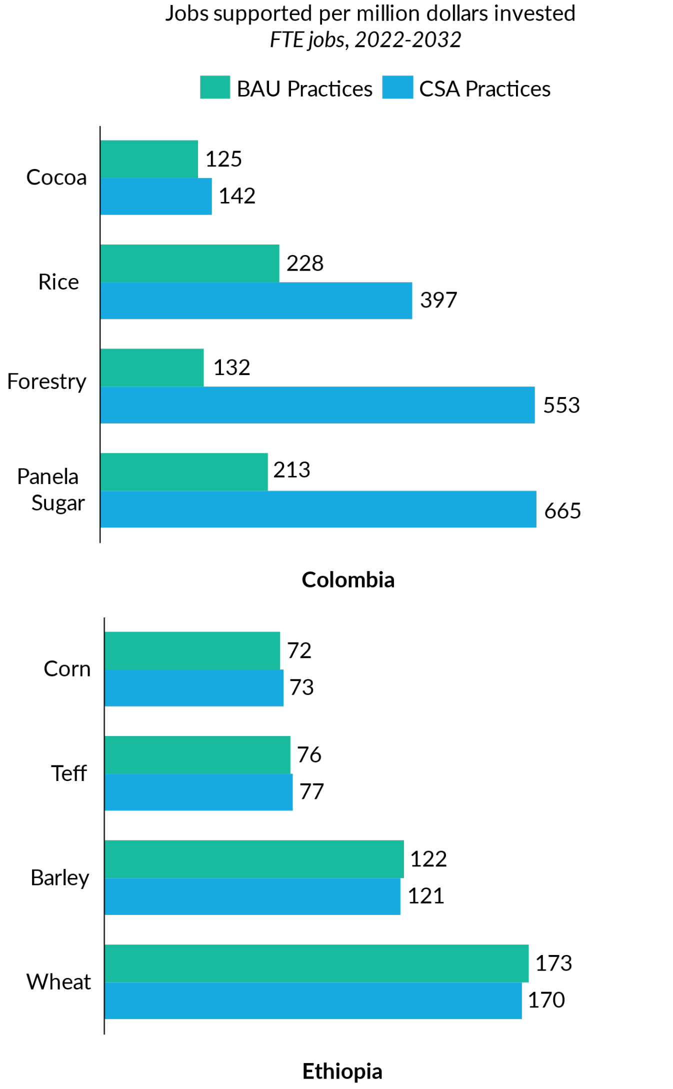
Findings on employment impacts:

The magnitude of jobs supported by the utilization of CSA practices outweighs the additional costs associated with introducing such practices in Colombia. For every USD 1 million invested in CSA practices for the crops assessed, Colombia can support between 142 and 665 jobs (depending on the crop). Conversely, under BAU, USD 1 million would yield between 125 and 228 jobs. In Ethiopia, allocating USD 1 million to CSA practices in the assessed crops would support between 73 and 170 jobs (depending on the crop), and under the BAU scenario, between 72 and 173 jobs. However, it is worth noting that, comparatively, both conventional and CSA practices yield similar results for employment per USD 1 million of investment. For both countries, this occurs because, despite CSA practices generating a higher overall number of jobs, introducing some of these practices increases non-labor production costs,[10] resulting in a smaller budget for hiring personnel.[11]

10 The methodology does not consider significant initial investments (e.g., infrastructure construction). Instead, it focuses on recurrent costs such as basic crop inputs (fertilizers, pesticides, tc.) and activities (maintenance, manure application, land preparation, etc.), electricity, storage, and transportation costs, among others.

11 Refer to Tables A4.1, A4.2, A4.3, and A4.4 in the Annex for sources of labor intensities information and costs of supplies and crops.

Figure 2. Jobs supported per USD 1 million invested in BAU vs CSA practices per crop per country, not considering climate impacts on labor



Source: Authors' development.

The gross value added per worker in the assessed agricultural value chains increased using CSA practices. This reflects increased agricultural productivity within the ten-year period, which is linked to the incorporation of CSA practices. In Ethiopia, the average increase in total gross value added is 42%, while in Colombia it is 20%. The increase in total gross value added varies by crop in both countries analyzed. In Ethiopia, the total gross value added increases significantly in corn (110%) and less so in wheat (13%). In Colombia, the increase is higher in irrigated rice (51%) and lower in cocoa (7%). The study recognizes that there are very large differences in incomes and productivity levels across the different types of farmers within each country and crop type, which might affect the estimation of gross value added. However, the assessment makes no distinction between them.

Policy Recommendations:

- Strengthen risk management and financing strategies to increase CSA. This is key to the additional generation of green jobs as they enable the adoption of adaptation and mitigation practices at scale in the sector. Thus, it is recommended to:
    - Accelerate efforts to develop an integral risk management strategy to increase the provision of agriculture insurance, resulting in increased access to finance for the deployment of CSA practices, particularly for small- and medium-scale farmers. [Colombia]
    - Scale up the utilization of payments for ecosystem services (PES) to finance CSA agroforestry and plantation management activities. [Colombia]
    - Increase awareness of micro, small, and medium-sized farms about agricultural value chain finance (AVCF) opportunities linked to the use of climate-smart solutions. [Colombia & Ethiopia]

Area 3. Unleashing the potential of women's labor force and reducing employment informality in the agricultural sector to accelerate the adoption of CSA practices.

Findings on employment impacts:

Implementing CSA practices improves working conditions in the agricultural sector by increasing agricultural productivity and, therefore, income—particularly for women and smallholder farmers (ILO, 2018). However, structural changes in regulation and financial incentives are required to increase women's participation in the sector and the deployment of CSA practices. This study forecasts the share of women's participation in the agricultural sector by 2032 based on historical growth rates of female labor participation. In Colombia, the model predicts a prevalent gender imbalance where men constitute, on average, 92% of the labor force. Colombia's female labor participation forecast has a compound annual growth rate (CAGR) of 2%, aligned with historical data. In Ethiopia, women's participation is forecasted at 49%.

Similarly, structural changes are required to reduce employment informality in the agricultural sector. The study forecasts employment informality rates in the sector. In Colombia, out of the 221,000 direct jobs estimated to be supported—under the BAU scenario for the four crops assessed—an estimated 109,000 formal jobs (49%) would be generated. In Ethiopia, out of the total direct jobs estimate of 300,000 for the four crops assessed in the BAU scenario, an estimated total of 129,000 (43%) formal jobs would be generated.

Policy Recommendations (Detailed in Section 7):

- Improve land tenure and resource rights for women. [Colombia]
- Reduce educational gender gaps in the agricultural sector. [Colombia]
- Strengthen Ethiopia's gender budgeting initiatives by incorporating gender-focused goals into budgeting instruments and promoting gender balance in development programs, particularly in agriculture, to enhance agricultural production and sustainable food security. [Ethiopia]
- Enhance support for women entrepreneurs by providing access to extension services, training, and contacts with extension agents, improving access to information, credit, and essential inputs. [Colombia & Ethiopia]

Area 4. Improving human capital skills and knowledge for the sustainable transformation of the agricultural sector linked to technology advancements and the utilization of CSA practices.

Findings on skills requirements:

In both assessed countries, the agricultural sector lacks sufficient human capital in technical occupations related to "quality control and monitoring", "establishing and following sanitation protocols", and "managing the production and commercialization of products". It is observed that the occupations considered as "lacking human capital" were also identified as those with relevant skills for accelerating CSA deployment. For example, the study observes that for cultivating most assessed crops in Colombia and Ethiopia, occupations such as Agricultural Technician and Agricultural Inspector, which engage in conducting research and complying with health procedures, require a high share of skills related to "monitoring safety or security and quality" that are crucial for ensuring the crops' market competitiveness. Another example is the scarcity of market-oriented agricultural workers or import-export agricultural specialists who have prominent skills in monitoring, inspecting, and analyzing information as well as in "implementing new procedures or processes", which are an enabler for CSA deployment. Addressing the skills gap in human capital would reduce youth unemployment, long-term unemployment, and underemployment in the agricultural sector while accelerating the adoption of CSA practices.

Policy recommendations (Detailed in Section 7):

- Improve human capital capacities (skills and knowledge)—at the territorial level—to increase deployment of CSA practices whilst preserving and blending them with the use of Traditional Territorial Practices and Techniques (TTT) that are resilient to climate change. [Colombia]
- Ensure the identification and development of necessary technical skills for implementing CSA practices—at the national level—and their linkage to skills relevant to the 4th industrial revolution, such as digitalization. [Colombia]
- Increase access to quality education at the territorial level and include CSA and related topics in the education curricula of rural schools from a basic level of education. [Colombia]
- Improve, at the national level, the provision of technical and vocational skills for the agricultural sector through apprenticeship opportunities and by updating the existing curricula for specific occupations to reinforce skill-based learning. [Ethiopia]

- Improve the quality and availability of labor data in the agricultural sector to provide accurate skills assessment in the country. [Ethiopia]

Area 5. Increasing employment quantity and quality across all the value chain stages of agriculture linked to implementing CSA practices.

Findings on employment impacts:

The model estimates an increase in the number of direct, indirect, and induced jobs supported when using CSA practices, in comparison to the BAU scenario. In Colombia, direct jobs will increase by 254%, indirect jobs by 8%, and induced jobs by 8%. In Ethiopia, this is 8%, 42%, and 42%, respectively.[12]

However, in the case of Colombia, for export-oriented crops with minimal domestic value-added post-harvest (e.g., cocoa), indirect jobs constitute a relatively minor share of overall job creation. This is because fewer industries are engaged in the in-country processing of the yield. On average, Colombia's direct jobs supported by CSA practices represent 94% of the total jobs, 1% of indirect jobs, and 5% of induced jobs. Meanwhile, Ethiopia's estimated share of direct, indirect, and induced jobs is more proportional, highlighting the country's substantial economic influence on agriculture and comparatively lower wages compared to other economic sectors. In Ethiopia, direct jobs account for 47% of the total jobs, indirect jobs for 14%, and induced jobs for 39%.

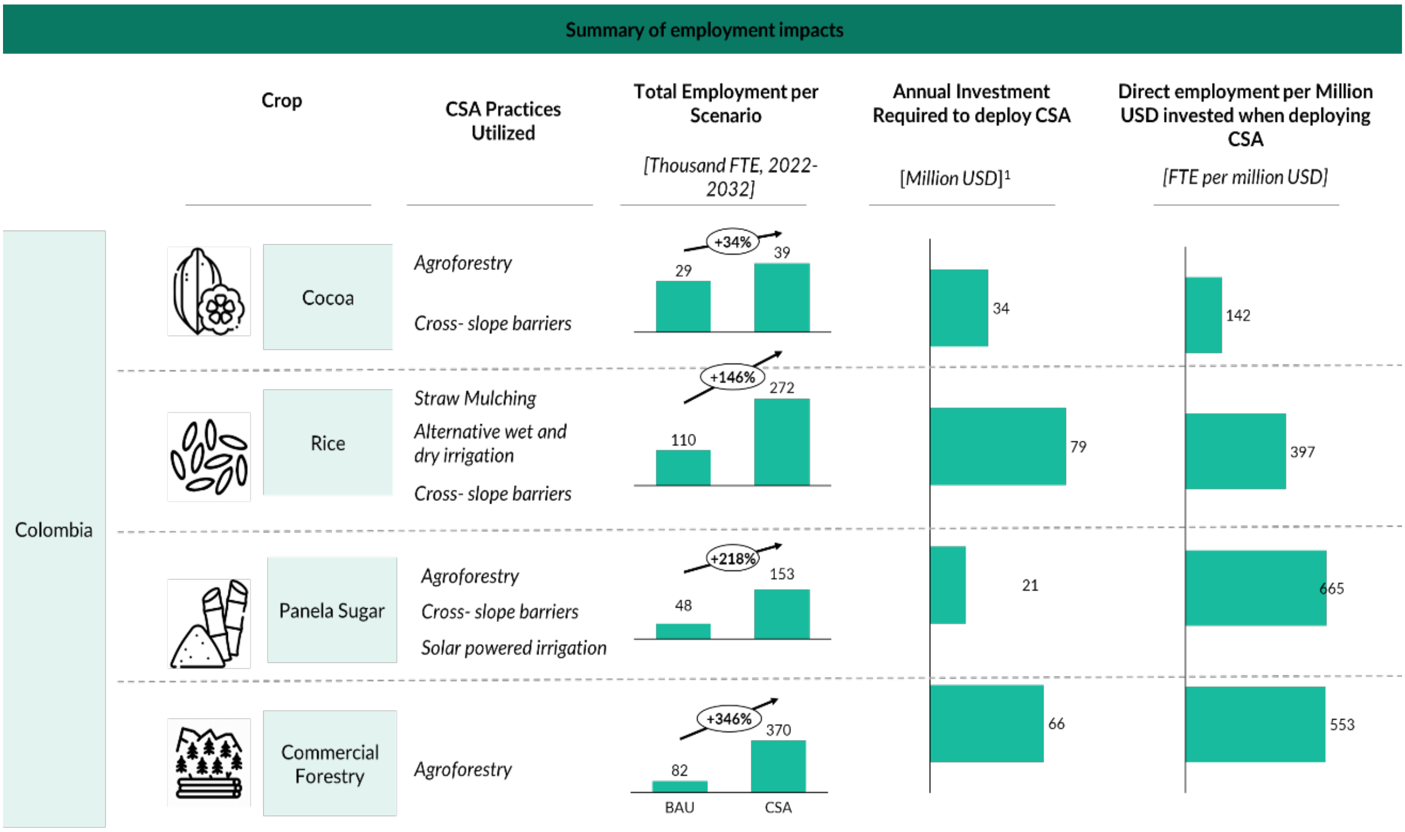
The modeling results indicate that between 70% to 90% of the total direct jobs supported when implementing CSA practices are concentrated in the production stage of the agricultural value chain. However, in coordination with other sustainable practices, CSA practices can support direct jobs in the value chain's transport, processing, and aggregation stages.

Policy recommendations (Detailed in Section 7):

- Accelerate the implementation of CSA practices to increase agricultural productivity, better integrate agro-processing value chains, and increase attractive employment opportunities at the territorial level. This, as a result, will help retain well-prepared professionals in rural areas. [Colombia]
- Increase employment opportunities and promote labor mobility for agricultural workers through existing labor programs. For example, extending the Public Employment Service to rural areas or promoting domestic labor mobility between rural areas could help agricultural workers relocate to other regions and reduce unemployment during periods of reduced activity for specific crops under programs such as Neocampesino. [Colombia]
- Incorporate robust monitoring and evaluation mechanisms to review and proactively address the progress of identified issues. [Colombia & Ethiopia]
- Enhance the adoption of certifications to ensure the adoption of CSA practices along the agrifood value chain. [Ethiopia]

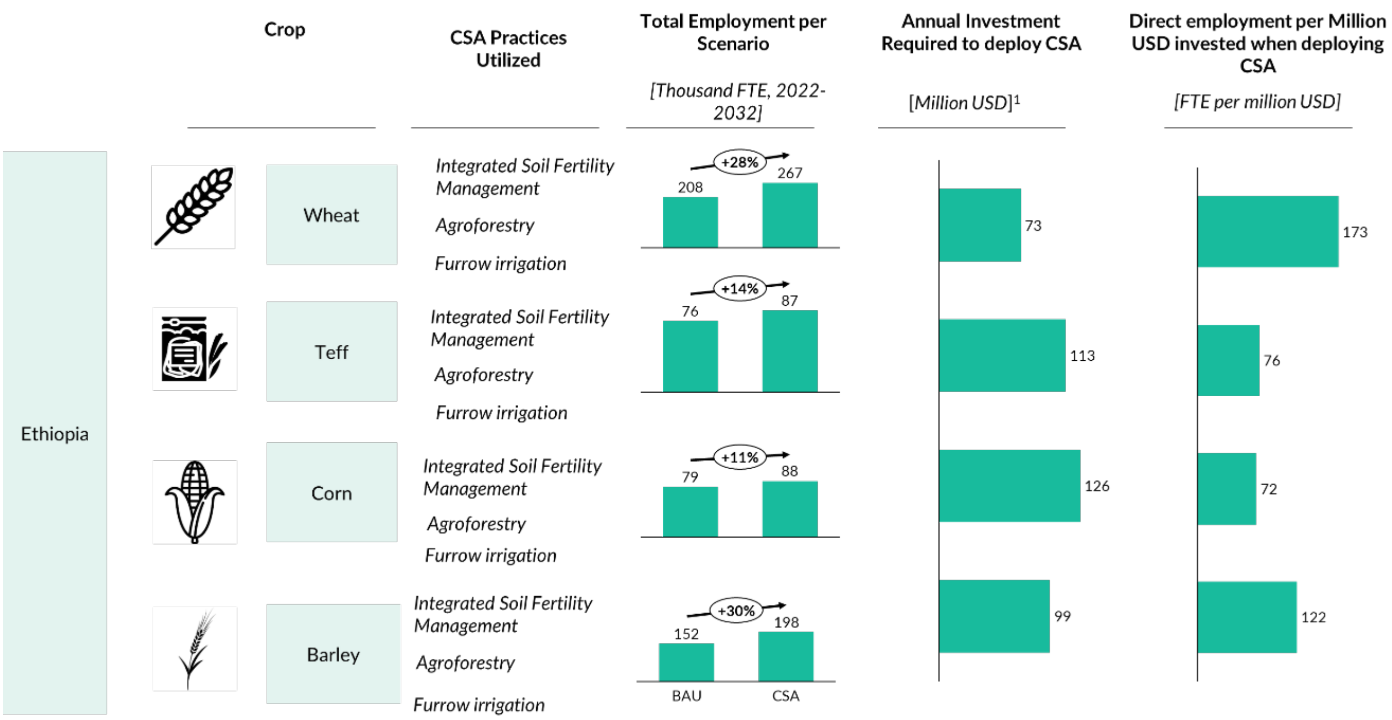
12 Refer to Annex 1 for national definitions of green jobs in Colombia and Ethiopia.

Figure 3. Summary of employment impacts per country and crop



1. Defined as labor and material costs required to fulfill the NDC production targets in hectares per year.

Note: Estimates rely on three bottom-up methods: i) case studies and sector-specific national and international literature, ii) labor markets and agricultural surveys and censuses, and iii) coefficients of input costs and labor intensity per upgrading practice. For more information, refer to Annex 3: Modeling Methodology.



1. Defined as labor and material costs required to fulfill the NDC production targets in hectares per year.

Introduction

Nationally Determined Contributions (NDCs) and Long-Term Low Emission Development Strategies (LT-LEDS) integrate ambitious climate action and green growth activities. NDCs and LT-LEDS that are aligned to governments' national development plans—such as National Adaptation Plans, Green Recovery Plans, and Sustainable Development Goals (SDGs)—can spur job creation (UNDP, 2022).[13] According to the International Labour Organization's (ILO) World Economic and Social Outlook 2018: Greening with Jobs report, maximizing the synergies between labor, climate, and development policies supports the creation of additional jobs in the medium to long term, as well as increases productive human capital. ILO estimates that a net increase of 18 million jobs by 2030 is possible by achieving the climate objectives stated by the NDCs (ILO, 2018).[14]

The agricultural sector is of high priority in achieving climate mitigation as well as adaptation commitments stated in the NDCs, particularly in low and middle-income countries. Climate-smart agriculture (CSA) deployment plays a prominent role within the agricultural sector's levers to achieve the NDC targets. The increasing adoption of CSA practices to achieve agricultural NDC targets has multiple employment impacts. According to the ILO (2018), employment and productivity in agriculture will be significantly affected by the transition to sustainability practices in comparison to other economic sectors. In addition, the transition to sustainability practices in agriculture will greatly impact the quality of jobs for women and vulnerable people—migrant workers, youth, people in poverty, indigenous people, and other vulnerable groups—who are particularly exposed to the risks and damages associated with environmental degradation in the sector.

The shift of agricultural employment linked to CSA deployment will be partially due to the extensive requirement of investment in infrastructure to enhance productive potential and resilience to climate change (e.g., irrigation, roads, transport, storage, etc.), as well as extension services and research and development to improve seed varieties. Moreover, employment in the sector through CSA deployment will benefit from the further decoupling of the sector's growth from environmental pressures (ILO, 2018).

In this context, the assessment of employment co-benefits from adaptation and mitigation actions in agriculture highlights the importance of setting more robust and ambitious NDCs and sectoral targets for addressing climate change and delivering socio-economic benefits. Employment impacts are one of the most compelling climate action co-benefits that "speak" to policymakers both at the national and local levels.

13 UNDP. (2022). Building the Economy of Tomorrow: Using NDCs to Inform Green Recovery. Retrieved from https://climatepromise.undp.org/sites/default/files/research_report_document/undp-ndcsp-ndcs-green%20recovery.pdf

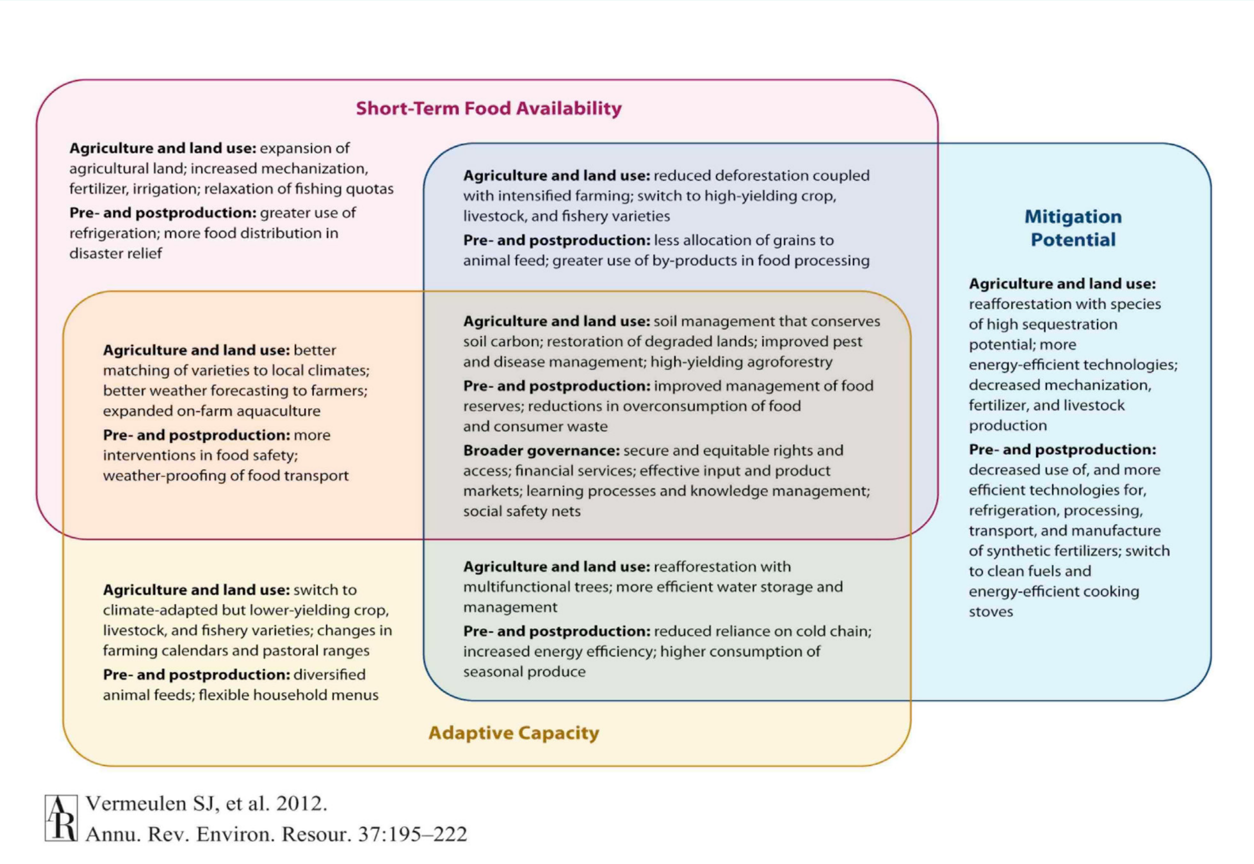
14 ILO. (2018). World Employment and Social Outlook: Trends 2018. Geneva, Switzerland: ILO. Available at World Employment and Social Outlook: Trends 2018 | International Labour Organization (ilo.org)

BOX 1. What is Climate Smart Agricutlure (CSA)?

The Food and Agricultural Organization (FAO) defines climate-smart agriculture (CSA) as "agriculture that (1) sustainably increases productivity - to support equitable increases in farm incomes, food security and development, (2) enhances resilience (adaptation) of agricultural and food security systems to climate change, and (3) reduces/removes GHGs (mitigation) from agriculture (including crops, livestock, and fisheries) where possible. (FAO, 2013)

What constitutes a CSA practice is context-specific, depending on local socio-economic, environmental, and climate change factors. CSA practices have some common characteristics. First, CSA practices aim to produce triple-win outcomes: increased productivity, enhanced resilience, and reduced emissions. Second, CSA practices combine different technologies and solutions, ranging from the elaboration of climate change models and scenarios to the use of information technologies, insurance schemes, value chains, and the strengthening of institutional and political enabling environments. Third, CSA practices maintain ecosystem services to minimize degradation. Finally, CSA practices aim to engage women and marginalized groups. (CGIAR, 2024)

Figure 4. Examples of CSA practices and their synergies and trade-offs (Source; Vermeulen et al. 2012, p. C-3)



This study evaluates the employment co-benefits associated with implementing CSA practices in specific crops—dictated by the NDC targets—within two Global Green Growth Institute (GGGI) member countries: Colombia and Ethiopia. The first section serves as an introduction to the study and presents its objectives. The second section provides an overview of the existing literature related to the topic. The third and fourth sections outline the scope and methodology of the study, respectively. The fifth section presents the results of modeling a CSA deployment scenario compared to a BAU scenario, alongside an assessment of the skills required for selected occupations. The sixth section discusses the findings. Finally, the seventh section offers policy recommendations to promote employment through the adoption of CSA practices, support skills development for a sustainable transition in the agricultural sector, and advance gender equity in agriculture.

1.1. Study objectives

The study quantitatively and qualitatively assesses the employment impacts of achieving Colombia's and Ethiopia's Nationally Determined Contribution (NDC) targets in the agricultural sector linked to utilizing CSA practices with specific crops.

The study has three clear objectives:

To quantify the employment impacts of utilizing CSA practices under two scenarios – BAU and CSA - for selected crops in Colombia and Ethiopia. Employment impacts are measured as (i) the total gross number of FTE jobs supported along the value chain of a crop, disaggregated by direct, indirect, and induced jobs as well as by value chain stage (i.e., production, aggregation, processing, and distribution/ transport (wholesale and retail), gender, formality, and year; and (ii) number of total jobs created per USD 1 million invested. The assessment considers the influence of climate change on labor productivity and, therefore, employment losses or creation.

To identify the (i) required key occupations and (ii) skills—including "green skills"—in the agricultural sector required to scale up the implementation of CSA practices. The study briefly discusses the primary skills gap in the agroforestry sector in Colombia and Ethiopia.

To provide actionable policy recommendations that can support employment creation by deploying CSA practices.

2 Literature review

CSA practices are a crucial element within policy frameworks to enhance agricultural productivity sustainably, foster resilience against climate-related risks, and mitigate GHG emissions. Furthermore, CSA represents a holistic approach that can effectively alleviate poverty by offering a pathway towards resilient poverty alleviation. Strategically designed CSA initiatives thus play a pivotal role in promoting sustainability and securing future food and nutrition security (Minang et al., 2015; Negera et al. (2022). Nevertheless, the adoption of CSA practices in Ethiopia and Colombia remains limited[15 16].

Various factors impede the widespread of CSA practices, mainly at the territorial level among smallholder farmers. These factors include the substantial initial investments needed, input requirements, operational expenses, restricted access to technology, and limited information on CSA options. Additional challenges include minimal short-term benefits, the necessity to balance productivity with sustainability and environmental conservation, insufficient knowledge regarding seasonal climate forecast trends, and inadequate coordination throughout agricultural value chains (Akinyi, 2022).

To overcome the multiple barriers hindering CSA adoption, numerous research studies assessing the socioeconomic aspects influencing CSA adoption and developing cost-benefit analyses for CSA adoption exist. However, there is limited literature on the impact of employment creation. Only one quantitative study on employment impacts was found to be relevant to this report. Sain, G., 2017 estimates the employment impact of CSA practices in Guatemala through a cost-benefit analysis. The study assumes that CSA installation and annual maintenance require the use of additional labor beyond that already used on the farm. Survey data was used to estimate the increase in labor for installation and maintenance multiplied by the average local cost of labor (US$ 4.9/person/day). The study results show that, on average, across CSA practices, labor increased by 4 person-days/ha in the first year of practice establishment and by 8 person-days/ha per year for operation and maintenance. This results in an across-practice average labor increase of almost US$ 167/ha in investment in the initial year and an annual increase of US$ 300/ha/year for the lifecycle of the practices. (Sain et al. 2017). Other studies quantitatively

15 World Bank; CIAT; CATIE. (2014). Climate-Smart Agriculture in Colombia. CSA Country Profiles for Latin America Series. Washington D.C.: The World Bank Group. Available at https://ccafs.cgiar.org/resources/publications/csa-country-profiles

16 CIAT; BFS/USAID. (2017). Climate-Smart Agriculture in Ethiopia. CSA Country Profiles for Africa Series. International Center for Tropical Agriculture (CIAT); Bureau for Food Security, United States Agency for International Development (BFS/USAID), Washington, D.C. 26 p. Available at https://ccafs.cgiar.org/resources/publications/csa-country-profiles

mention the potential employment impacts of CSA adoption. Notably, the community-based aspect of a CSA makes unpaid internships common on CSA farms because members want to be involved and connected to their food. [17]

Other studies relevant to this report that assess Colombia and Ethiopia are worth mentioning. Yitbarek and Tesfaye, for example, assess the welfare impacts of CSA adoption and its complementarity with non-farm employment in Ethiopia using representative survey data. The study concludes that households adopting both CSA and non-farm employment enjoy higher welfare than those who do not practice CSA or engage in non-farm employment. However, CSA adoption alone appears to provide higher consumption expenditure than its combination with non-farm employment [18]. Moreover, Howland F. et al. assess the socioeconomic aspects influencing CSA adoption in Colombia. The study concludes that knowledge and learning were among the most important factors that either facilitated or slowed down CSA adoption, which supports the idea that adoption processes are very closely linked with a mixture of changes in farmers' knowledge, attitudes (influenced by experiences of success), and skills (through training)[19]. Similarly, FAO's Climate-Smart Agriculture Source Book discusses decent rural employment and the CSA jobs approach. This book highlights the importance of focusing efforts on enhancing, upgrading, and developing skills and capabilities in ways that will allow the rural poor to adapt to a greener labor market[20]. In contrast, Negera et al. (2020) explore the influence of farmers' education level on adopting CSA practices in Ethiopia. The study echoes others—such as Faleye and Afolami (2020)—that highlight a negative influence of farmers' education level on CSA adoption, and justifies that educated individuals prefer white-collar employment to diversify their income rather than moving toward CSA adoption[21]. Nevertheless, the study also states these results as unexpected and inconsistent with many empirical studies.

Notably, Akinyi et al. (2022) evaluate the costs vis-à-vis benefits associated with prioritized climate adaptation practices among smallholder farmers in selected value chains in five SSA countries, including Ethiopia. Their study concludes that in Ethiopia, the most viable CSA practices were improved seed and conservation agriculture in the faba beans value chain[22]

17 Endres B.A., Schlessinger L., Endres R. Embracing The Sharing Economy and Preparing for Risj : The CSA Expérience. Drake Journal of Agricultural Law. Retrieved from (https://aglawjournal.wp.drake.edu/wp-content/uploads/sites/66/2019/11/Endres-Macro-Final-Reprinted.pdf

18 Yitbarek, E., Tesfaye, W. (2022) Climate-Smart Agriculture, Non-Farm Employment and Welfare: Exploring Impacts and Options for Scaling Up. Sustainability, 14(23):15981. https://doi.org/10.3390/su142315981

19 Howland, F., Andrieu, N., Bonilla-Findji, O. (2018). Understanding socioeconomic aspects influencing CSA adoption. CCAFS Working Paper no. 247. Wageningen, The Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at www.ccafs.cgiar.org.

20 Food and Agriculture Organization of the United Nations. (FAO) (2013). Climate-Smart Agriculture Sourcebook. Retrieved from https://www.fao.org/3/i3325e/i3325e.pdf.

21 Negera M., Alemu T., Hagos F., Haileslassie A. (2020). Determinants of adoption of climate-smart agricultural practices among farmers in Bale-Eco region, Ethiopia. Heliyon, 30;8(7):e09824. doi: 10.1016/j.heliyon.2022.e09824.

22 Akinyi, D. P., Ng'ang'a, S. K., Ngigi, M., Mathenge, M., & Girvetz, E. (2022). Cost-benefit analysis of prioritized climate-smart agricultural practices among smallholder farmers: evidence from selected value chains across sub-Saharan Africa. Heliyon, 8(4),e09228. https://doi.org/10.1016/j.heliyon.2022.e09228

BOX 2. Global overview of employment and occupations related to CSA

According to the ILO, approximately 384 million people were employed in the agricultural sector in 2022 (equivalent to 24% of the global employed population). The sector comprises 96% of crop and animal production workers, 2% of fishing and aquaculture workers, and 1% of forestry and logging workers. The occupational composition of the sector varies greatly from one country to another. (ILO Labor Force Statistics, 2022)

The implications for employment when using CSA are commonly unassessed. Changes in agricultural land management, such as conservation tillage, agroforestry, and rehabilitation of degraded crops and pasture land, could create jobs. However, some proposed changes may also reduce direct employment in agriculture and increase indirect employment in related industries. For example, conservation tillage requires fewer labor inputs but increases the use of specialized machinery, leading to an increase in manufacturing jobs (UNEP, 2008).

Megatrends in agricultural employment:

- Employment shifting from agriculture to service sectors will continue (CEDEFOP, 2023).
- Digitalisation will increase yields and reduce inputs (production) (ibid) while, in many cases, reducing labor requirements (Balmford et al., 2018).

BOX 2. Global overview of employment and occupations related to CSA

- Agricultural occupations linked to primary productive work (e.g., sowing, harvesting, planting, breeding, or fattening) and the handling or use of machinery would be at high risk of being replaced because they are routine and easily protocolized tasks, while occupations linked to the management and/or supervision of personnel, as well as support from scientific and technological research would be rather complemented by the integration of new digital technologies. (ODEPA, 2019)
- Digital transformation will shift upwards the level of digital skills employers ask for, even in low-skilled occupations where no special training was needed in the past (such as agriculture) (CEDEFOP, 2023).

Occupations for CSA:

- The green transition will transform the tasks of the current occupations in agriculture rather than drive the creation of new occupations within the sector.
- Examples of occupations related to the deployment of CSA are Environmental Scientist, Field Technician, Pest And Disease Monitoring Operator, Agrochemical Applicator Operator, Irrigation Operator, Agricultural Machinery And Implements Operator, Technician Irrigation Manager, Organic Crop Management Operator, Soil Scientist, Sustainable Supply Chain Executive, Climate Smart And Sustainable Agribusiness Expert, etc. (ODEPA, 2019)

Global skills gaps and knowledge needs for CSA deployment:

- The technological needs of CSA drive the need to regularly refresh skillsets in areas such as equipment automation and digital information.
- Environmental management and natural capital management skills are identified as a priority.
- Agricultural technical skills, notably digital automated technologies, are required for tasks such as precision agriculture, which can potentially reduce the excessive use of pesticides.
- An increase in entrepreneurship skills—to link farm activities with other income sectors such as tourism—is desirable.
- Agricultural laborers need to enhance their operating and maintaining machinery skills—particularly for precision instruments—while skilled farm workers need to increase their competencies in farm management, marketing, and accounting, including their understanding of statistical standards to produce means and standard deviations, operational knowledge of computerized spreadsheet applications, knowledge of precision agriculture software (database query, interface, and mapping) .
- Knowledge of certifications, monitoring, and evaluation of the agricultural process and other value chain stages would be valuable (OECD, 2023b).

Scope of the assessment

This study assesses employment and economic impacts at the national level for Colombia and Ethiopia. The assessed countries were selected based on five factors: 1. Relevance of the agricultural sector to the national economy, measured as a share of GDP; 2. Relevance of the agricultural sector for employment, particularly for vulnerable populations, measured as a share of total employment; 3. High climate vulnerability of the agricultural sector, measured as the percentage of crops affected by negative climate change impacts; 4. Relevance of CSA practices for climate mitigation and adaptation in the agricultural sector – stated in the NDCs and NAPs; and 5. High opportunity to support synergies between climate targets and development policies in the agricultural sector, measured as the degree of disjunction between policies to reach climate targets and development policies to increase agricultural productivity.

Moreover, the study assesses four staple crops per country. In Colombia, panela sugar, rice, cocoa, and forest plantations cultivated for commercial purposes are examined. In Ethiopia, wheat, corn, teff, and barley were selected. The assessed crops were selected based on the targets to utilize CSA practices as stated in the country's NDCs and/or other climate or sectoral policy documents. Additionally, these crops were selected for Ethiopia because, according to FAOSTAT (2023), they ranked among the top five crops with the highest production in the country in 2023 (the latest available data): corn (10 million tons), teff (included in the "Cereals n.e.c." category – 6.54 million tons), wheat (5.8 million tons), and barley (2.45 million tons). In the case of Colombia, the selected crops are also crucial to the country's economy. For instance, panela sugar is the crop with the highest production in 2023 (32.42 million tons), while rice and corn are the third and seventh most produced crops, with 3.01 million tons and 1.95 million tons, respectively.

Finally, the study assesses multiple CSA practices per crop. The study uses FAO's definition of CSA practices: "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals" (FAO, 2013). The study also acknowledges the World Bank's definition of climate-smart, which refers to "agricultural transition to low-carbon growth, in addition to enhancing development and reducing vulnerability" (Sova, C. A et al., 2018). The study recognizes that CSA practices are not a one-size-fits-all solution but rather an adaptable approach contingent upon local circumstances. CSA practices involve managing various aspects of agriculture—crops, livestock, aquaculture, and fisheries—as well as landscape management to balance food security and livelihood needs with long-term adaptation and mitigation goals. Furthermore, CSA practices extend their influence beyond individual farms, encompassing interventions across the whole value chain[23]. Therefore, the study exclusively assesses the ongoing CSA practices for the selected crops in each country that have a documented impact on employment, crop yields, and capital costs.

The study defines conventional farming (also known as traditional farming or industrial agriculture) as high-input or high-yield agriculture systems that include the frequent use of synthetic chemical fertilizers, fungicides, insecticides, herbicides, high-yielding cultivars, monoculture, GMO, heavy machinery, intensive tillage, and irrigation (Antonin Le Campion, Francois-Xavier Oury, Emmanuel Heumez, Bernard Rolland, 2020)

The following country profiles detail the selection factors for countries, crops, and CSA practices.

3.1 Colombia

As of 2023, agriculture was the 4th most important sector in Colombia. Agriculture generated 9.32% of the country's value-added, surpassed only by the wholesale and retail trade sector that contributed 20.12%, the public administration and defense sector with 14.36%, and the manufacturing sector with 13.18% (DANE, 2023)24. Agriculture's performance has improved as peace negotiations have prioritized rural development; the sector's value-added compound annual growth rate is approximately 2.42% from 2019 to 2023, similar to the national total economy CAGR growth of 1.96% (DANE, 2024)25.

Moreover, the agricultural sector in Colombia is the 2nd sector with the highest employment share in the country, employing 14.6% of the working population as of 2024 (DANE,2024)[26]. The sector is highly important for employing vulnerable populations. For example, the share of female employment over the total female workforce in the sector is equal to 6.6% (MADR, 2019).

However, the negative impacts of climate change seem to threaten Colombia's agricultural productivity and employment potential. The country's agricultural sector is one of the most vulnerable to climate change. By 2050, climate-related weather extremes and patterns will impact 80% of crops in more than 60% of current areas of cultivation in Colombia. This will have severe impacts on perennial and exportable crops (Ramirez-Villegas et al., 2012), affecting the productivity of all agricultural subsectors, and resulting in negative consequences for food security and livelihoods (Bezner et al., 2022). Colombia ranks among the countries with the highest recurrence of extreme events in South America, with most of the population being exposed to two or more hazards. The effects of climate change exacerbate flooding and landslides, and the country is also at risk of droughts, which pose a significant threat to the agricultural sector. Colombian agriculture is particularly vulnerable to increasing aridity, soil erosion, and desertification, which already pose serious problems and potentially could threaten food security (World Bank, 2022).

Colombia's revised NDC recognizes the value of CSA in mitigating GHG emissions and adapting to climate change within the agricultural sector.[27] Implementing CSA practices is a lever for climate risk reduction, supporting the subsistence of smallholder farmers and the sector's productivity and preserving the employment of vulnerable populations[28]. Colombia's updated NDC includes some Nationally Appropriate Mitigation Actions (NAMAs) related to CSA practices, such as the climate-smart coffee growing pilot program and the panela production program. Moreover, Colombia's Agriculture-specific National Adaptation Plan (NAP-Ag) and the Comprehensive Management Plan of Climate Change for the Agricultural Sector (PIGCCSAg) include measures such as 1. Promoting research and development of technologies and innovation for climate-smart agriculture; 2. Designing financing instruments to promote the development of climate-smart practices; and 3. Scaling up adoption of CSA practices[29].

Colombia's NDC outlines plans to enhance the adaptive capacities of the rice, cocoa, and panela sugar sub-sectors in response to climate variability and change. Moreover, Colombia's Ministry of Agriculture and Rural Development focuses on sustainable forest plantations for commercial purposes, the life cycle of cocoa production, and technology adoption for irrigated rice production[30]. In congruence with the above, this study assesses panela sugar, rice, cocoa, and forest plantations cultivated for commercial purposes as the four selected crops. Table 2 shows the characteristics of the assessed crops.

23 FAO. (2013). Climate-Smart Agriculture Sourcebook. Retrieved from https://www.fao.org/3/i3325e/i3325e.pdf.

24 DANE. (2023). PIB Bogotá y Colombia, 2015-2023. Accessed from https://www.ccb.org.co/es/informacion-especializada/observatorio/analisis-economico/crecimiento-economico/pib-bogota-y-colombia-2015-2022

25 DANE. (2024). Cuentas Nacionales. Available at https://www.dane.gov.co/index.php/estadisticas-por-tema/cuentas-nacionales/cuentas-nacionales-trimestrales/historicos-producto-interno-bruto-pib

26 DANE. (2024). Principales indicadores del mercado laboral Marzo de 2024. https://www.dane.gov.co/files/operaciones/GEIH/bol-GEIH-mar2024.pdf

27 UNFCCC. (2020). ACTUALIZACIÓN NDC COLOMBIA – 2020. Retrieved from https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20actualizada%20de%20Colombia.pdf

28 FAO, ILO & IUF; (2007). Agricultural Workers and Their Contribution to Sustainable Agriculture and Rural Development. Retrieved from https://www.fao.org/3/bp976e/bp976e.pdf

29 https://accionclimatica.minambiente.gov.co/pigcc-sectorial/

30 OECD. (2022). Policy Highlights: OECD Rural Policy Review Colombia 2022. Retrieved from https://www.oecd.org/regional/rural-development/Policy-Highlights-Rural-Colombia.pdf

Table 2. Characteristics of selected crops in Colombia

Variable	Unit	Crops	Circa 2022	Target of CSA utilization by 2030	Source
Area planted	Ha (Hectare)	Irrigated rice	596,000	462,046	Encuesta Nacional Agropecuaria (2022); NDC (2030)
		Panela sugar	215,000	165,980	
		Cocoa	194,428	230,000	
		Forest plantations for commercial purposes	528,555 total area or 12,394 new hectares in 2021.	368,836	
Production	Tons	Irrigated rice	3,526,949	N/A	Encuesta Nacional Agropecuaria (2022); Sociedad de Agricultores de Colombia
		Panela sugar	1,333,000	N/A	
		Cocoa	1,601,939	126,000	
Productivity	Tons/Ha	Irrigated rice	5.4	–	Encuesta Nacional Agropecuaria (2022) & FEDEPANELA (2021)
		Panela sugar	6.2	–	
		Cocoa	0.7	–	
Employment*	# of FTE	Irrigated rice	50,859	–	GEIH, 2022
		Panela sugar	81,870	–	ILO, 2020
		Cocoa	53,152	–	Ministry 2021
	# of producers	Forest plantations for commercial purposes	32,181	–	GEIH 2022; NYT, 2021.
		Panela sugar	20,000	–	
Wage	Average monthly (USD, exchange rate of 4200).	Irrigated rice	312	–	GEIH 2022 Gran Encuestra Integrada de Hogares (GEIH) at the ISIC class level.
		Panela sugar	238.1	–	
		Cocoa	190.8	–	
		Forest for commercial purposes	367.7	–	
Interventions		Irrigated rice	–	Improve production	NDC
		Panela sugar	–	Technical conversion and restoration	
		Cocoa	–	Increase cultivation	
Investment in the crops	USD	Irrigated rice	N/A	85 million[31]	NDC (2030); MADR y FINAGRO (Cocoa 2020)
		Panela sugar	N/A		
		Cocoa	252.335[32]		
Vulnerability to climate change	IPCC Scale	Irrigated rice	Medium		IPCC AR 6 Chapter 5 p.718
		Panela sugar	High		Zhao & Yanng-Rui (2015)
		Cocoa	High		IPCC AR 6 Chapter 5 p.788

*Source: Authors' development. Notes: Most of the crops included in the study are represented as individual products within the social accounting matrices. However, when a specific crop was not available as a standalone entry, we used closely related crop products as proxies for their IO structure. For example, in the case of Colombia, DANE classifies cocoa under industrial code 2303, forest plantations under 03, and panela under 2302. For irrigated rice, however, we approximated its structure using the category "Agricultural products (except coffee) and related services [0101]." *Employment figures were taken from microdata surveys when available, and refer to the number of direct jobs within each crop.*

31 Investment required to strengthen the capacity to mitigate and adapt production systems to climate change for the next seven years for rice, panela sugar , cocoa, and bovine livestock.

32 Total support per year.

The study identifies potential CSA practices per agricultural value chain stage per crop. However, only a few of the CSA practices listed were selected for assessment. (See Table 3, where CSA practices marked with * were used in this study). (Annex 1 provides the definition of each CSA practice listed). Selected CSA practices were previously identified by practitioners as practices with high adoption rates in the country, with a high impact on productivity and high climate smartness (World Bank, 2014). Moreover, selected CSA practices have a documented impact on employment, crop yields, and capital costs.

Table 3. Identified and selected climate-smart practices in Colombia

Value Chain Stage	Objective	Sustainable agricultural practice	Impact			Utilization in Colombia			
			Mitigation of GHG emissions	Increasing climate resilience	Increasing smallholder farmers participation	Rice	Cocoa	Panela Sugar	Forestry
Production	Conservation agriculture	Minimum mechanical soil disturbance	X	X					
		Permanent soil organic cover	X	X					
		Species diversification	X	X					X
	Risk management of crop and income loss	Crop insurance		X	X	X	X	X	X
		Income diversification			X	X	X	X	X
		Improve access to credit			X	X	X	X	X
		Strengthen household capacity (time allocation)			X	X	X	X	X
		Educational campaigns and training acquirement			X	X	X	X	X
	Soil Conservation (Management of soil nutrients)	Integrated soil fertility management (ISFM) *				X	X	X	X
		Increase use of organic fertilizers *	X			X	X	X	
		Conservation tillage	X	X					
		No-till/ Zero tillage farming *	X	X		X			
		Minimum tillage	X	X					
		Contour farming or row planting	X	X					
		Intercropping *	X	X	X	X	X	X	
		> Mixed intercropping	X	X	X				
		> Row/Alley/Strip cropping	X	X					
		> Relay cropping	X	X					
		Windbreaks or shelter belts	X	X					
		Crop rotation	X	X	X				
		Straw incorporated /mulching *		X		X			
		Transplanting of teff							
		Cover crops							
		Biopesticides	X						
		Natural Fungicides	X						
		Biofumigation	X						
		Micro-dosing	X	X					
	Improved irrigation and water management	Alternate wet and dry irrigation of rice (AWDI) *	X	X		X			
		Intermittently flooded vs Continuously flooded	X	X		X			
		Flood or furrow irrigation*	X	X		X			
		Bank Stabilization	X	X					
		Buffer Strips	X	X					
		Grassed waterways	X	X					
		Sprinkler and drip irrigation, particularly solar-powered *	X	X		X	X	X	
		Modern irrigation systems	X	X					
		Deficit irrigation *	X	X		X			
		Irrigations based on evapotranspiration (ET)	X	X					
		Irrigations based on soil water content/tension	X	X					
		Cross-slope barriers *	X	X		X	X	X	
	Management of genetic resources	Single seedling systems	X	X		X			
		Use high yielding modern crop varieties		X	X	X	X		
		Use local climate resilient and improved varieties	X	X		X			
	Agroforestry	Agrisilvicultural systems	X	X		X	X	X	X
		Silvopastoral systems	X	X		X	X	X	X
		Agrosylvopastoral systems	X	X					X
Aggregation	Cost reduction of transportation and storage	Building local processing plants	X	X	X	X	X	X	
	Energy efficiency	Using clean fuel for transportation	X	X	X	X	X	X	X
Processing	Energy efficiency	Processing plants powered by renewable energy	X	X	X	X	X	X	X
Distribution	Improved distribution structure	Developing market networks			X	X	X	X	X
		Developing price information system			X	X	X	X	

*Source: Authors' development. Notes: * Denotes CSA practices used in this study.*

The speed of deployment of CSA practices in Colombia partially depends on the degree of cohesion between policies to reach climate targets and development policies to increase agricultural productivity. Among the key policy disjunctions hindering the scale-up of CSA practices in Colombia are: (1) Investment allocation that prioritizes the provision of short-term input subsidies to agricultural producers instead of strategic long-term investments that can increase productivity and competitiveness across the sector, such as off-farm irrigation systems, transport infrastructure, etc. (OECD, 2021)[33]. (2) The inability to adapt CSA practices to the local context of the small farmers without compromising their scalability at the regional or national level (Thornton et al. 2018)[34]. (3) The formalization of land ownership continues to hinder the utilization of potential agricultural areas.

3.2 Ethiopia

Agriculture plays a crucial role in fueling economic growth in the Ethiopian economy, contributing around 37.6% to GDP in 2022[35] and 80% of the country's overall export revenue[36]. According to a report published by the United States Department of Agriculture (USDA), Ethiopia's total agricultural exports in 2022 stood at $3.3 billion, with crops like coffee beans, pulses, and sesame seeds being the most exported agricultural commodities. The sector's value-added compound annual growth rate (CAGR) from 2019 to 2023 is approximately 5.7%[37] and is forecasted to grow at a CAGR of 5.5% from 2024 to 2029[38]. In 2021, Ethiopia ranked third in the world with the highest value added in the agricultural sector as a percent of GDP (i.e., 38%).[39]

Moreover, as of 2021, the agricultural sector employed more than half of Ethiopia's total labor force (i.e., 64%). Although female employment in the agricultural sector has shown a decreasing trend since 2006, as of 2021, 55% of employed women work in this sector. Furthermore, the country has a high level of poverty, and agriculture is a key sector that most of the population depends on, especially for pastoral and agro-pastoral communities in drought-prone areas.

Ethiopia is at a significantly high risk of natural disasters like flooding and droughts, which tremendously affect the agricultural sector. The increasing aridity and recurring drought conditions present the most significant climate hazard for agro-pastoral activities, as the sector heavily relies on rainfall. The change in rainfall patterns is expected to heavily affect agricultural production and harvest seasons (World Bank, 2022). Smallholder farmers in Ethiopia are engaged in subsistence production systems where farms are already under significant climate stress. (Ebrahim et al. 2022)

The primary focus of Ethiopia's Climate Resilient Green Economy, National Adaptation Plan, and Ten Years Development Plan is to increase the resilience of its food security through CSA and increase the number of decent jobs in the agricultural sector, among others[40]. Moreover, Ethiopia's adaptation to climate change efforts prioritizes enhancing food security by improving agricultural productivity in a climate-smart manner (promoting CSA practices for yield increase)41. Similarly, Ethiopia's LT-LEDS anticipates an increasing trend of areas of agricultural land under CSA practices42.

Specific institutions, such as the Agricultural Transformation Institute (ATI) of Ethiopia, are also making significant efforts to promote sustainable agriculture and youth employment across the country. ATI leads different initiatives on Agricultural Commercialization Clusters (ACC) related to inputs, production, CSA, job creation, and other topics. One of these initiatives is the Soil Health and Fertility Management (SHFM) project, which addresses critical challenges related to soil degradation, fertility loss, and climate risks in ACC districts. It promotes climate-smart practices by introducing innovative technologies to smallholder farmers, delivering capacity-building trainings, and facilitating policy dialogues at regional and federal levels in collaboration with Agricultural Transformation Centers and the Ministry of Agriculture (ATI, 2024a). Another initiative is the Agriculture-focused Dignified Employment for Youth in Ethiopia (ADEY). This aims to create 611,000 dignified jobs (80% for women) for youth in eight regions through agribusiness development, digital agriculture, input supply, and financial services. The program targets rural (70%), peri-urban (20%), and urban (10%) youth, including 4% with disabilities and 6% who are internally displaced. It also seeks to establish or strengthen 15,000 youth-led enterprises, fostering both self-employment and wage employment while transforming the agricultural sector (ATI, 2024b).

33 OECD. (2021), Agricultural Policy Monitoring and Evaluation 2021: Addressing the Challenges Facing Food Systems, OECD Publishing, Paris. Accessed from https://www.oecd-ilibrary.org/sites/34561bf9-en/index.html?itemId=/content/component/34561bf9-en#section-d1e39574

34 https://www.repository.fedesarrollo.org.co/bitstream/handle/11445/4053/Co_Eco_Diciembre_2020_Forero_y_Gonz%C3%A1lez.pdf?sequence=4&isAllowed=y

35 World Bank Database. https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS

36 International Trade Administration. (2023). Ethiopia AG Sector Opportunities. Retrieved from https://www.trade.gov/market-intelligence/ethiopia-ag-sector-opportunities

37 This was calculated based on Ethiopia GDP from 2019 to 2024 using data sourced from https://tradingeconomics.com/ethiopia/gdp-from-agriculture

38

39 The figures in this section are derived from ILOSTAT (2022) estimates unless stated otherwise.

40 Ethiopia's Climate Resilient Green Economy National Adaptation Plan. Accessed from https://www.fao.org/faolex/results/details/en/c/LEX-FAOC187265/

41 Federal Democratic Republic of Ethiopia (2022). Updated National Determined Contribution. Accessed from https://unfccc.int/sites/default/files/NDC/2022-06/Ethiopia%27s%20updated%20NDC%20JULY%202021%20Submission_.pdf

42 Ethiopia long-term low emission and climate resilient development strategy (2020-2050). Retrieved from https://unfccc.int/sites/default/files/resource/ETHIOPIA_%20LONG%20TERM%20LOW%20EMISSION%20AND%20CLIMATE%20RESILIENT%20DEVELOPMENT%20STRATEGY.pdf

The ATI initiatives have shown positive outcomes in promoting the use of improved seeds, agrochemicals, and fertilizers. According to FAO (2020), households producing priority crops were 18 percentage points more likely to use organic fertilizers and 23 percentage points more likely to use chemical fertilizers as a result of ATI's interventions. The use of nitrogen-phosphate-sulphur (NPS) fertilizer increased more than fivefold due to general ATI efforts, and more than tenfold where ATI fertilizer and extension programs were directly involved, compared to households that did not use chemical fertilizers. Agrochemical usage also increased by just over 10 percentage points, likely due to rising demand for herbicides, as many smallholders rely on less-diverse cropping systems instead of crop rotation. In terms of improved seeds, notable results were observed specifically under the ACC initiative, which raised the likelihood of their use by 15 percentage points, particularly for teff and wheat. Shifts in the fertilizer mix contributed to higher yields for priority crops—especially maize, teff, and wheat—with wheat yields nearly doubling, resulting in approximately 1.593 kg/ha increase in returns (FAO, 2020).

Ethiopia's NDC aims to enhance food security through CSA productivity improvements in rain-fed cropland and expand irrigation for crops like corn and wheat. Considering that grain and cereal crops, pulses, and oil crops are pivotal for food and employment in Ethiopia (Ethiopia, 2018a), this study assesses wheat, corn, teff, and barley as the four selected crops. (See Table 4)

Table 4. Considered variables for selected crops in Ethiopia.

Variable	Unit	Crops	Circa 2022	Target by 2030	Note
Area	Thousand Ha (Hectare)	Wheat	1,895.34	2,049.31	Smallholder farmers at main rainy season (Meher)
		Corn	2,362.02	2,733.32	
		Teff	3,108.77	3,172.12	
		Barley	954.19	957.61	
Production	Million Quintals	Wheat	56.7	100.5	
		Corn	100	204.9	
		Teff	57.5	86.3	
		Barley	23.9	31.3	
Productivity	Quintal/Ha	Wheat	29.9	49	
		Corn	42.4	75	
		Teff	18.5	27.2	
		Barley	25	32.7	
Employment	# of producers	Wheat	4,579,491	–	Private peasant holdings for Meher season
		Corn	10,189,355	–	
		Teff	6,866,855	–	
		Barley	3,738,220	–	
Wages	USD	Wheat	N/A	–	Ethiopia's 2018-2019 National Socioeconomic Survey.
		Corn	N/A	–	
		Teff	N/A	–	
		Barley	N/A	–	
Interventions		Wheat		Enhance food security and improving productivity	
		Corn			
		Teff			
		Barley			
Investment in the crops	USD	Wheat	–	–	
		Corn	–	–	
		Teff	–		
		Barley	–		

Vulnerability to climate change	IPCC Scale	Wheat			
		Corn			
		Teff			
		Barley			

Source: Authors' development. Notes: Most of the crops included in the study are represented as individual products within the social accounting matrices. However, when a specific crop was not available as a standalone entry, we used closely related crop products as proxies for their IO structure. For example, in the case of Ethiopia, within the IO matrices, corn is classified under the category "maiz", which correspons to maize; barley and wheat are grouped together in a single category labeled "whea"; while the structure of teff is approximated using the category "sorg," which corresponds to sorghum and millet. *Employment figures were taken from microdata surveys when available, and refer to the number of direct jobs within each crop.

The study identifies potential CSA practices per agricultural value chain stage per crop (See Table 5). (Annex 1 provides the definition of each CSA practice listed). However, only a few of the CSA practices listed were selected for assessment. Selected CSA practices were previously identified by practitioners as practices with high adoption rates in the country, with a high impact on productivity and high climate smartness (World Bank, 2014). Moreover, selected CSA practices have a documented impact on employment, crop yields, and capital costs.

Table 5. Identified and selected CSA practices in Ethiopia

Value Chain Stage	Objective	Sustainable agricultural practice	Impact			Utilization in Ethiopia			
			Mitigation of GHG emissions	Increasing climate resilience	Increasing smallholder farmers participation	Wheat	Corn	Teff	Barley
Production	Conservation agriculture	Minimum mechanical soil disturbance	X	X			X	X	
		Permanent soil organic cover	X	X					
		Species diversification	X	X			X		
	Risk management of crop and income loss	Crop insurance		X	X	X	X	X	X
		Income diversification			X	X	X	X	X
		Improve access to credit			X	X	X	X	X
		Strengthen household capacity (time allocation)			X	X	X	X	X
		Educational campaigns and training acquirement			X	X	X	X	X
	Soil Conservation (Management of soil nutrients)	Integrated soil fertility management (ISFM) *				X	X	X	X
		Increase use of organic fertilizers *	X			X	X	X	X
		Conservation tillage	X	X					
		No-till/ Zero tillage farming *	X	X		X			X
		Minimum tillage	X	X					
		Contour farming or row planting	X	X					
		Intercropping *	X	X	X				
		> Mixed intercropping	X	X	X				
		> Row/Alley/Strip cropping	X	X					
		> Relay cropping	X	X					
		Windbreaks or shelter belts	X	X					
		Crop rotation	X	X	X	X	X	X	X
		Straw incorporated /mulching *		X		X			
		Transplanting of teff						X	
		Cover crops				X			
		Biopesticides	X						
		Natural Fungicides	X						
		Biofumigation	X						
		Micro-dosing	X	X					
	Improved irrigation and water management	Alternate wet and dry irrigation of rice (AWDI) *	X	X					
		Intermittently flooded vs Continuously flooded	X	X					
		Flood or furrow irrigation*	X	X		X	X	X	X
		Bank Stabilization	X	X					
		Buffer Strips	X	X					
		Grassed waterways	X	X					
		Sprinkler and drip irrigation, particularly solar-powered *	X	X		X	X	X	X
		Modern irrigation systems	X	X					
		Deficit irrigation *	X	X		X			
		Irrigations based on evapotranspiration (ET)	X	X					
		Irrigations based on soil water content/tension	X	X					
		Cross-slope barriers *	X	X					
	Management of genetic resources	Single seedling systems	X	X					
		Use high yielding modern crop varieties		X	X	X	X	X	X
		Use local climate resilient and improved varieties	X	X		X	X	X	X
	Agroforestry	Agrisilvicultural systems	X	X		X	X	X	X
		Silvopastoral systems	X	X					
		Agrosylvopastoral systems	X	X		X	X	X	X
Aggregation	Cost reduction of transportation and storage	Building local processing plants	X	X	X	X	X	X	X
	Energy efficiency	Using clean fuel for transportation	X	X	X	X	X	X	X
Processing	Energy efficiency	Processing plants powered by renewable energy	X	X	X	X	X	X	X
Distribution	Improved distribution structure	Developing market networks			X	X	X	X	X
		Developing price information system			X	X	X	X	X

*Source: Authors' development. Notes: * Denotes CSA practices used in this study.*

The speed of deployment of CSA practices in Ethiopia partially depends on the degree of cohesion between policies to reach climate targets and development policies to increase agricultural productivity. According to Sentinel (2022), the three main climate and development target disassociations hindering the scale-up of CSA practices in Ethiopia are: (1) Goals aimed at establishing land for commercial livestock farming and horticultural production appear conflicting with goals to cut habitat conversion resulting from agricultural expansion in half; (2) Goals to boost the utilization of inorganic fertilizers appear to conflict with goals to lower fertilizer demand to mitigate pollution and emissions; and (3) Goals to diminish greenhouse gas emissions from crop production and animal husbandry seem to clash with goals to expand farming land and increase input usage.

It is also important to consider macroeconomic goals and their impact on the development of CSA practices. In 2023, the Ministry of Irrigation and Lowlands announced its decision to end and ban the importation of water pumps powered by diesel or gasoline, shifting focus instead to green energy alternatives. While encouraging results have been achieved in irrigation areas using these irrigation generation systems, there are also negative consequences for the country. For example, Ethiopia faces more challenges than other countries in obtaining fuel, with frequent and severe fuel shortages occurring due to distribution issues. Foreign exchange plays a key role in this, as Ethiopia is not an oil-producing nation and relies heavily on costly imports. As fuel demand increases, this leads to further depletion of the country's limited foreign currency reserves (Yapp, 2023).

Methodology

To estimate the employment impacts at the national level, the study combines two assessment approaches: (1) a scenario approach based on IO modeling, and (2) a value chain approach. The study developed an Excel tool based on FAO's EX-ACT-VC Excel-based tool through which to apply these two approaches[43]. The Excel tool's main focus is to asses employment impacts over time, providing information on the rate at which potential employment requirements vary per year. The assessment is conducted annually over a 10-year modeling horizon, from the commencement year in 2022 to 2032. This modeling horizon considers relevant agriculture NDC targets to be met by 2030.

4.1 Scenarios

Two scenarios for each crop are utilized to compare the employment impacts at (1) a current or pre-utilization of CSA practices phase or BAU scenario, and at (2) a post-utilization of CSA practices phase (CSA Scenario) in line with the NDC agriculture targets. The BAU scenario is considered the baseline of the assessment, and the employment impacts are presented as the difference between both scenarios. The scenario approach answers the question: "How much would employment increase or decrease by reaching the NDC targets linked to the utilization of CSA practices in a specific crop?"

The BAU scenario considers only the utilization of conventional agricultural practices. The NDC scenario assumes the utilization of CSA practices across a certain percentage of the targeted hectares (defined by a literature review as the minimum, median, or conventional threshold of practice adoption). Both scenarios are based on the number of targeted hectares for each crop by 2030, as determined by Colombia's and Ethiopia's NDCs. Both BAU and the CSA scenarios draw labor intensities for sub-activities utilizing CSA practices within each crop from the pertinent literature.

4.2 Agriculture value chain

Under both assessed scenarios for each crop, the study estimates direct employment in the food or forest products value chain's four core stages– production, aggregation, processing, and distribution/transportation (wholesale and retail) - following the value chain framework from the Food and Agriculture Organization (FAO, 2014). These stages have direct contact with the product or service.

1st. Production - This stage involves activities such as preparing the area of land, planting seeds, using any type of fertilizers, and taking care of the crop so that it can grow healthy, for example, through weeding and harvesting. This stage includes growing (trees or crops) and harvesting.

2nd. Aggregation – This stage involves clustering small volumes of production from widely dispersed smallholder producers. The aggregation function can be taken on by producer groups,

43 https://www.fao.org/3/cc7977en/cc7977en.pdf

intermediaries specialized in aggregation, food processors, or, less commonly, food distributors (wholesalers or retailers). E.g., upstream transport. The aggregation stage is observed primarily in developing countries with conventional agricultural value chains.

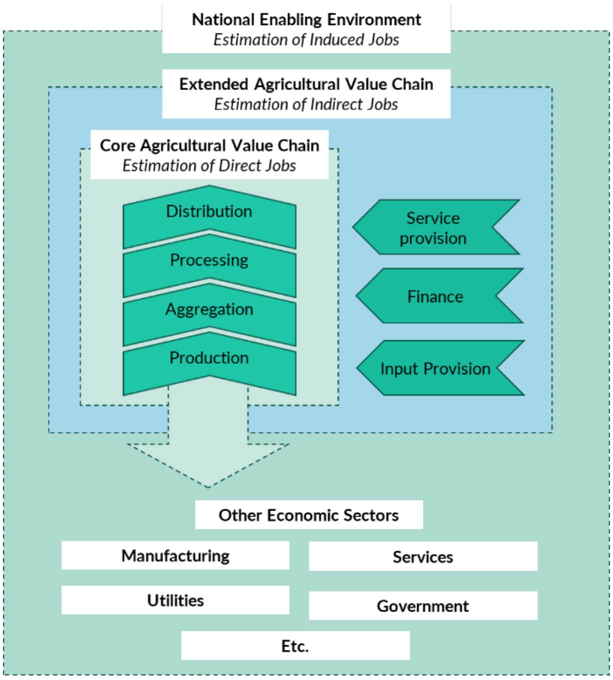
3rd. Processing – Post-harvesting activities such as milling, threshing, or shelling the crop, cleaning and drying, marketing, packaging, labeling, etc. In the case of forest products, this stage includes sawing.

4th. Distribution/downstream transportation – The stage only focuses on transportation within the country of production, from producers to the local market; international export is therefore excluded.

Agricultural value chains rely on a diverse and complex environment, with multiple actors, service providers, and economic stages. Figure 5 shows the complexity of the agricultural system. It distinguishes three levels: direct jobs within the core agricultural chain (production, aggregation, processing, and distribution), indirect jobs in the extended chain (input provision, services, and finance), and induced jobs linked to the national enabling environment (manufacturing, government, etc.)[44]. For the estimation of direct employment, this study excludes additional industrial processing stages of crops beyond the distribution to markets or manufacturing facilities. For example, the estimation excludes the number of direct jobs involved in transforming cacao beans into chocolate products (the "additional processing" threshold is therefore defined after cacao beans are dried and shipped to wholesale centers or chocolate producers directly).

44 Our analysis does not include details on the services, manufacturing, utilities, government, and other economic sectors associated with each crop.

Figure 5. Estimation of Employment Impacts Linked to the Agricultural Value Chain



Source: Authors' Development

The number of indirect jobs captures upstream value chain stages, which consist of three main types of support providers such as service, finance, and input providers (i.e., upstream providers of fertilizers, pesticides, agricultural machinery, and feed; as well as providers of financing and technical assistance for primary production, certifications, farm labor contractor services, knowledge generation, research, labor training, etc.). Moreover, the number of induced jobs captures those generated due to additional spending of household income of direct and indirect jobs created along the four stages of the agricultural value chain.

The study recognizes that a single crop can be transformed into multiple products, simultaneously producing multiple byproducts. Therefore, the assessed products and their specific value chain activities to be analyzed per crop are delimited in Table 6.

Table 6. Activities within crop value chains

Value Chain Stage	Activities per selected crop							
	Colombia				Ethiopia			
	Irrigated rice	Cocoa	Panela sugar	Forest plantations for commercial purposes	Wheat	Corn	Teff	Barley
Production	Fertilization Land preparation Planting Irrigation Weeding Cropping Harvesting Packing	Fertilization Land preparation Planting Weeding Pruning Pest control Harvesting Pod opening Shelling Fermentation Washing Drying Selection	Planting Irrigation Wroth Fertilization Pest control Burn and reap[45] Harvesting	Fertilization Forest renewal and maintenance Cutting Trees, Felling, logging, Drying Chopping sawmilling and pit sawing, crosscutting to obtain blocks and boards.	Fertilization Land preparation Planting irrigating Weeding Gathering Threshing Storage	Fertilization Land preparation Ploughing Planting Irrigating Weeding Harvesting Drying Storage	Fertilization Land preparation Planting Irrigating Weeding Tilling Plowing Harvesting Threshing Storage	Fertilization Land preparation Poughing Planting Weeding Irrigating Harvesting Threshing Drying Storage
Aggregation	Upstream transportation to the windmill Storage in gathering centres	Wholesalers and commission agents sell the purchased product to the processing industry	Upstream transportation to the mills (trapiches) Storage in gathering centres	Trucking Ferrying to the loading site Transport to selling point / log depots (hauling of the products obtained out of the forest)	Transportation	Local trader assembling and transports to larger buyers Wholesalers use brokers to find buyers or sell to retailers and processors	Transportation to traders for direct marketing Upstream transportation for processing	Upstream transportation to processors

45 This method would not be applicable in the case of a green harvest.

Processing	Reception Cleaning Drying Storage Hulling Whitening Polishing Selection Packing	Roasting Threshing Alkalinization Grinding Pressing	Grinding Milling Combustion of bagasse in boilers Co-generation Juice clarification Crystallization Centrifugation Drying (Known as Trapiches or Ingenios in Spanish)	Primary processing is done prior to transportation	Cleaning Milling Packaging Labeling	Cleaning Drying Sorting Storage	Milling Packaging	Cleaning Conditioning Bleaching Blocking and Pealing Aspiration Polishing Steam Cooking and Flaking Drying Milling Packaging
Distribution	Collecting Transport	Manufacturing and trading of different final products obtained from cocoa basic products Transportation to local market e.g. supermarkets, stores, cafeteria	Packing, Stor-age,Transportation to commercialization or intermediaries	Facilitating direct commercial exchange between communities and final consumers	Distribution of flour to bulk wheat Flow and wheat bran	Sell to consumers	Transportation and distributing to traders	Transportation and distributing to traders

Source: Authors' development based on Parra-Peña et al. (2022), Bergh et al. (2019), Rashid et al. (2019), Minten et al. (2018), Nishihara et al. (2017), Rios et al. (2017), Aguilar-Rivera (2017), Garcia-Caceres et al. (2014), and EU (2022) Note: For sources of labor intensities information per sub-activities in each crop refer to Tables A4.1, A4.2, A4.3, and A4.4 in the Annex.

4.3 Estimation of employment impacts

Direct Jobs

The number of direct jobs is estimated using employment intensities per sub-activities within a crop. Employment intensities reflect the time in days required for one person to complete an activity in a specific value chain stage. This is described in the literature as person-days. Person-day requirements were obtained from literature, including FAO's value chain assessment reports that rely on the EX-ACT suite of tools[46]. The impact of implementing CSA practices on direct employment is estimated by the changes in employment intensity compared to conventional practices. In addition, the implementation of CSA practices also impacts the cost structure of a given crop as it implies changes in the utilization of inputs such as fertilizers and pesticides. Table 7 shows the average employment intensities and associated costs per CSA practice utilized in the model.

The number of direct jobs in the target scenarios is estimated by multiplying total labor intensities in person-days (i.e., time in days required for one person to complete an activity) by number of "farms/production sites," which is simultaneously estimated by dividing the targeted NDC land area over the average farm size in hectares, as shown in equation 1 (where *ij* denotes each country-crop-production-stage combination). The model assumes a constant average farm area for each country-crop combination over all the mode period. Total crop area and average farm area data were retrieved from the latest available national agricultural surveys, i.e., Colombia's National Agricultural Survey, 2019 (ENA for its Spanish acronym), and Ethiopia's Agricultural Sample Survey 2021/22.

Equation 1. Direct jobs impact calculation

$$Direct\ Jobs_{ij} = \left[\frac{(person\_days_{ij})}{250\ \left(\frac{days}{year}\right)}\right] \times \left[\frac{NDC\ land\ target\ (ha)_{ij}}{Average\ farm\ size\ (ha)_{ij}}\right]$$

Table 7. Average employment intensities and associated costs per CSA practice

CSA Practice	Percentage change in produce production yield (%)		Additional/reduced costs/inputs (Nominal dollars per hectare)	Additional/ reduced (Person-days per hectare)	Source
	Range	Average			
Agroforestry	1 to 14	7.5	60	17	Hoff, M. (2017), Alavalapati & Mercer (2004), Segerstrom (1979)
Integrated soil fertility management (ISFM)	-3.0 to 56.0	14	175	3.5	Komarek, AM. Thurlow. J. Koo. J. De Pinto, A (2019)
Cross-slope barriers	0.5 to 1.0	0.75	60	15	FAO (2011)
Organic fertilizers	0.1 to 1.3	0.7	33	3.5	Mgbenka R. (2013)
Zero tillage	0.1 to 0.7	0.4	0	-17	Akowuah (2010); Paustion et al. (1995)
Intercropping	15.6 to 49.9	33	44	8	Chai, Q et al. (2021).
Straw mulching	5.4	5.4	50	2	Zhang, J., et al (2021).
Deficit Irrigation	9.90 to 9.94	9.92	-35	2	El Baroudy, A., Ibrahim, M., Mahamoud M. (2014).
Solar powered irrigation	-30	-30	-30	5	WFP (2021)
Alternative wet/dry irrigation	0 to 20	15	-43.8	18	Ishfaq, M., et al. (2020).
Furrow irrigation	27 % less inputs & up to 28 % more yields	27	-44.8	15	Ockerby, S.E., Fukai, S. (2001).

Source: Authors' elaboration. Note: Annexes 5 and 6 include the total number of person-days per crop for both the BAU and CSA scenarios.

46 Economic and Policy Analysis of Climate Change. Available at https://www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/en/

The use of selected CSA practices is applied to a specific share of the total production area of a crop. This allocation is contingent on parameters derived from both existing literature and national production targets. For example, studies suggest that for most crops, between 20% and 30% of the total planted area is needed to implement an introductory agroforestry project (Alavalapati & Mercer, 2004).

Indirect and induced jobs

IO modeling is used to estimate indirect and induced jobs. IO modeling allows the derivation of indirect and induced impacts on job creation using IO tables. IO tables present the linear relations between the inputs and outputs from each economic sector, providing the information needed to estimate the additional inputs required from other sectors to increase the sector's production under consideration. IO tables for both countries were retrieved from the national economic accounts. The base year for Colombia's IO table is 2017, and 2015-2016 for Ethiopia's IO table.

The input variable in the IO model is the variation (increase) in the total output of the agricultural sector. The variation in the total output is estimated considering the sector's cost structure and investment multipliers for each country assessed. An increase in the total output implies an increase in the inputs required for production, including labor.

To assess the impact on indirect and induced employment, the IO model applies Ghosh's supply-driven framework to model the relations between inputs and outputs (Duran Lima & Banacloche, 2022; Jarvis et al., 2011). See equation 2.

Equation 2. Reduced form of the induced/indirect jobs equation

$$\boldsymbol{Indirect, induced\, Jobs_{ij}} = \boldsymbol{A_{ij}^{-1}} \cdot \boldsymbol{X_{ij}}$$

Where $A_{ij}^{(-1)}$ is the Ghosh matrix (inverse of the IO coefficient matrix), and represents the investments vector with non-zero values only for the selected agricultural sector.

- Indirect employment impacts, which result from upstream expenditure in the supply chain, are based on changes in Gross Production Value (GPV). GPV is estimated as sales revenue plus the value of intermediary goods. Yearly flows of GPV are then multiplied by the Consumption Multiplier Matrix, derived from the IO Ghoshian model.[47] Induced employment impacts resulting from increased expenditure by households require additional data on average wages per sector. Wage data per ISIC class is retrieved from Colombia's National Household Survey (Gran Encuesta Integrada de Hogares –GEIH- 2022) and Ethiopia's 2018-2019 National Socioeconomic Survey. The official matrices include a labor compensation vector that allows us to gauge the importance of wages for each industry. Ultimately, this enables us to calculate employment multipliers and estimate a wages multiplier matrix, as outlined in the methodological annex (Annex 3).

- Given that consumption depends on many factors such as consumer preferences, regional differences, supply chains, government policies, etc. IO modeling can make assumptions to distribute the total output to be used by the consumption multipliers. This study assumes that induced effects come from additional spending from families for whom spending is mostly within their rural communities, and therefore, the model utilized does not apply a uniform distribution based on the IO structure for the whole economy. This makes consumption spending spread more towards the sectors where these direct and indirect jobs were created.

Gender disaggregation of employment.

The number of direct female jobs is calculated by multiplying direct jobs by the share of female employment in each agricultural sub-activity or International Standard Industrial Classification of All Economic Activities (ISIC) class[48]. The expected change in the share of employed women is forecasted based on historical data of the share of employed women in the agricultural sector per country. Specifically, the growth rate identified in the last two national survey years is applied to forecast future periods. Moreover, a qualitative assessment of female participation in agrifood systems was performed based on a literature review of current gender policies.

Disaggregation of employment by formality/informality and remunerated/non-remunerated conditions

A large share of agriculture in the assessed countries is subsistence farming, persistently characterized by low productivity and high informality labor environments. To estimate the breakdown of formal/informal jobs, the study first processes the share of informal employment from household and labor market surveys (i.e., the percentage of total employment that does not contribute to social security). Formality/Informality projections are made using each country's most recent inter-survey formality growth.

Additionally, much like the FAO's EX-ACT-VC tool, the study makes a distinction between "remunerated" and "non-remunerated (family) labor" and applies the same definitions:

- "Remunerated employment refers to the workforce receiving wage remuneration. It corresponds to employees.

- Non-remunerated (family) labor refers to the workforce not rerceiving wage remuneration, either because it rerceives income from the operation or because it is non-remunerated being at the family level." (FAO, 2023)[49]:

47 Ghoshian model was preferred over the Leontief model because the intent is to see how changes in production costs transmit to increase levels of overall economic activity.

48 In absence of ISIC level information for Ethiopia we used the economy-wide female labor participation rate.

49 FAO. (2023). Ex-Ante Carbon-balance Tool for Value Chains | EX-ACT VC – Guidelines. Third edition. Rome. https://doi.org/10.4060/cc7977en

Impact of climate change on agricultural employment

The model takes into consideration data from the Climate Vulnerability Monitor for Colombia and Ethiopia to factor in the influence of increasing heat due to climate change on labor productivity and crop yield (CVM3, 2023).[50]

The impacts on labor productivity were derived from considering the shift in the percentage of total work hours lost under intense labor conditions without sun protection under a high work intensity corresponding to a metabolic rate of 400W, adequate to represent typical agriculture labor. These computed hours are then extrapolated to equivalent full-time positions, assuming a standard 8-hour workday over 250 days per full-time employment. The percentage of total work hours lost forecast is based on a scenario with policy measures intended to keep global temperatures on the trajectory of a 2°C increase from 2021 to 2040.

The assessment of changes in crop yield was limited to simulating decreases in rice yields for Colombia due to higher temperatures linked to climate change. This limitation is due to the based on the availability of information from the Climate Vulnerability Monitor. The changes in crop yield are based on a scenario with policy measures intended to keep global temperatures on the trajectory of a 2°C increase from 2021 to 2040.

Units of measurement

The study measures employment impacts—direct, indirect, and induced jobs—as the number of FTE jobs. An FTE is a position working on an average of 250 days per year. This definition excludes non-remunerated family workers, who are subtracted from the job count using averages of the prevalence of such unpaid work at the ISIC class level taken from official statistics.

4.4 Estimation of economic impacts

The study follows the EX-ACT-VC tool methodological framework to calculate value-added measures throughout the value chain. This is based on the System of National Accounts macroeconomic framework (SNA, 2008). Value added is defined as the wealth created or accumulated along the different value chain activities (FAO, 2021). The study measures value added at each value chain stage and aggregates it per crop. The value-added indicator is further broken down into three indicators: (1) gross value added, (2) net value added, and (3) net income. Moreover, as part of the intermediate incomes required to estimate the gross value added, the study estimates the investment requirements per crop for implementing CSA practices.

50 Climate Vulnerable Forum & V20, (2022): Climate Vulnerability Monitor, 3rd Edition: A Planet on Fire [M. McKinnon, T. Lissner, M. Romanello, F. Baarsch, M. Schaeffer, S. Ahmed, A. Rosas (eds.)]. Available at https://knowledge4policy.ec.europa.eu/sites/default/files/Climate%20Vulnerability%20Monitor%2C%20Third%20Edition%20%28CVM3%29.pdf

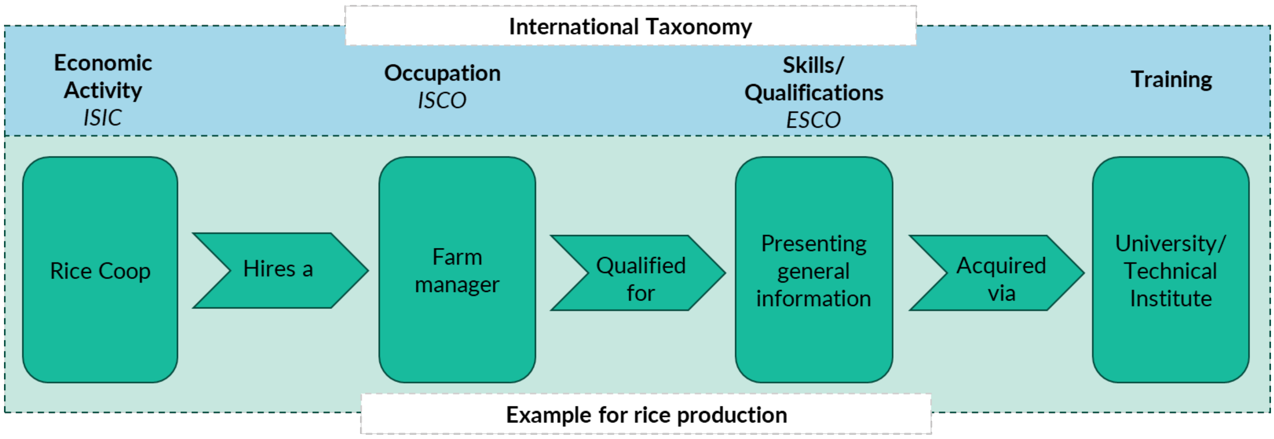
Table 8. Value-added measures

Equation	Economic measures of value added	Estimation	Data sources and assumptions
C=A+B	Gross production value		
A	Sales revenue	Price per unit of product sold times the quantity of product sold	For sources of costs of supplies and crops refer to Tables A4.1, A4.2, A4.3, and A4.4 in the Annex
B	Final self-consumption	Product that was self-consumed times the selling price	
D	Production costs	Price of inputs for production and supporting services such as transport times by the amount of the corresponding inputs used	
E=C-D	Gross value added		
F	Fixed capital costs	Costs of fixed assets e.g. vehicles, machinery, and equipment	Fixed capital is not modelled under the assumption that small holders would rely on existing capital and government grants for major capital investments.
G=E-F	Net value added		
H	Wages	Include payments in cash, or in-kind contributions to hired employees and the remuneration of family labor	Salaries are taken from household and labor market surveys at the ISIC class level (sectors of economic activities at the 4-digits level)

I	Interests		
M=H+I	Production factors[51]		
J=G-M	Net income		

Note: Current and forecast inflation rates are applied to each country and used to estimate wage growth, increase in prices per unit sold, and increase in costs of inputs by 2032. Data on inflation rates was retrieved from the International Monetary Fund's World Economic Outlook Database (IMF-WEO, April 2023). Source: Adapted from FAO 2023. Ex-Ante Carbon-balance Tool for Value Chains (EX-ACT-VC) Guidelines.

Figure 6. Taxonomies to identify economic activities, occupations, and skills



Source: Adapted from CEDEFOP (2022).

For the estimation of economic impacts, the study uses a unique set of market prices for each crop, without differentiation regarding the application of CSA practices. Consequently, wages and selling prices per ton remain constant—only growing by inflation—potentially leading to negative net income when sales fall short of operational costs. The introduction of differentiated market prices for sustainably produced crops, such as those with organic certifications and distributed through sustainable retail channels, presents various challenges, and their analytical benefit vis-à-vis the report's focus on employment creation is unclear. Nevertheless, given that the model does differentiate between jobs stemming from conventional practices versus jobs from CSA practices, measures of gross production, value-added, and net income can be disaggregated between conventional and CSA approaches per crop.

4.5 Identification of occupations and skills

The study utilizes international taxonomies to identify economic activities, occupations, and skills for the agricultural sector. The International Standard Industrial Classification of All Economic Activities (ISIC) is used to categorize the sub-economic activities assessed, the International Standard Classification of Occupations (ISCO) taxonomy to identify occupations within the agricultural sub-economic activities, and the European Skills, Competences, Qualifications, and Occupations (ESCO) to link such occupations to skills and green skills (See Figure 6)[52].

Firstly, ESCO's skills-to-occupation matrices are utilized to map skill contents for a range of occupations identified within the pre-selected agricultural activities[53]. The identification of the most common occupations for the selected crops comes from official microdata (i.e., Colombia's 2022 Gran Encuesta Integrada de Hogares (DANE) and Ethiopia's 2018-2019 Socioeconomic Survey (CSA, 2019)). This heuristic first identifies occupations within the targeted economic sectors, then aligns the share of ESCO skills labels for each occupation. This approach yields a distribution of skillsets that are subsequently assigned to the overall distribution of new employment (Figure 7).

Additionally, a machine learning method matches the ESCO's dictionary of green skills with the description variable of the European Commission's ESCO at the 5-digit level[54]. The result of this string-matching operation is imputed as an attribute variable for the occupations identified within the four selected economic activities per country.

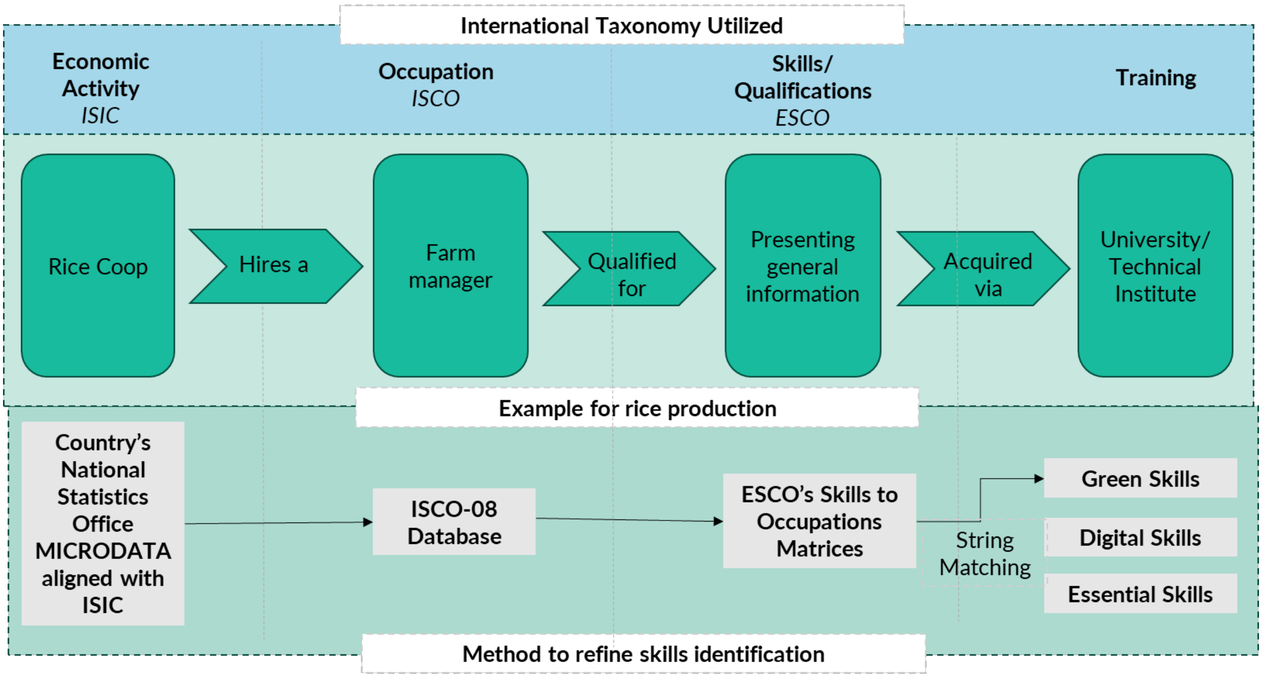
51 Contrary to the EXACT VC Tool methodology this assessment does not consider taxes nor subsidies.

52 As an alternative for identifying key elements in skills development within the agricultural sector in Colombia, the Green Skills and Profiles Registry of the Pacific Alliance (2024) can also be considered.

53 ESCO includes sectorial skills acquired through formal, non-formal, and informal learning. The granularity of ESCO disaggregation of occupations and skills (over 3,000 classes for each) allows for the design of tailored learning and training programs for each job (CEDEFOP, 2022).

54 Refer to Box 2 in the results section for a detailed description of this green skills identification method.

Figure 7. Mapping Skills within Occupations: A Taxonomic Approach to Identification



Source: Authors' elaboration.

Finally, a literature review on qualifications for the agricultural sector is performed to contextualize sectoral human capital gaps and qualitatively assess the educational offer for the agricultural sector (Lesmes et al., 2019). For example, the report considers Colombia's Methodology for the Identification and Measurement of Human Capital Gaps developed by the Ministry of Labor (Mintrabajo, 2022) as well as ILO's rapid skill assessment results for the agricultural sector in Ethiopia (ILO, 2021). Moreover, a literature review of occupations and skills critical for the deployment of CSA in developing countries was performed to identify skills gaps that might hinder the achievement of CSA targets.

BOX 1. Identifying and Measuring Human Capital Gaps in Colombia

The Colombian Ministry of Labor developed a methodology to identify and measure human capital gaps as part of the country's Productive Development Policy. This method categorizes human capital gaps in quantitative gaps and qualitative gaps. Quantitative gaps relate to deficits or oversupply in demand or supply for training programs and human talent in specific sectors or regions. Qualitative gaps encompass deficiencies in quality, skills, and relevance between labor supply and the requirements of the productive sector.

The comprehensive approach adopted by the Ministry aims to bridge the gap between the skills demanded by the labor market and the skills individuals possess. By addressing these gaps and aligning human capital with the requirements of the productive sector, Colombia seeks to enhance its economic competitiveness, promote social development, and achieve sustainable economic prosperity. Further categorization of human capital gaps is based on related gap-closing strategies. The Ministry proposes the following typology and methodologies for identifying and measuring human capital gaps:

Macroeconomic gaps: These are measured by examining the dispersion of employment rates among different educational or qualification levels. The larger the difference in proportions between qualification groups in occupations and the economically active population, the greater the human capital gap.

Quantity gaps: These gaps are identified through four indicators:

a. Imbalance between labor supply and demand: This indicator calculates the difference between the number of vacancies published for a specific occupation and the number of job seekers. It represents the deficit or surplus of labor supply for that occupation.

b. Imbalance between potential job offer and current vacancies: This indicator focuses on the number of graduates applying for training programs compared to the number of vacancies available. It aims to identify the mismatch between the labor market demands and educational programs.

c. Identification of deficits in higher education programs: This indicator identifies training programs that have a deficit in meeting the requirements of the labor demand.

d. Deficit in demand for training programs: This indicator analyzes the demand for training programs and the enrollment and graduation rates to identify the low demand for programs that match the requirements of the productive sector.

Skills gaps: These gaps are classified based on four indicators:

a. Lack of skills required in human talent (skill shortage): This indicator measures the proportion of employers who face difficulties in filling vacancies due to a lack of required skills.

b. Imbalance between the skills in demand and the skills of the labor supply: This indicator assesses the relevance of the labor supply by comparing the skills required by the productive sector with the skills possessed by the workforce.

c. New skills gap: This type of gap arises due to emerging competencies or requirements in the productive sector resulting from trends. It is identified by extracting information from a matrix of occupational impacts.

d. Obsolete skills gap: This gap refers to competencies that become irrelevant or obsolete in certain positions due to trends in the productive sector. It is also identified from the matrix of occupational impacts.

Relevance gaps: These gaps are measured using two indicators:

a. Imbalance between the competencies demanded and the competencies in which the different educational programs are formed: This indicator evaluates the relevance of education by comparing the skills required by the productive sector with the skills taught in educational programs associated with the sector.

b. Participation of the productive sector in planning training: This indicator examines the involvement of the productive sector in the planning of training programs.

Quality gaps in educational programs: This indicator identifies deficiencies in the competencies formed by educational programs compared to demand. It involves analyzing the skills demanded by the sector and the skills taught in educational programs.

Profiling gaps: These gaps are categorized into three types

a. Non-existent positions: These are new or emerging positions that are not registered in the occupational classification systems.

b. Work experience gap: This refers to the difference between the required work experience for a position and the experience possessed by job applicants.

c. Profile gaps: This indicates a disparity between the profiles of job applicants and the requirements of a certain position.

Temporary adjustment gaps: These gaps are measured by examining two indicators:

a. Average duration to fill a vacancy: This indicates the average time taken to fill a vacancy for a particular position.

b. Average length of job search: This measures the time individuals spend looking for a job.

Source: Based on Mintrabajo (2022).

4.6 Limitations of the study

The assessment is subject to limitations that impact the accuracy of the results:

I. Limitations linked to the modeling approach.

Results reflect a static representation of the economic structure of each country at a specific point in time due to the use of an IO modeling approach[55]. Therefore, the analysis is static, i.e., it does not incorporate the dynamics of the economy and labor markets that may affect employment generation.

Results do not consider exogenous conditions that impact employment or economic outcomes. Another commonly referenced limitation of IO modeling occurs when the multiplier effects downstream from one sector to the rest of the economy are modelled exogenously to other external conditions that could affect sectoral outputs (e.g., labor strikes, weather conditions, policy reforms, etc.) (Steinback, 2004).

Results reflect gross employment impacts and not net impacts**.** The IO modeling does not estimate the displacement of other economic activities due to investment in CSA practices. Thus, it does not estimate potential job losses. Losses in employment might arise from the deployment of CSA practices that are less labor-intensive than conservative agricultural practices.

Results do not show uncertainty assessments. The assessment does not capture any uncertainty related to the calculated employment or economic indicators.

Results are not disaggregated by size or type of farmer. The study recognizes that there are substantial differences in incomes and productivity levels across different types of farmers, from large-scale farmers to small or self-subsistence farmers. However, the assessment makes no distinction between them.

Results are highly sensitive to changes in wage data. The modeling approach is highly sensitive to wages. Through a sensitivity analysis, the report demonstrates how changes in wage levels can influence job creation within the sector. This is because the estimation of indirect jobs per crop is estimated by dividing the domestic investment in labor by the average annual salary in the sector. Moreover, induced employment impacts resulting from increased expenditure from households are also estimated using average wages per sector.

II. Limitations linked to the modeling assumptions.

Results assume the absence of economies of scale and the absence of land fragmentation. The assessment assumes an average-sized farm at the national level. This assumption is noteworthy due to the inherent heterogeneity of agricultural plots in size, technology, labor intensity, and crop type, all of which can significantly influence the model's outcomes.

Results assume a single actor across the value chain assessed. This assessment assumes only one actor—an agricultural producer—and does not differentiate employment across different actors, such as manufacturers, wholesalers, or retailers.

Results do not distinguish between regions and their individual productive systems, as the assessment is done at the national level.

Results do not consider other drivers of the future labor markets, such as digitalization, radical technological change, and automation. Technological change may be significant in agriculture, which, as technology develops, may increase productivity and reduce production costs by improving yield performance or reducing labor requirements.

Results disregard the potential technical, economic, and social barriers hindering farmers' adoption of CSA practices. Despite government support programs and technical assistance, farmers are reported to struggle to adopt CSA practices due to inappropriate design and ineffective targeting of incentives.

Results do not account for the current level of implementation of CSA practices across country–crop combinations. Moreover, there is a lack of detailed information on the percentage of producers who are certified or who benefit from differentiated prices through fair trade mechanisms or the application of CSA.

III. Limitations linked to data availability.

Results depend on the accuracy, appropriateness, and newness of the data input. The accuracy of the results relies on the availability of updated information on primary variables such as the number of hectares per crop, agricultural production, capital costs, wages, NDC targets, etc.

Despite these constraints, the assessment remains valuable for providing insights into orders of magnitude for employment and economic impacts of adopting CSA practices. The assessment helps pinpoint the most effective and efficient CSA practices for increasing employment.

These limitations can indeed be viewed as opportunities for future research. Upcoming studies may build upon this analysis by addressing some of the identified gaps. For example, future work could incorporate dynamic economic and labor market changes, include farm-size disaggregation, and assess the influence of technological advancement and digitalization in agriculture. Additionally, more refined data and methods could allow for a better understanding of net employment impacts and the socio-economic barriers affecting the adoption of CSA practices. In this way, future analyses can provide a more comprehensive and contextualized understanding of the employment implications of transforming the agricultural sector.

55 Adjusting IO coefficients or using Computable General Equilibrium (CGE) models provide more temporal dynamism but rely on similar time-trend assumptions.

Results

The subsequent section offers a summary of eight standalone analyses—one per crop per country assessed—that evaluate the economic and employment impacts of achieving Nationally Determined Contribution (NDC) targets in agriculture linked to the utilization of CSA practices in the crops assessed. Annexes 5 and 6 show the individual crop assessments for each country.

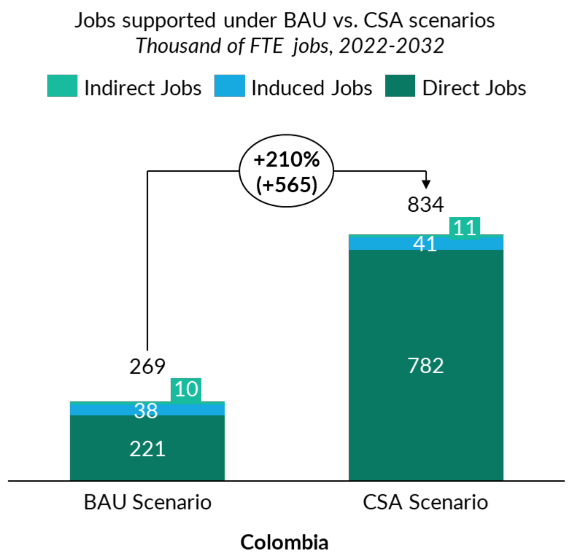
5.1 Colombia

Employment creation: BAU vs CSA scenario

Colombia's NDCs encompass multiple initiatives aimed at promoting CSA practices and reducing greenhouse gas emissions across various agricultural sectors. These include efforts to rehabilitate and expand cocoa production under agroforestry systems, establish commercial forest plantations, enhance rice cultivation through the adoption of technology, and foster low-emission practices in panela production. These strategies aim to increase carbon stocks, improve environmental sustainability, and contribute to the overall economic development of the country's agricultural sector (Govt. of Colombia, 2022).

In comparison to a BAU scenario that employs conventional agricultural practices, achieving the NDC targets linked to CSA practices in the assessed crops could support an additional 564,883 total direct, indirect, and induced jobs (+210%) in the agricultural sector by 2032. The CSA scenario could support a total of 833,748 jobs by 2032 or an average of 83,400 jobs per year, a substantial increase from the 268,865 jobs or 26,900 jobs per year projected under BAU scenario. (See Figure 8)

Figure 8. Total jobs supported per scenario in Colombia



Source: Authors' elaboration.

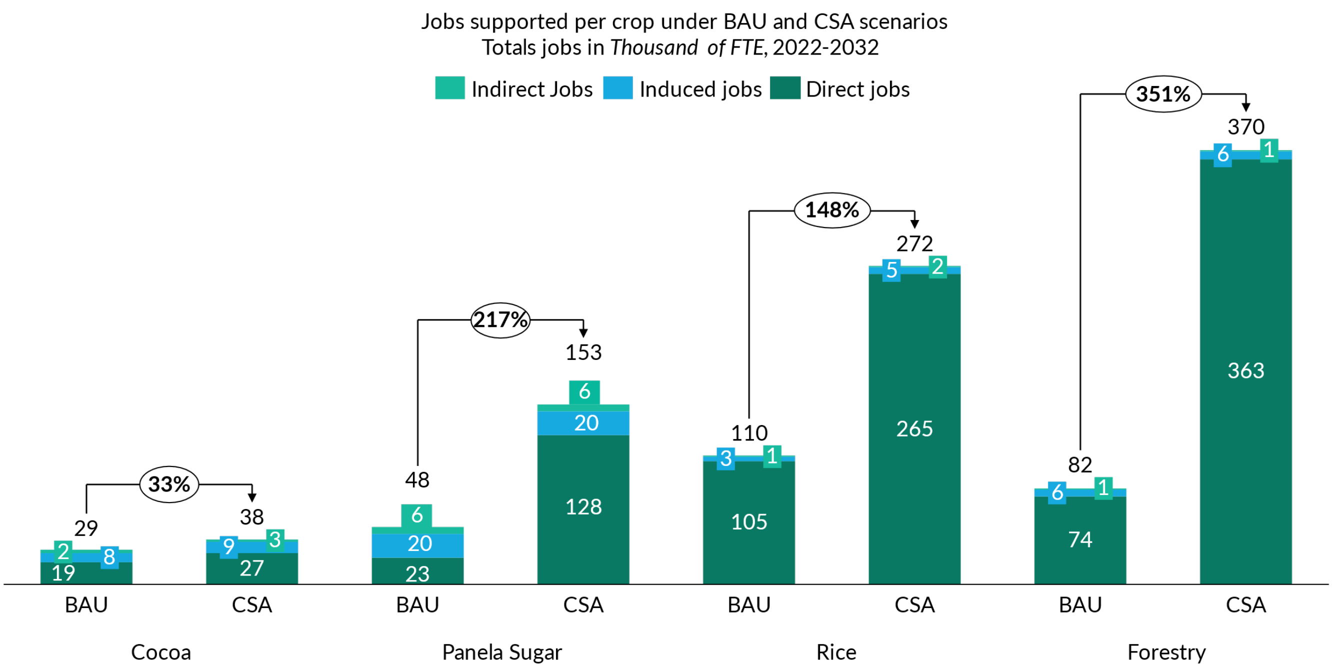
This model estimates suggest that CSA practices could support a higher number of jobs for the production of all assessed crops, i.e., cocoa, irrigated rice, forestry, and panela sugar. In the case of cocoa production, using CSA practices leads to 26,856 direct jobs, whereas conventional agricultural practices support 18,600 direct jobs. Concerning panela sugar production, the CSA scenario estimates 127,600 direct jobs, while the BAU scenario supports 22,605 direct jobs. Similarly, rice cultivation using CSA practices supports 264,512 direct jobs, surpassing the 105,060 direct jobs projected under BAU practices. Notably, the commercial forestry sector profits the most from the use of CSA practices in terms of employment. This takeaway is also observed in other similar employment studies[56]. Under the CSA scenario, the commercial forestry sector could support 362,720 direct jobs, whereas the BAU scenario supports 74,400 direct jobs. (See Figure 9)

The same pattern of increased job creation is observed in the indirect and induced job categories for each crop. However, it is worth noting that for export-oriented crops, particularly those with minimal domestic value-added post-harvest (e.g., cocoa), indirect jobs constitute a relatively minor share of overall job creation[57]. Similarly, staple crops such as rice and panela sugar, which undergo more processing but primarily reach consumers as final goods without substantial manufacturing, also present smaller shares of indirect job creation. In contrast, stable crops generate a higher share of induced jobs, which in turn stem from household expenditures resulting from new income streams generated by both direct and indirect employment.

Employment creation across the value chain stages under the CSA scenario

The modeling results indicate that most of the direct jobs supported—assuming achievement of NDC targets linked to CSA practices in the crops assessed—are generated by sub-activities in the production stage (Figure 10 illustrates the percentage distribution). For cocoa, out of the 27,000 direct jobs, 71% are allocated in the production stage, followed by processing (13%), transport (11%), and aggregation (4%). Similarly, in rice, the majority of the 265,000 direct jobs come from the production stage (90%), followed by processing (5%), transport (4%), and aggregation (1%). For panela sugar, the majority of the 127,000 direct jobs come from the production stage (89%), followed by transport (5%), processing (4%), and aggregation (2%). In the case of forestry, out of the 363,000 jobs, the majority are from the production stage (93%), followed by transport (3%), aggregation (2%), and processing (1%).

Figure 9. Job creation per crop under BAU and CSA Scenarios in Colombia, 2022 - 2032

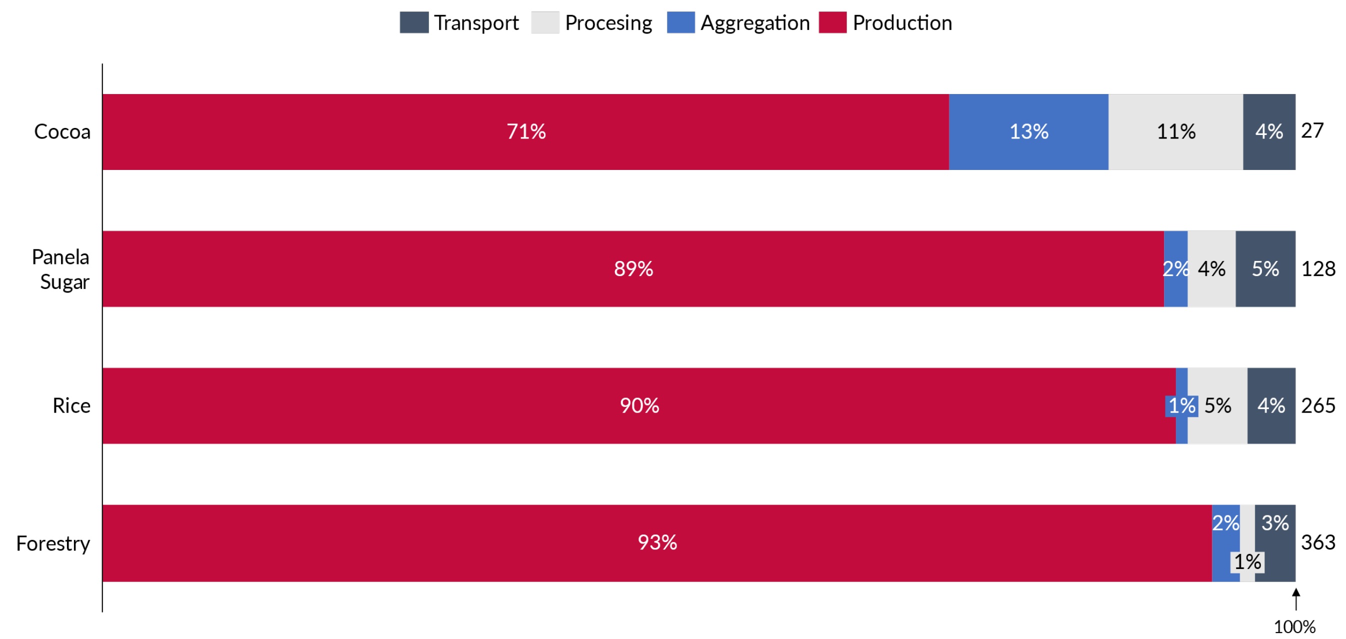


Source: Authors' elaboration.

56 FAO Knowledge Repository BETA. Available at https://www.fao.org/3/i1025e/i1025e02.pdf

57 Duran Lima & Castresana (2016, Table 2) identified a comparable Direct/Indirect job ratio within the agricultural sector in Ecuador, estimating a ratio of 6.9 direct jobs for every indirect job. Our findings for Colombia reveal a direct/indirect job ratio of 7.3 across all four crops under study.

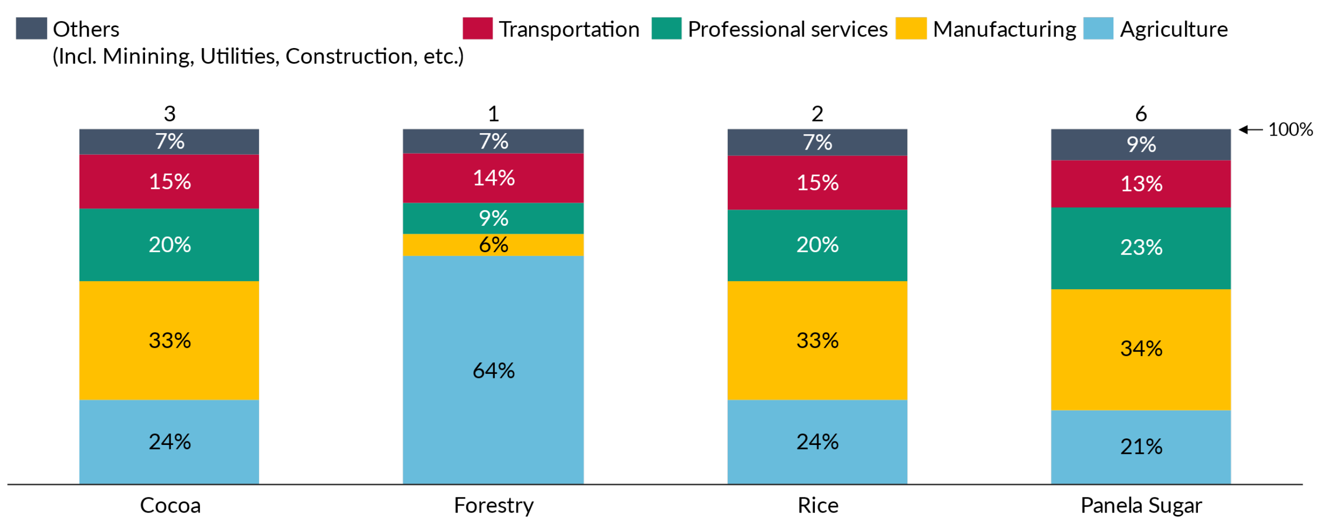
Figure 10. Distribution of direct jobs by value chain stage per crop in Colombia under the CSA scenario



Source: Authors' elaboration.

The distribution of indirect jobs across the assessed crops follows a consistent pattern of economic inter-dependencies (Figure 11). In the case of cocoa, most indirect jobs are derived from production linkages with manufacturing (405 jobs), other agricultural activities (289 jobs), and professional services (246 jobs). Similarly, for rice, the primary sources of indirect employment are production linkages with manufacturing (244 jobs), other agricultural activities (174 jobs), and professional services (149 jobs). Likewise, the indirect job distribution for panela sugar production centers around production linkages with manufacturing (2,000 jobs), other agricultural activities (1,300 jobs), and professional services (1,300 jobs). In the context of forestry, the predominant contributors to indirect employment are production linkages with other agricultural activities (424 jobs), transportation (91 jobs), and professional services (58 jobs).

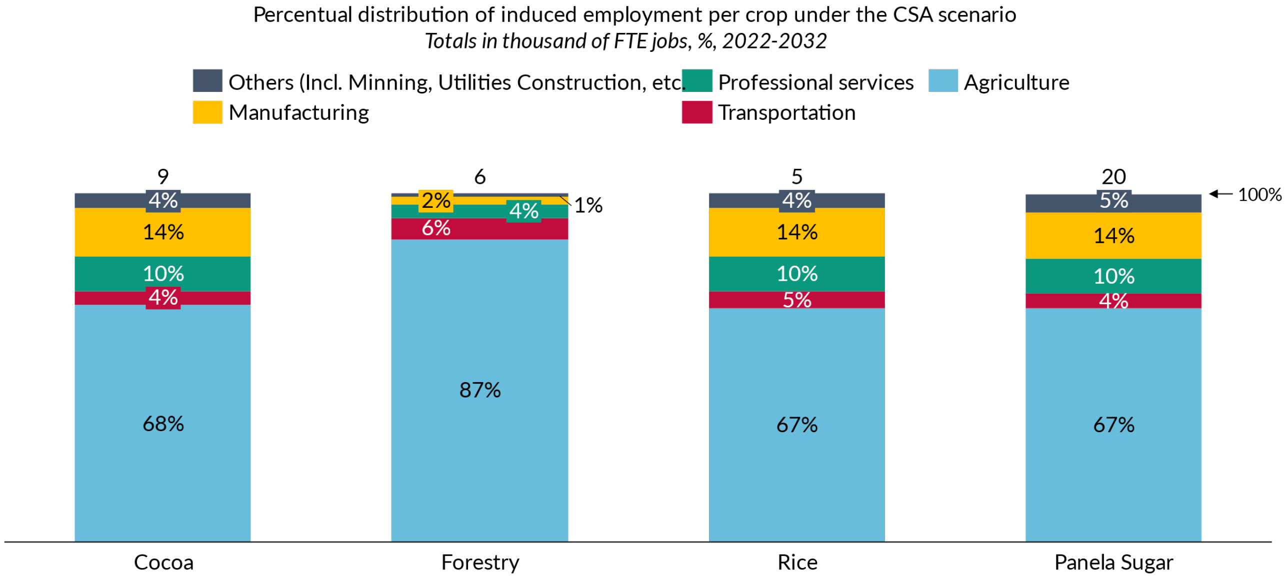
Figure 11. Distribution of indirect jobs per crop by economic sector in Colombia under the CSA scenario



Source: Authors' elaboration.

The distribution of induced job creation across four crops in Colombia illustrates a similar pattern of economic impacts (Figure 12), with distinct sectors driving employment. In the case of cocoa production, most induced jobs originate from production linkages with other agricultural activities (2,600 jobs), manufacturing (535 jobs), and professional services (395 jobs). Similarly, for forestry, the primary sources of induced employment are production linkages with other agricultural activities (2,400 jobs), transportation (154 jobs), and professional services (110 jobs). The distribution of induced jobs in rice cultivation centers around production linkages with other agricultural activities (1,500 jobs), manufacturing (323 jobs), and professional services (239 jobs). Likewise, in the context of panela sugar production, the predominant contributors to induced employment are production linkages with other agricultural activities (13,400 jobs), manufacturing (2,700 jobs), and professional services (2,000 jobs).

Figure 12. Distribution of induced jobs per crop by sector of economic activity in Colombia under the CSA scenario



Source: Authors' elaboration.

Gender balance

Colombia continues to grapple with significant inequality, and the country's economic growth has not proven sufficient to mitigate this issue, largely due to persistent barriers to economic opportunities. These barriers disproportionately affect women, specific ethnic groups, and certain geographic regions, effectively hampering socioeconomic mobility. Addressing and narrowing these gender gaps is paramount for fostering long-term economic prosperity.

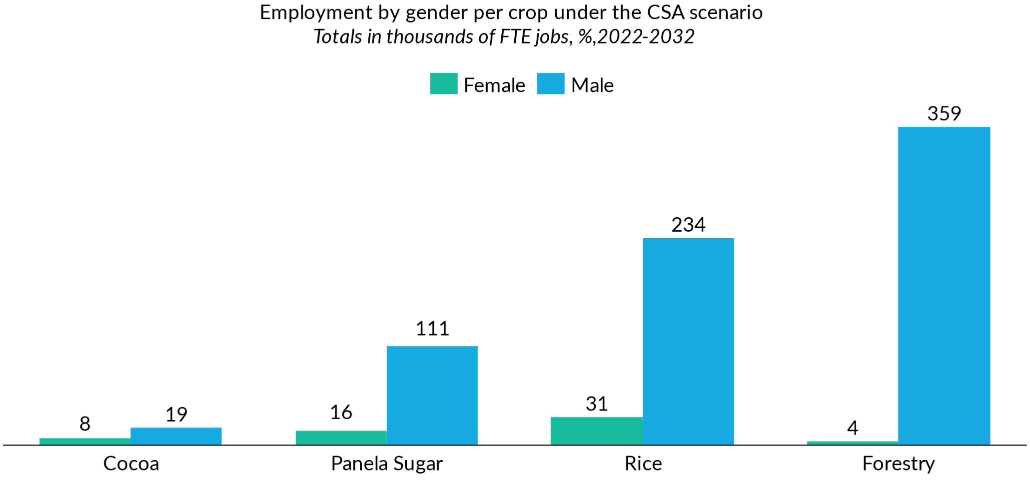
Achieving gender equality in Colombia is critical to the country's future economic development and social cohesion, yet it remains an ongoing challenge. This is particularly evident in rural areas, where structural barriers continue to limit women's access to economic opportunities. In 2022, 73.7% of the population outside the labor force in rural areas were women (2.456 million), highlighting a significant level of economic exclusion. This limited participation is reflected in higher levels of vulnerability. That same year, 29.8% of rural households headed by women were in a situation of multidimensional poverty—3.9 percentage points higher than male-headed rural households and 19.3 percentage points above female-headed households in urban areas (DANE, 2023).

These gender disparities in rural Colombia are further reflected in the dynamics of the agricultural labor market. In 2022, the population employed in the agricultural sector reached its lowest number in the last 10 years—3.2 million people (ILOSTAT, 2022). The share of women employed in the agricultural sector was approximately 530,000, representing 16% of total employment in the sector[58] (ILOSTAT, 2022). Regarding the gender wage gap in agriculture, ILOSTAT statistics for 2022 show that, on average, women earned 6.9% less than men among skilled agricultural, forestry, and fishery workers.

Given the prevalent gender imbalance in the agricultural sector in Colombia, the modeling results show that most job opportunities would rely on male workers. Out of the total direct job estimate of 782,000 for the four assessed crops, an estimated total of 59,000 employment posts would be occupied by women. (See Figure 11). These calculations are based on up-to-date data and forecasts of female labor participation rates—ranging from 1% in forestry to 27% in cocoa—derived from official microdata sources. The projections underscore the urgent need to implement policies that facilitate the increased participation of women in Colombia's agricultural labor markets.

58 The employee population comprise all persons of working age who, during a specified brief period, were in one of the following categories: a) paid employment (whether at work or with a job but not at work); or b) self-employment (whether at work or with an enterprise but not at work). Thus, in the agricultural sector, the data considered women working on their own farms.

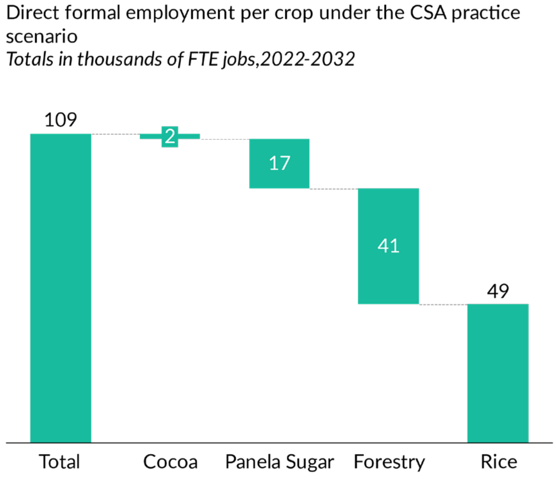
Figure 13. Employment by gender per crop under the CSA scenario in Colombia



Employment informality

Given the prevalent informality of labor in the agricultural sector in Colombia, it is assumed that a vast majority of potential job opportunities would rely on informal labor[59]. Of the total 782,000 direct jobs estimated under CSA for the four crops assessed, approximately 109,000 formal jobs are expected to be generated. (Figure 8). These calculations are based on present-day data and forecast the prospective expansion of current sector-specific formality rates (ranging from 7% in cocoa to 17% in rice) derived from official microdata sources. Additionally, throughout the decade, an estimated 41,000 jobs would emerge from non-remunerated household labor across these industries. Our forecasts apply the growth patterns identified in the last two survey years to future periods concerning the following two crucial indicators: formalization, and the proportion of non-remunerated labor. These projections underscore the urgent need to implement policies that do not only seek to support the formalization of labor in the sector but also ensure the compliance of other decent employment characteristics such as fair income, safe working conditions, equal access to employment, etc..

Figure 14. Employment formality per crop assessed under the CSA scenario in Colombia



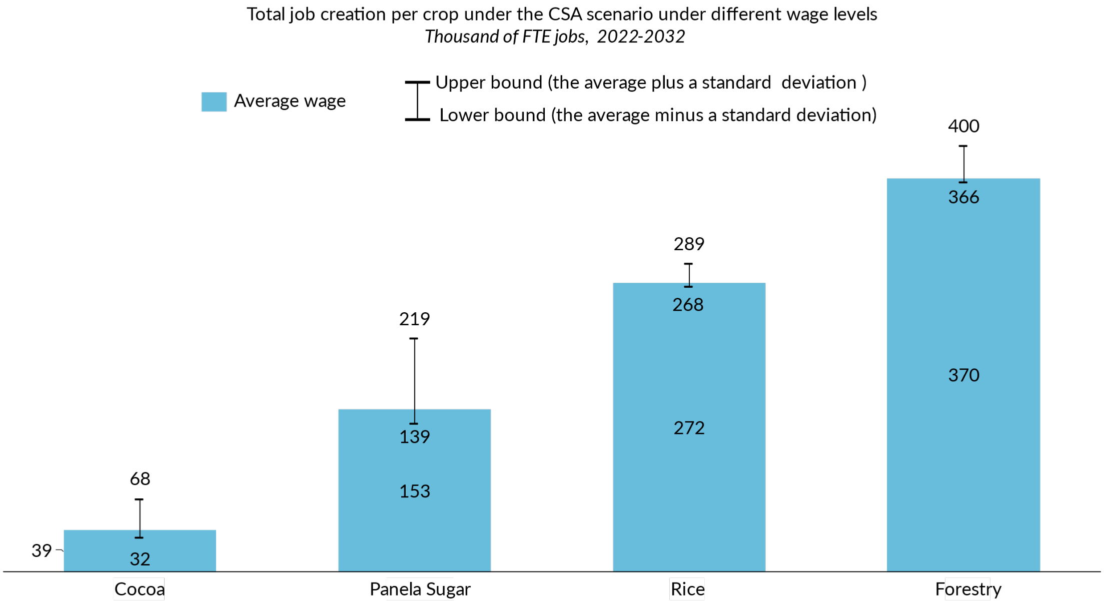
59 In the context of the legal classification of informality, it refers to the percentage of workers who do not contribute to social security. Refer to Annex 2 – Definitions

Sensitivity analysis for employment

Total job creation highly depends on the wages used in modeling. Thus, employment impacts were compared using three sets of wage scenarios: the average wage, a lower bound wage (the average minus a standard deviation), and an upper bound wage (the average plus a standard deviation). For example, using wages as one standard deviation under the mean, the total employment created in the CSA scenario rises to 976 million over the course of the decade. On the other hand, the total estimate decreases to 805,000 new jobs over the decade if higher salaries are used (1 standard deviation above the mean). This sensitivity analysis demonstrates how changes in wage levels can influence job creation within the sector[60]. These scenarios provide a range of potential outcomes based on different wage sensitivities, allowing policymakers to assess the potential impacts of wage changes on job creation. (See Figure 15)

60 This exercise can also be interpreted as increases (decreases) in labor productivity, wherein fewer (more) workers are producing the same output.

Figure 15. Total job creation per crop under the CSA scenario under different wage levels in Colombia



Source: Authors' elaboration.

Economic impacts

Table 9 outlines the specific agricultural practices modeled for each crop and provides insights into the financial implications of utilizing CSA practices. The expenses linked to each CSA practice encompass both general and crop-specific production costs for a prototypical agricultural unit (i.e., average-sized farms remunerating labor and inputs at prevailing market rates). Data on stereotypical farms is extrapolated at the national level to achieve the number of hectares per crop targeted by their respective NDC. The table offers a comparison of production costs per hectare (in USD) between conventional agricultural practices and CSA practices. It is observed that the average production costs per hectare increase by 17% when comparing the BAU and CSA scenarios, considering all crops assessed.

Furthermore, costs utilized in the BAU scenario pertain to the conventional agricultural methods used in each crop, while costs in the CSA scenario reflect the expenses associated with implementing the CSA agricultural practices per crop outlined in the NDCs. Overall, the table highlights the financial considerations associated with their implementation. The average annual cost for implementing CSA practices across the assessed crops is estimated at USD 50 million. The yearly costs of implementing CSA practices for cocoa production are estimated at approximately USD 34.1 million, forestry projects at approximately USD 66.4 million, irrigated rice projects at USD 79.2 million, and panela sugar projects at USD 21.3 million.

Table 9. CSA practices and costs estimate per sector in Colombia

Sectors	Cocoa	Forestry	Irrigated Rice	Panela sugar
CSA practices	*Agroforestry; cross-slope barriers*	*Agroforestry*	*Cross-slope barriers; straw mulching; alternative wet and dry irrigation*	*Agroforestry; cross-slope barriers; solar powered irrigation*
Costs estimates				
Costs per project* (USD millions)	34.1	66.4	79.2	21.3
Costs of conventional agricultural practices per hectare (USD)	1,986	2,966	2,494	1,509
Costs of CSA practices per hectare (USD)	2,274	3,321	3,106	1,824

Table 10. Gross value added per worker per crop in CSA scenario in Colombia

Crop	Baseline (2022)	Change in Year 1	Change in year 10	2032	Percentual change Y1 vs Y10
Irrigated rice	4,193.45	(76.41)	(37.20)	3,998.02	51%
Cocoa	2,422.54	(603.50)	(562.81)	2,083.80	7%
Panela sugar	2,858	33	300	3,158	10%
Forestry	667.08	75.76	83.71	672.41	10%

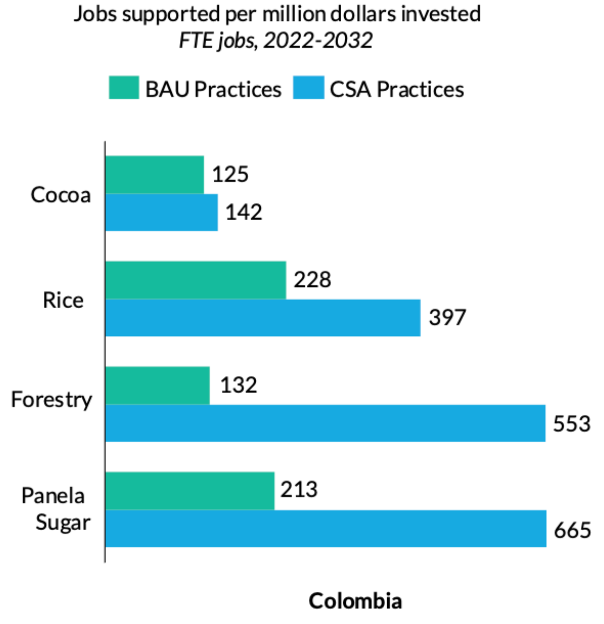
Source: Authors' calculations

Employment per USD 1 million invested

An internationally comparable measure is the number of jobs created per USD 1 million invested. Based on this metric, the model results estimate that achieving Colombia's NDC targets related to the use of CSA practices for commercial panela sugar has the highest job creation potential among all crops assessed, with 665 jobs created per USD 1 million invested. In the case of forestry production, using CSA practices can generate 553 jobs for the same amount. Irrigated rice comes in third with 397 jobs created, while cocoa provides the fewest job opportunities among the four, with 142 jobs per USD 1 million invested. Total job creation is greater for the CSA practices' scenario in all crops compared to the BAU scenario (Figure 16).[61] The overarching message is that the magnitude of new job creation in Colombia outweighs the additional costs associated with the introduction of CSA practices in the assessed activities.

The literature measuring the labor impact resulting from investments in specific economic sectors relies on diverse methodologies and information sources. Common methods include macroeconomic models based on IO matrices, the utilization of ad-hoc surveys, and the examination of project accounting profiles. While these studies are more prevalent in developed nations, the evidence for developing countries suggests significantly greater job creation potential in the latter (Moszoro, 2021). International evidence specific to the agricultural sector remains limited; hence, we put our findings into context by comparing them with analogous studies conducted in developed and developing nations, both within and beyond the realm of agriculture. For example, previous studies on Latin American countries have observed a relatively high employment multiplier in rural road maintenance projects, with the potential to generate between 200 and 500 direct jobs for every USD 1 million invested (Schwartz, Andres & Dragoiu, 2009). For public infrastructure investments in Latin America, Pastor et al. (2020) find an average job creation potential ranging from 48 to 99 total jobs per USD 1 million invested. A global estimate developed by Payen and Lieuw-Kie-Song (2020) indicates that, in the forestry sector, 281 to 458 direct jobs could be created per USD 1 million invested. For a group of Eastern European countries, Heyndrickx Fredix and Purwanto (2013) estimate an average of 85 direct jobs per USD 1 million invested in the transportation sector[62]. Less comparable studies measure the number of jobs created for every USD 1 million of final demand. For example, using IO modeling for Ecuador, Duran Lima and Castresana (2016, Table 1) suggest that the production of USD 1 million in agriculture requires 152 direct jobs. Using a similar method, Mon and Holland (2006) estimate that producing apples in the US requires 35 direct jobs for every USD 1 million of final demand.

Figure 16. Jobs supported per 1 million USD



Source: Authors' elaboration.

Impact of climate change on agricultural employment

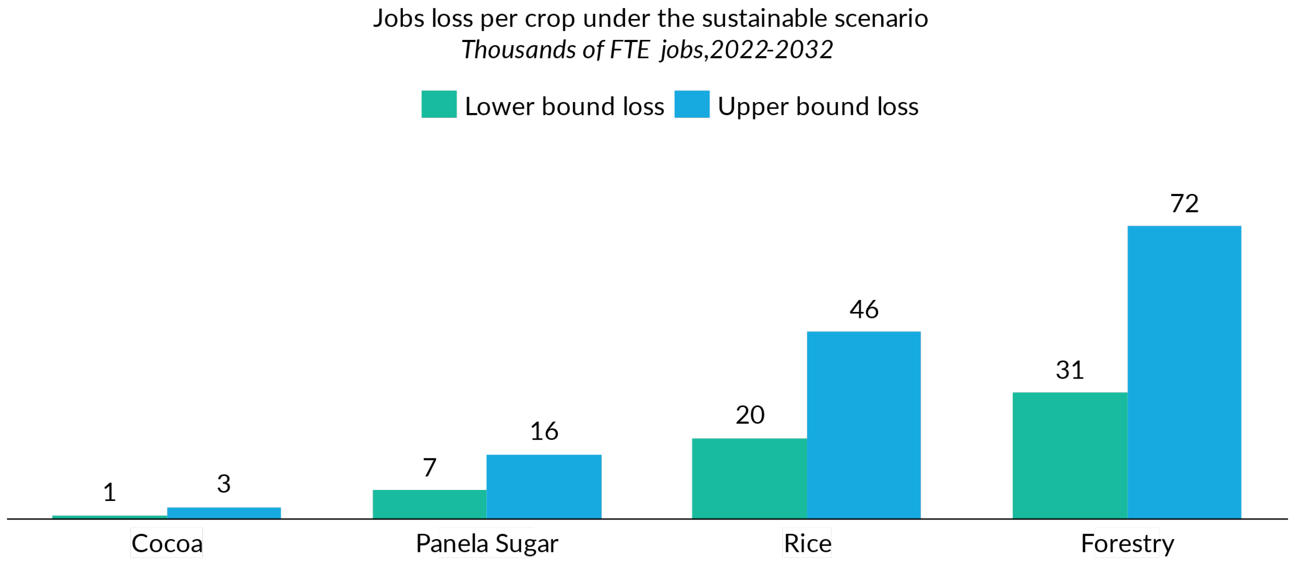
The estimations reflect the minimum and maximum productivity declines projected for Colombia by the Climate Vulnerability Monitor. This projection is based on the scenario of adopting policy measures aimed at maintaining global temperatures within the 2°C increase trajectory from 2021 to 2040. Based on the proposed methodology and scenarios provided by the NDC targets, the negative impacts of climate change are projected to result in a loss of between 59,000 and 137,000 FTE jobs out of the total 834,000 new jobs estimated under the CSA scenario—including direct, indirect, and induced jobs[63]. (Figure 17).

61 Refer to Annex 4 for the estimates on direct, indirect, and induced job creation per USD 1 million invested.

62 The countries included in the study were Bulgaria, Czechia, Estonia, Hungary, Latvia, Poland, Romania, and Slovakia.

63 Under the BAU scenario, the exposure to negative climate change would result in a loss of between 19,000 and 44,000 FTE jobs in Colombia; and a loss of 4,000 to 18,000 in Ethiopia.

Figure 17. Impact of climate change-related heat on labor



Source: Authors' elaboration.

5.2 Identification of occupations and skills

Human capital is a key driver of economic development and social progress in any country. Training within an educational system must be aligned with the requirements of the productive sector to develop human capital properly. However, over the years, the disparity between training offers and labor market demand has become increasingly evident, and this imbalance between the supply and demand of human capital skills is reflected in stagnant productivity (ILO, 2022; IDBG, 2021). Additional consequences of the skills gap in human capital include youth unemployment, long-term unemployment, and underemployment.

By identifying specific occupation-skill dyads that can support an accelerated deployment of CSA and classifying them into four educational tiers (i.e., Managers, Engineers, Technicians, and Non-Professionals), it is possible to develop targeted workforce development strategies that reflect the unique characteristics and requirements of each industry.

The report's skills assessment shows that skilled farm workers possess higher levels of technical skills in the areas of agribusiness, natural resources, and engineering rather than practical skills. This enables them to deploy new CSA technologies, increase production, access markets, and sell at competitive prices, as well as collaborate and engage in beneficial and efficient decision-making based on data. Moreover, skilled farm workers have higher knowledge shares of environmental laws, management, and sectoral certifications. Complementarily, agricultural laborers possess higher degrees of physical skills requiring dexterity and technical skills using specialized machinery. Agricultural laborers are also observed to have moderate levels of non-technical skills, such as liaising and networking, organizing, planning and scheduling, strategizing, etc. The following section provides examples of the individual crop assessments —found in Annex 5—that highlight the intricate structure of occupation-degree of skill dyads.

Cocoa

The cocoa industry demonstrates a wide variety of skill needs—from the negotiating expertise of an import-export manager to the technical proficiency of a cacao bean roaster. Moreover, the following four-tier system enables strategic workforce planning and the development of educational initiatives that align with the industry's demands.

- Management: Occupations such as import-export managers in coffee, tea, cocoa, and spices focus on planning, analyzing, and executing financial transactions. Examples of these types of skills include "negotiating and managing contracts and agreements", which account for 19% of the skill requirements for import-export managers.

- Engineers: The cacao press operator role requires skills in operating machinery and performing technical tasks. Examples include "complying with health and safety procedures" (10%) and "complying with operational procedures" (10%).

- Technicians: Occupations such as import-export specialists engage in monitoring, inspecting, and analyzing information. "Implementing new procedures or processes" (13%) is an example of such skills.

- Non-Professionals: Roles like cacao bean cleaner require skills in operating food processing machinery. Examples of these types of skills include "operating food processing machinery" (21%) and "complying with operational procedures" (10%).

Forestry

Forestry in Colombia requires a unique blend of technological, managerial, and manual skills. The following tiered system facilitates the identification of specific educational requirements and can inform targeted educational programs and workforce planning within the sector.

- Management: Occupations such as forester and forestry adviser are associated with skills in decision-making and strategic planning. Examples of these types of skills include "monitoring, inspecting and testing" (20%) for forestry advisers or "organizing, planning and scheduling work and activities" (24%) for foresters.

- Engineers: Roles like forestry machinery technician require skills in operating and maintaining machinery. Examples of these types of skills include "operating mobile plants", which account for 14% of the skill requirements for forestry machinery technicians.

- Technicians: Occupations like forestry inspector and forestry technician focus on monitoring and inspection. Examples of these types of skills include "monitoring, inspecting, and testing" for forestry technicians (32%).

- Non-professionals: Forest workers and forestry equipment operators deal with physical tasks such as tending to plants and lifting materials. For example, "tending plants and crops" (29%) is a requirement for forest workers.

Irrigated Rice

From the organizational competence of a farm manager to the manual abilities of a paddy worker, the rice farming industry in Colombia demands a multifaceted workforce, reflecting the sector's complex nature.

- Management: The farm manager role emphasizes skills in "promoting products, planning production processes" (11%) and "directing operational activities" (6%).

- Engineers: Occupations like agricultural engineer focus on maintaining electrical and mechanical equipment. Examples of such skill requirements for agricultural engineers include "designing systems and products" (9%).

- Technicians: Occupations such as agricultural technician and agricultural inspector are engaged in conducting research and complying with health procedures. Examples include "monitoring safety or security" (15%).

- Non-professionals: The mixed Farmer and paddy workers roles align with skills like cultivating land and "operating agricultural equipment" (18%).

Panela sugar

Panela sugar cultivation requires medium- to low-skill roles such as "atizador," "alfandoques," and "pesador" (as per their names in Spanish). These occupations contrast with others such as import-export specialists in panela sugar. A clear divide is observed between managerial, engineering, technician, and non-professional skills.

- Management: Occupations like sugar, chocolate, and sugar confectionery distribution manager rely on skills such as "risk analysis" (14%) and "ensuring legislative compliance" (10%).

- Engineers: Roles such as sugar operator require skills in "operating food processing machinery" (8%).

- Technicians: Occupations like wholesale merchant in sugar, chocolate, and sugar confectionery focus on complying with health and safety procedures. Specific examples of skills needed include "negotiating and managing contracts and agreements" (19%).

- Non-professionals: These roles often involve cleaning tools and complying with basic operational standards.

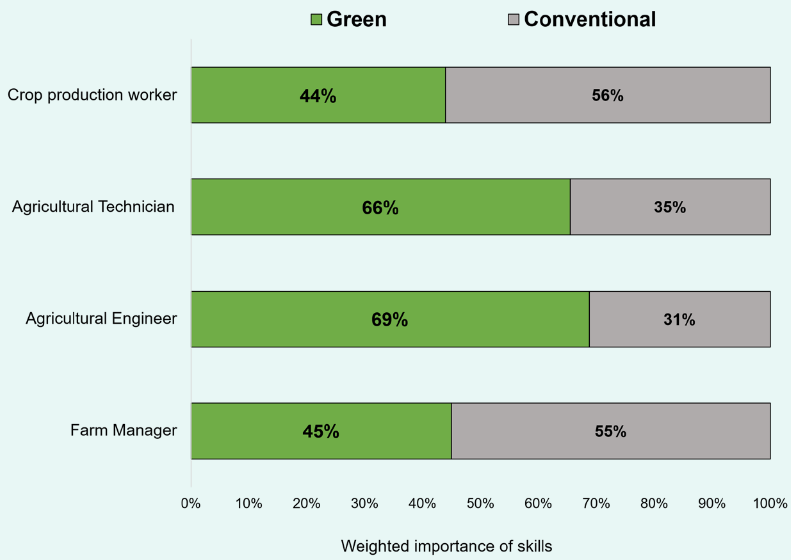
BOX 2. Identifying Green Skills in Agricultural Occupations

This study employs string similarity matching using ESCO's taxonomy and Spacy's medium-sized English language model to identify "green" skills in agriculture.[64] ESCO taxonomy's skills-to-occupation matrices map the skills required for various agricultural occupations. CEDEFOP provides two relevant datasets for this task: one containing 296 general skills applicable to as many as 3,000 occupations, and another containing 570 green skills[65]. Using cosine similarity coefficients, the model measures the resemblance between these two skill label sets, aiding in the classification of skills as either green or conventional. (Refer to Annex 1 for definitions). Notably, without this automation, the alternative would entail the manual comparison of more than 168,000 skill-label dyads, highlighting the efficiency gained through our approach.

Other projects have followed a similar method to identify skills within conventional and unconventional labor market data. One notable example is the initiative by the UK's Department of Business, Energy, and Industrial Strategy (BEIS), which employs a supervised machine learning model trained on a dataset developed by industry experts to categorize Lighthouse job vacancy data into "clean growth jobs" and "not clean growth jobs" industries. Similarly, the Jobs and Skills Australia project also utilizes Lighthouse job vacancy data, aligning these records with the Australian Skills Classification (ASC) to identify and profile emerging and trending skills. Additionally, LinkedIn's Global Green Skills Report employs machine learning to correlate its vast database of 850 million members with a list of green skills, developed internally and based on the O*NET and ESCO taxonomies (OECD, 2023).

The following figure provides insights into the results of this exercise applied to four distinct agricultural occupations: farm manager, agricultural engineer, agricultural technician, and crop production worker (each representing one tier from our four-tier framework of educational requirements per occupation). The percentages indicate the extent to which each occupation relies on green versus conventional skills, offering a clear delineation of skill requirements in these roles. Occupations such as agricultural engineers and technicians, have a significantly higher share of green skills (skills related to sustainable and eco-friendly practices) compared to conventional skills. Conversely, farm managers and crop production workers have a higher proportion of conventional skills relative to green skills.

Figure 18. Green/Conventional Skill Composition in Four Occupations



Source: Authors' calculations.

64 medium-sized English language model

65 A similar dataset is provided by O*NET (2022) in its identification of "green topics" within occupations and education programs for the US.

The next table offers a detailed breakdown of the results achieved through the application of machine learning techniques to identify green skills in the agricultural context. First, a selection of general skill string labels is displayed alongside their respective percentages, denoting the degree to which each skill is relevant to the tasks performed in the occupation (agricultural technician in this example). A second column, labeled "Green," indicates whether each skill label was assessed as similar (= 1) to one of the 570 green skills labels provided by CEDEFOP. We classified a general skill label as green if its cosine similarity coefficient was greater than or equal to 0.80 [66]. The final column adds the percentage of green skills for those skills labels categorized as green.

Table 11. Skills Composition and Green Skills classification for Agricultural Technicians

General Skill String Labels	Percent	Green	Percent Green
cultivating land and crops	6%	1	6%
complying with health and safety procedures	6%	1	6%
conducting academic or market research	9%	1	9%
advising on business or operational matters	6%	1	6%
analysing business operations	6%	1	6%
analysing scientific and medical data	11%	1	11%
technical or academic writing	6%	0	0%
advising on environmental issues	3%	1	3%
evaluating systems, programmes, equipment and products	6%	1	6%
monitoring environmental conditions	6%	1	6%
gathering information from physical or electronic sources	6%	0	0%
performing calculations	6%	0	0%
cleaning interior and exterior of buildings	3%	0	0%
assessing land or real estate	3%	0	0%
tending and breeding aquatic animals	6%	1	6%
maintaining electrical, electronic and precision equipment	6%	0	0%
monitoring operational activities	3%	0	0%
cleaning tools, equipment, workpieces and vehicles	3%	0	0%
advising on products and services	3%	1	3%
Sum	**100%**	**11**	**66%**

Source: Authors' calculations.

The table shows that a substantial portion (66%) of the skills required for agricultural technicians includes green elements, highlighting the increasing importance of eco-friendly competencies across various domains. This data provides valuable insights into the skill requirements for different occupations within agriculture, offering a clear distinction between green and conventional skills essential for their function in the agricultural sector.

Despite being informative, extensible, and scalable, this type of analysis has at least two limitations. Data quality and labeling bias: the analysis relies on the quality and completeness of the initial CEDEFOP datasets, and the reliance on cosine similarity coefficients for labeling may not fully capture the nuanced nature of some skills. Contextual nuance and temporal validity: the analysis assumes a fixed definition of green skills and may not fully account for the contextual nuances of how skills are applied in specific agricultural contexts. It is important to be aware of these limitations when interpreting the results. Data quality and labeling bias can potentially lead to misclassification of skills, while temporal validity and contextual nuance can impact the accuracy of the results in different contexts and across time. Despite these limitations, this type of analysis can be a valuable tool for understanding the green skills landscape in agriculture. It can help to identify areas where there is a need for upskilling and reskilling, and it can also be used to track progress over time.

66 This GitHub repository contains the Python code used for this task.

Skills gap

According to the 2017 skills gap analysis in the agriculture and forestry sectors developed by the Colombian Agricultural Research Corporation (AGROSAVIA), Colombia exhibits the following skill gaps at the national level[67].

Quantity gaps

The number of professionals in the agricultural sector—which primarily operates in rural areas—is insufficient to meet the market demand due to several factors:

- Technical and highly qualified professionals are concentrated in the capital cities and rarely deployed to rural areas.
- The country faces an aging workforce in the countryside, creating a labor deficit.
- Young people are disincentivized from pursuing agricultural studies due to the perceived lack of access to better income opportunities.
- There is a lack of educational programs that respond to the needs of the labor market. Particularly in the forestry sector, postgraduate programs related to forest resource management are scarce. Similarly, in the agricultural sector, there is an absence of programs that train for roles such as lifter and harvester operation technicians, panela sugar technicians (i.e., paneleros), and rural mechanics technicians.

Relevance gaps

Companies report a lack of administrative knowledge (such as formulation of plans, management, and negotiation), soft skills (such as leadership, assertive communication, and teamwork), and management protocols (such as value added to the products) among graduates, as well as insufficient ability to work in international contexts and limited research capacity.

Skills gaps

Both the forestry and agricultural sectors face a shortage of human capital in technical occupations related to quality control and monitoring, establishing and following sanitation protocols, and managing the production and commercialization of products. Moreover, a lack of digital skills amongst entrepreneurs in the agricultural sector is another key barrier to CSA adoption.

The existing agricultural workforce in Colombia requires upskilling through formal, on-the-job, short-course training as part of their role, as more manual, repetitive, or physically demanding tasks are replaced with technology.

67 https://www.colombiaaprende.edu.co/sites/default/files/files_public/2021-08/analisis-brechas-sector-agropecuario.pdf

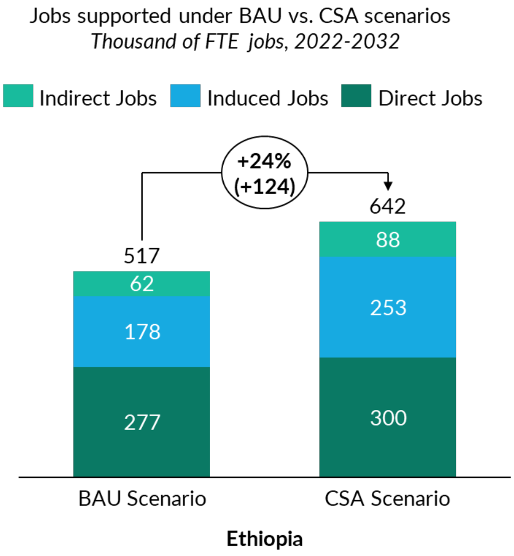
5.3 Ethiopia

Employment creation: BAU vs CSA scenario

Ethiopia's NDCs aim to enhance food security by improving agricultural productivity in a climate-smart manner. This involves the promotion of yield-increasing techniques and economic coordination to boost barley, corn, teff, and wheat production across the country, in line with the strategy for enhancing food security (Govt. of Ethiopia, 2021).

In comparison to the conventional agricultural methods (BAU scenario), the use of CSA practices outlined in Ethiopia's NDC has the potential to generate a total of 642,079 jobs by 2032 (an average of 110,000 new jobs per year). This represents a 24% increase from the 517,305 jobs anticipated under BAU practices (111,000 new jobs per year), as depicted in Figure 19.

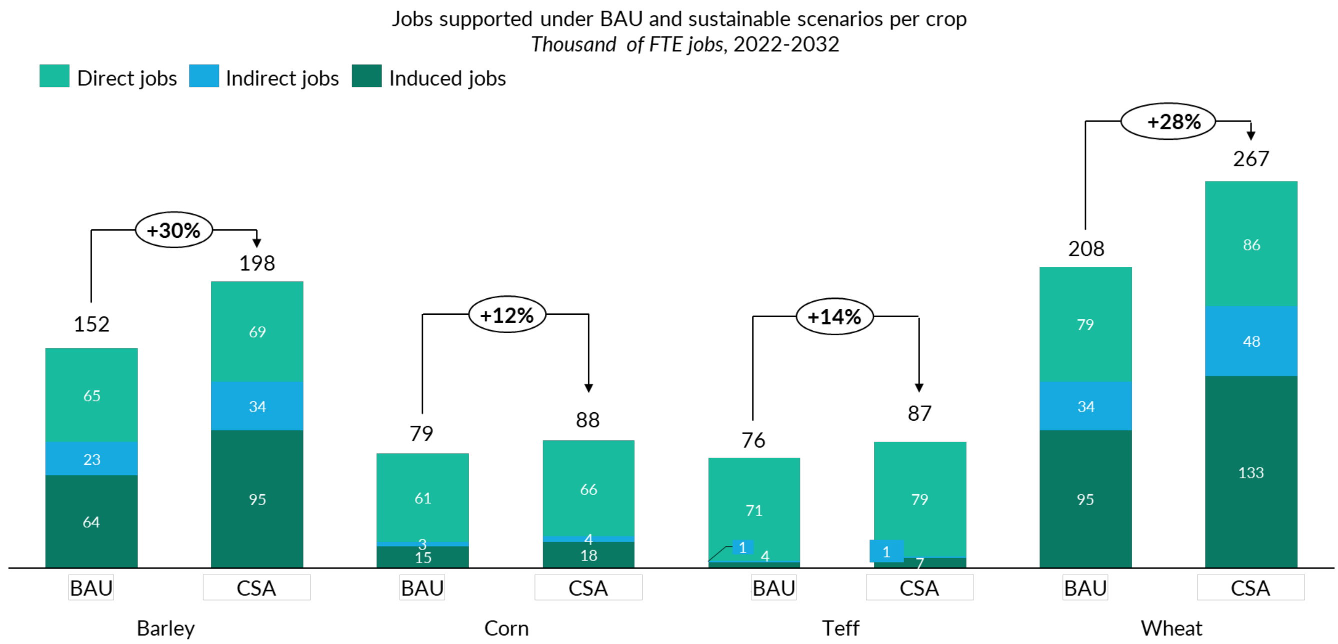
Figure 19.Total jobs supported per scenario in Ethiopia



Source: Authors' elaboration.

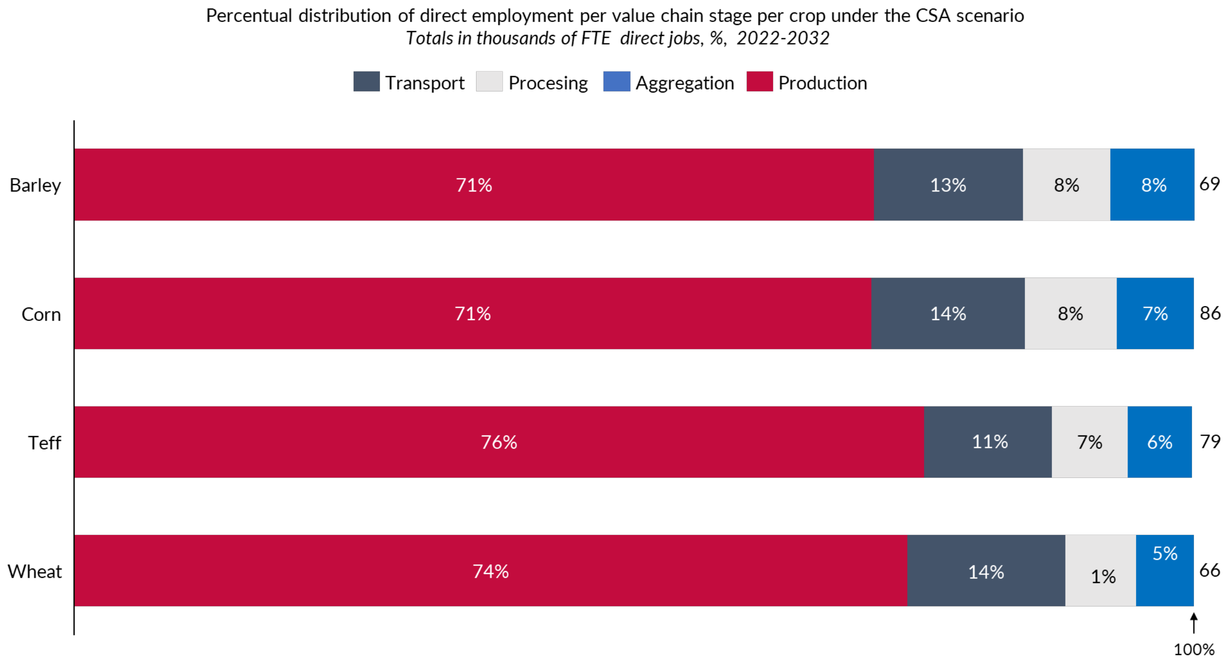
By comparing conventional agricultural approaches with CSA practices, Figure 20 illustrates that CSA practices yield higher job opportunities in the realms of barley, corn, teff, and wheat production in Ethiopia. In the case of barley production, the CSA approach generates 69,000 direct jobs, whereas BAU practices result in 65,000 direct jobs. Similarly, in corn, the introduction of CSA practices yields 66,000 direct cumulative jobs, compared to 61,000 under BAU. In the case of teff production, CSA practices generate 79,000 direct jobs, whereas BAU practices generate 71,000 direct jobs. In wheat production, the CSA approach generates 86,000 direct jobs, compared to the 79,000 direct jobs created by BAU practices. This same trend of increased job creation is evident in the categories of indirect and induced employment for each crop, underscoring the beneficial impact of CSA practices on employment prospects within individual crop sectors in Ethiopia.

Figure 20. Job creation per crop under BAU and CSA Scenarios in Ethiopia, 2022 - 2032



Source: Authors' elaboration.

Figure 21. Distribution of direct jobs by value chain stage



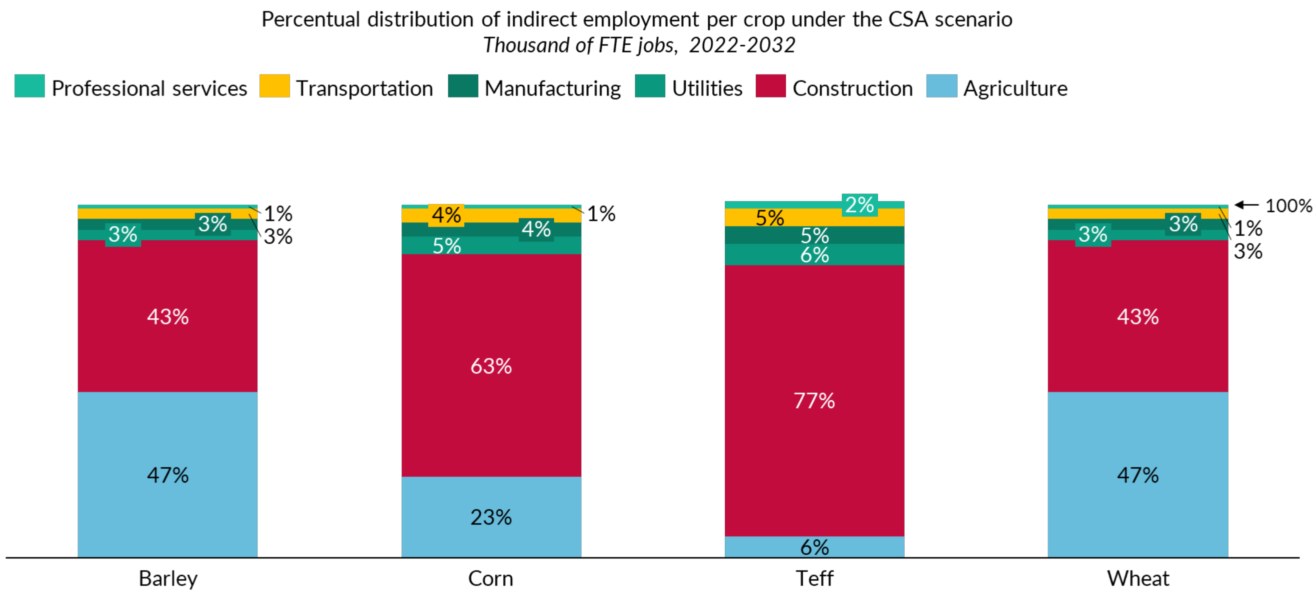
Source: Authors' elaboration.

Employment creation across the value chain stages under the CSA scenario

The analysis of potential job creation, under the CSA scenario, reveals that most jobs are associated with specific phases of the production process, as indicated by the percentage breakdown in Figure 21. In the case of barley, most new direct jobs come from the production stage (71.4%), followed by transport (13.0%), processing (7.8%), and aggregation (7.8%). Similarly, for corn, the largest proportion of new jobs originates from the production stage (71.2%), followed by transport (13.7%), aggregation (8.2%), and processing (6.9%). Teff sees the most new jobs coming from the production stage (75.9%), followed by transport (11.4%), processing (6.8%), and aggregation (5.7%). Lastly, in the case of wheat, the primary source of new jobs is the production stage (74.4%), followed by transport (14.1%), processing (6.3%), and aggregation (5.2%).

The distribution of indirect jobs in Ethiopia exhibits a consistent pattern of economic interdependencies, as illustrated in Figure 22. This is evident in the significant contribution of production linkages with other agricultural activities to the distribution of indirect employment. For barley, a significant portion of indirect jobs is attributed to production linkages with other agricultural activities (11,900 jobs), followed by construction (11,000 jobs), and utilities (802 jobs). In the case of corn, the primary sources of indirect employment are production linkages with construction (2,000 jobs), followed by other agricultural activities (750 jobs), and utilities (151 jobs). Teff, similarly, relies heavily on production linkages with construction (956 jobs), followed by other agricultural activities (71 jobs), and utilities (70 jobs) for indirect job distribution. Lastly, for wheat, most indirect jobs come from production linkages with other agricultural activities (16,000 jobs), followed by construction (15,000 jobs), and utilities (1,000 jobs).

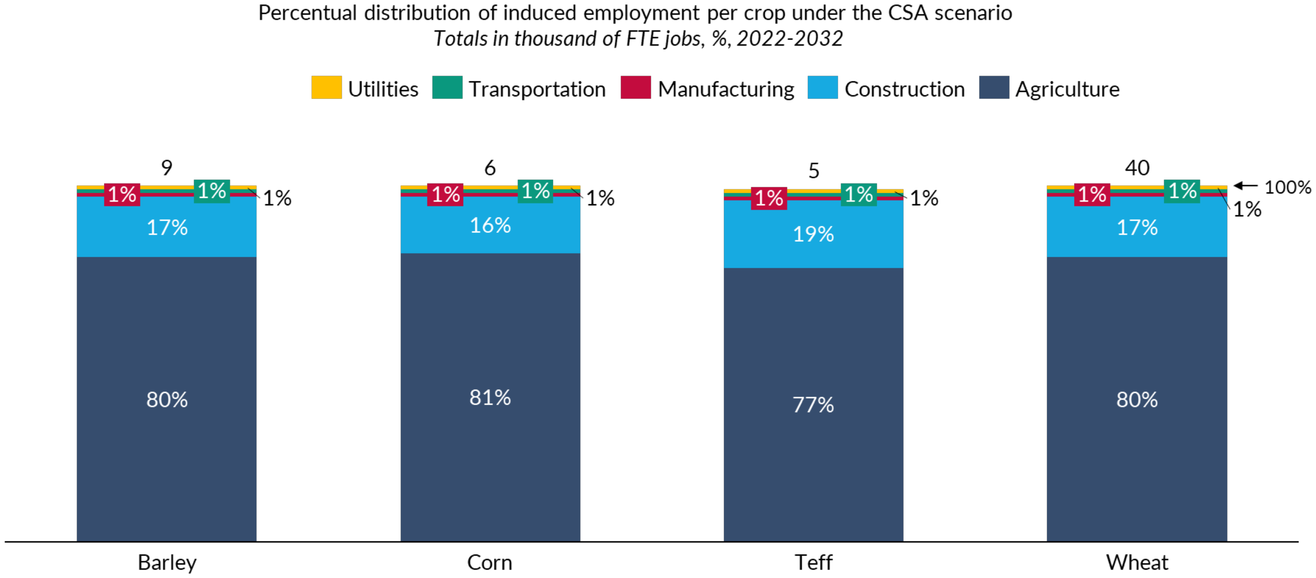
Figure 22. Distribution of indirect jobs per crop by economic sector in Ethiopia under the CSA scenario



Source: Authors' elaboration.

The distribution of induced job creation in Ethiopia also reveals a consistent pattern of economic dependence on agricultural activities, as depicted in Figure 23. In the context of barley production, most induced jobs are linked to other agricultural activities (59,700 jobs), followed by construction (12,700 jobs) and utilities (924 jobs). For corn cultivation, the primary sources of induced employment are found in other agricultural activities (11,900 jobs), followed by construction (2,400 jobs), and utilities (174 jobs). Teff production also depends heavily on other agricultural activities (4,000 jobs) for induced job distribution, followed by construction (1,000 jobs) and utilities (80 jobs). Lastly, wheat production leads to a significant number of induced jobs in other agricultural activities (83,000 jobs), followed by construction (17,000 jobs) and utilities (1,000 jobs).

Figure 23. Distribution of induced jobs per crop by economic sector in Ethiopia under the CSA scenario



Source: Authors' elaboration.

Gender balance

Agriculture in Ethiopia exhibits a gender disparity, with 71.4% of men involved in agricultural activities for their livelihood, compared to just over half of women, at 51.1%. (Friedrich Ebert Stiftung, 2023)[68]. Given the prevailing low levels of remunerated female participation in agricultural production in Ethiopia, most direct jobs created are expected to be filled by male workers. Out of the total direct jobs estimate of 300,000 for the four crops, an estimated total of 140,000 employment posts will be occupied by women (Figure 24). These calculations are based on female labor participation rates of 43% derived from official microdata sources. The projections extend the growth rates observed in the preceding two national survey years for female labor participation to future years. These forecasts emphasize the critical need for enacting policies that actively promote and facilitate the greater inclusion of women in the agricultural labor markets of Ethiopia.

Employment Informality

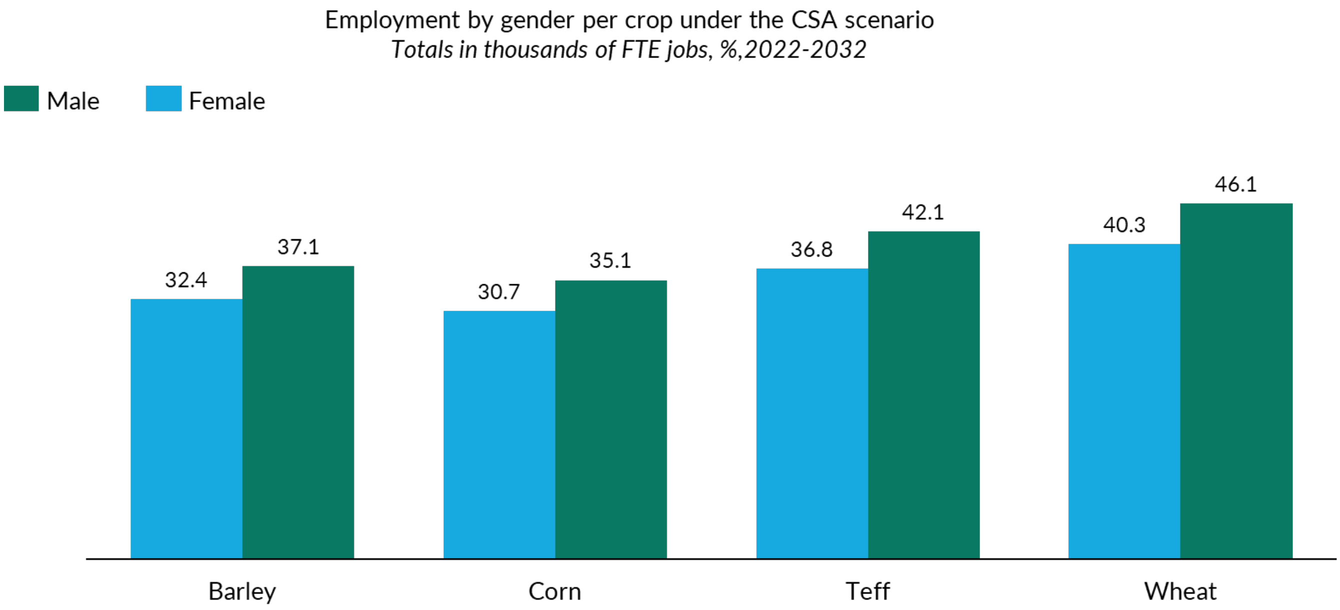
The Ethiopian economy is largely agriculture-based. However, as of 2022, the agricultural sector presented the highest share of employment informality in the whole economy, with nearly two-thirds (62.6%) of the sector's employed population[69]. Given the prevalence of informality in the sector, it is forecasted that most direct jobs created will remain informal. Out of the total direct job estimate of 300,000 for the four crops, an estimated total of 129,000 (43%) formal jobs would be generated. Additionally, throughout the modelled decade, an estimated 90,000 jobs in the agricultural sector would emerge from non-remunerated household labor (Figure 25). It is important to highlight that Ethiopia's informal economy displays effective organization, with informal workers belonging to associations, cooperatives, or indigenous groups that possibly provide access to social services[70].

68 Freidrich Ebert Stiftung (2023). Working in the Shadows. Strollreiter, S., & Traub-Merz, R. (Eds). Retrieved from. https://library.fes.de/pdf-files/bueros/aethiopien/20353.pdf

69 Freidrich Ebert Stiftung (2023). Working in the Shadows. Strollreiter, S., & Traub-Merz, R. (Eds). Retrieved from. https://library.fes.de/pdf-files/bueros/aethiopien/20353.pdf

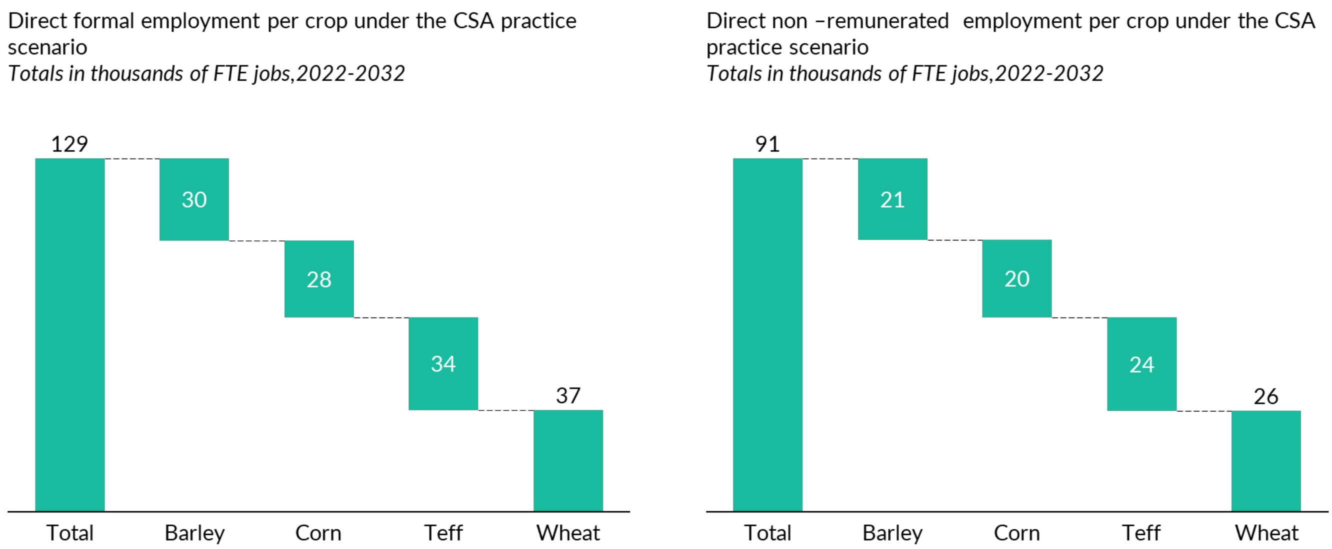
70 Freidrich Ebert Stiftung (2023). Working in the Shadows. Strollreiter, S., & Traub-Merz, R. (Eds). Retrieved from. https://library.fes.de/pdf-files/bueros/aethiopien/20353.pdf

Figure 24. Employment by gender per crop under the CSA scenario in Ethiopia



Source: Authors' elaboration.

Figure 25. Employment formality per crop assessed under the CSA scenario in Ethiopia

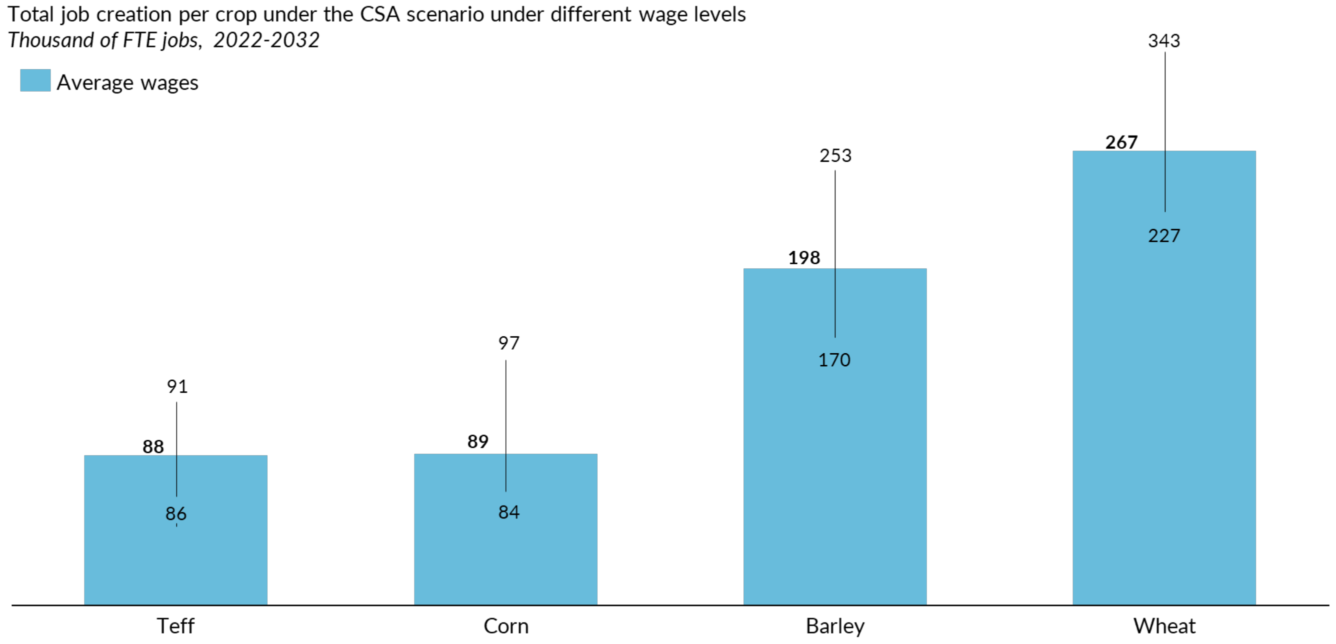


Source: Authors' elaboration.

Sensitivity analysis for employment

The estimated total number of jobs created can vary depending on the wage levels considered in each scenario. Therefore, the model shows employment estimation across three wage sets: the average wage, a lower bound wage (which is the average wage minus one standard deviation), and an upper bound wage(which is the average wage plus one standard deviation). For instance, if we use wages one standard deviation below the average, the total employment growth over the decade is projected to be 784,179. Conversely, if higher wages (one standard deviation above the mean) are used, the total estimate decreases to 567,312 new jobs over the same period. This sensitivity analysis illustrates how alterations in wage levels (which also provide proxies for labor productivity) can impact job creation across various sectors.

Figure 26. Total job creation per crop under the CSA scenario under different wage levels in Ethiopia



Source: Authors' elaboration.

Economic Impacts

Table 12 provides an overview of the CSA practices modeled for each crop and offers insights into the financial requirements for implementing these CSA approaches. The estimated production costs include both general and crop-specific production variable expenses for a stereotypical agricultural unit, where average-sized farms compensate for labor and inputs at current market rates. We extend this standard farm representation to the national scale to determine the hectares per crop aligned with their corresponding NDC targets.

The average expenditure for these methods rises to an annual average of USD 4,196 per hectare in the absence of CSA and increases to an annual average of USD 4,546 per hectare when incorporating the CSA practices outlined in the table. Project costs are estimated on a yearly basis in millions of US dollars, with barley projects costing approximately USD 99 million, corn projects at USD 126 million, teff projects at roughly USD 113 million, and wheat projects at USD 73 million annually[71]. The total average annual cost of implementing CSA amounts to USD 103 million. Additionally, the table presents a comparison between conventional practices and CSA practices costs per hectare in USD. Conventional costs refer to the conventional methods employed in each sector, whereas upgraded costs reflect the expenses associated with adopting the CSA practices outlined in the NDC targets.

71 Projects are defined as labor and material costs required to fulfill the NDC production targets in hectares per year.

Table 12. CSA practices and costs estimate per sector

Sectors	Barley	Corn	Teff	Wheat
CSA practices	ISFM*; Agroforestry; Furrow irrigation	ISFM*; Agroforestry; Furrow irrigation	ISFM*; Agroforestry; Furrow irrigation	ISFM*; Agroforestry; Furrow irrigation
Costs estimates				
Costs per project** (USD millions)	99	126	113	73
Costs of conventional agricultural practices per hectare (USD)	4,069	5,213	4,614	2,886
Costs of CSA practices per hectare (USD)	4,390	5,571	5,011	3,213

*Source: Authors' calculations. *ISFM stands for Integrated Soil Fertility Management. **Defined as labor and material costs required to fulfill the NDC production targets in hectares per year.*

Table 13.Gross value added per worker per crop in CSA scenario

Crop	2022	Change in Y1	Change in Y10	2032	Percentual change Y1 vs Y10
Barley	11,349.08	22,229.68	25,964.76	13,950.91	17%
Corn	-2,340.15	1,623.93	3,406.35	-1,921.84	110%
Teff	-430.70	5,376.76	6,948.78	76.10	29%
Wheat	22,724.29	32,613.99	36,824.38	24,079.71	13%

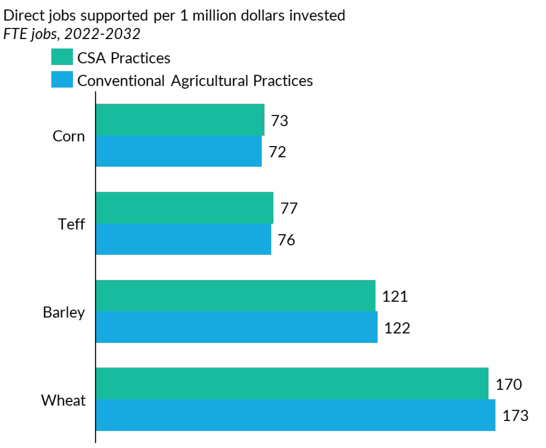
Source: Authors' calculations

Employment per USD 1 million invested

An internationally standardized metric involves assessing the total number of jobs generated per USD 1 million invested. In this context, Ethiopia's NDC strategy for wheat emerges as the most potent in terms of job creation, producing 170 jobs for every USD 1 million invested. Barley follows with the capacity to generate 121 jobs for the same investment amount. Teff ranks third with 77 jobs, while corn appears to offer comparatively fewer job opportunities among the four, providing 73 jobs per USD 1 million invested (Figure 16)[72]. On average, allocating USD 1 million to these sectors would result in supporting approximately 110 jobs. It is worth noting that, comparatively, both conventional and CSA practices yield similar results for employment per USD 1 million invested. This occurs because, despite CSA practices generating a higher overall number of jobs, the introduction of some of these practices increases production costs (see Komarek et al., 2019 for smart-agriculture cost estimates in Ethiopia).

In terms of international comparison within the African continent, a Faecal Sludge Treatment in Uganda demonstrated an employment intensity of 680 workers per USD 1 million invested (CEWAS, 2018). Moreover, a separate project in Uganda—involving a USD 1 million investment for supplying solar lanterns to fishers—is reported to have created 865 additional jobs in ice-making enterprises (Rockefeller Foundation, 2021). Additional references regarding job creation per USD 1 million invested were presented in the preceding section that focused on the outcomes for Colombia.

Figure 27. Direct jobs supported per 1 USD million

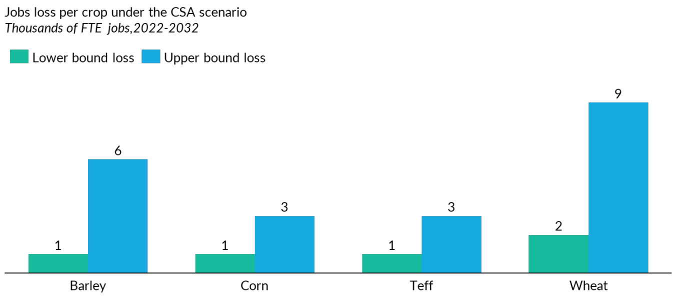


72 Refer to Annex 4 for the estimates on direct, indirect, and induced job creation per USD 1 million invested.

Impact of climate change on agricultural employment

The model also incorporates information from the Climate Vulnerability Monitor for Ethiopia to account for the impacts of climate change on labor productivity. These estimates result from accounting for the change in the percentage of total work hours lost at a heavy work intensity with no protection from the sun, corresponding to a metabolic rate of 400W. The calculated hours are subsequently extrapolated to FTE positions, assuming standard 8-hour workdays across a total of 250 days per full-time employment. The scenario encompasses the minimum and maximum anticipated reduction in productivity for Ethiopia, as forecasted by the Climate Vulnerability Monitor. This projection relies on policy measures designed to uphold global temperatures within the 2°C increase trajectory from 2021 to 2040. Based on the strategy proposed in this exercise and different scenarios, climate change would result in a loss of between 4,000 and 21,000 FTE jobs from the total job estimates of 642,100 (Figure 28).

Figure 28. Impact of climate change-related heat on labor productivity



Source: Authors' elaboration.

Identification of occupations and related skills

Despite Ethiopia's increased capacity to train highly skilled workers for the agricultural sector, the increasing demand for qualified agricultural professionals has intensified the human capital gap. Additionally, Ethiopia faces a skills gap when implementing CSA practices. Agricultural workers lack skills for CSA deployment, such as the use of techniques on water and soil conservation that consider climate change impacts, the use of new fertilizers and irrigation systems, knowledge in improved drought-resistance, heat-tolerant, and diseases-resistant crops, as well as the use of new applications of digital technologies for weather forecasting, accessing new markets, etc (FAO, 2016). Improving young people's access to education and training—including formal and informal on-the-job training—is needed to address this skills mismatch (FAO, 2014b).

The results of the skills requirements analysis—which focuses on the construction of occupations-skills matrices for selected occupations within the barley, corn, teff, and wheat sectors in Ethiopia—highlight the most prominent skills among high and low-skilled agricultural workers. These matrices are grounded in CEDEFOP skill labels and the ESCO taxonomy of occupations. Furthermore, skill-occupations groups have been identified and categorized according to four levels of educational requirements: managers, engineers, technicians, and non-professionals. The following paragraphs provide examples from these standalone analyses, highlighting the intricate structure of these occupation-skill dyads. The analysis is detailed in Annex 6.

Barley

The barley industry presents a diverse spectrum of skill requirements across various occupations, reflecting the multifaceted nature of the sector. These skills range from strategic expertise, essential for roles like farm manager, to the technical abilities demanded by positions such as agricultural engineer. Furthermore, a four-tier framework facilitates effective workforce planning and the design of targeted educational programs to meet the evolving needs of the barley industry.

- Management: Occupations like farm manager require strategic skills such as "promoting products, services, or programs" (11% of the total skills requirements for this occupation) to optimize crop production and land management.

- Engineers: In contrast, roles like agricultural engineer emphasize technical skills like "designing systems and products" (9%) and "using computer-aided design and drawing tools" (9%) to enhance agricultural machinery and systems.

- Technicians: Occupations such as agricultural technician and agricultural inspector demand skills related to "analyzing scientific and medical data" (11%), "evaluating systems, programs, equipment, and products" (6%), and "conducting academic or market research" (9%) to ensure crop quality and compliance.

- Non-professionals: On the hands-on side, positions like crop production workers and agronomic crop production team leaders focus on practical skills like "moving and lifting" (15%) and "tending plants and crops" (38%), which reflect the manual aspects of barley cultivation.

Corn

A unique blend of technological, managerial, and manual skills characterizes the corn industry in Ethiopia. This tiered system helps identify specific educational requirements, making it a valuable tool for informing targeted educational programs and workforce planning in this sector.

- Management: Occupations such as farm manager and agronomic crop production team leader are associated with skills like "promoting products, services, or programs" (11%) or "presenting general information" (6%).

- Engineers: Roles such as agricultural engineer require skills in technical design, the use of computer-aided design and drawing tools, and the development of efficient agricultural systems for corn production. An example of such skills is "conducting academic or market research" (9%).

- Technicians: Occupations such as agricultural technician and agricultural inspector focus on skills related to analyzing scientific and agricultural data, evaluating systems and equipment, and conducting research to enhance corn crop quality. One example of skills for agricultural inspectors is "monitoring safety or security" (15%).

- Non-professionals: Crop production workers and agronomic crop production team leaders engage in physical tasks such as planting, tending to corn crops, handling materials, and contributing to the practical aspects of corn cultivation. One example of such skills for mixed farmer occupations is "tending and breeding animals" (18%).

Teff

The teff sector's skills-occupations matrix reveals the distribution of various competencies within different teff-related roles. These skills encompass domains such as land and crop cultivation, safety procedures, research, and equipment operation.

- Management: Occupations such as farm manager and agronomic crop production team leader are associated with skills related to decision-making, strategic planning, and crop management, essential for successful teff cultivation. For example, "developing objectives and strategies" is a skill with a 3% association to the farm manager role.

- Engineers: Roles such as agricultural engineer require technical skills like "using computer-aided design and drawing tools" and "designing systems and products," both of which have a 9% association, highlighting their significance in enhancing teff farming processes.

- Technicians: Occupations like agricultural technician emphasize skills such as “analyzing scientific and medical data” (11%) and “conducting academic or market research” (9%), which are vital for ensuring teff crop quality and market competitiveness.

- Non-professionals: Crop production workers are engaged in physical tasks such as “moving and lifting” (15%), “tending plants and crops” (38%), and “cleaning” (6%). These hands-on skills are crucial for the practical aspects of teff cultivation.

Wheat

The wheat industry is characterized by a diverse range of skills, which are systematically categorized into a hierarchical, tiered framework. These skills encompass domains such as land and crop cultivation, safety procedures, research, and equipment operation.

- Management: Occupations such as farm manager and agronomic crop production team leader are associated with skills related to decision-making, strategic planning, and crop management. For example, “developing objectives and strategies” is a skill with a 3% association to the farm manager role.

- Engineers: Roles such as agricultural engineer require technical skills like “using computer-aided design and drawing tools” and “designing systems and products,” both of which have a 9% association. These skills are instrumental in optimizing wheat farming processes.

- Technicians: Occupations like agricultural technician emphasize skills such as “analyzing scientific and medical data” (11%) and “conducting academic or market research” (9%). These competencies are vital for ensuring the quality and competitiveness of wheat crops.

- Non-professionals: Crop production workers engage in physical tasks such as “moving and lifting” (15%), “tending plants and crops” (38%), and “cleaning” (6%). These hands-on skills are essential for the practical aspects of wheat cultivation.

Analyzing these four primary crops in Ethiopia through the lens of CEDEFOP-based skill labels and the ISCO framework provides a detailed insight into the intricacies of the job market. By pinpointing the precise relationships between occupations and skills and categorizing them into four educational tiers, it becomes feasible to create tailored strategies for workforce development that consider the distinct features and needs of each sector. This examination can serve as a guide for policymakers, educators, and industry stakeholders, enabling them to cultivate a workforce that harmonizes with the ever-changing requirements of Ethiopia’s agricultural industries.

6 Discussion

The research assessing the job creation potential of Colombia's and Ethiopia's NDC targets has unveiled significant opportunities for employment growth in both countries' agricultural sectors. Specifically, the implementation of the CSA initiatives outlined in their NDCs has the potential to create a substantial number of jobs, and governments in Colombia and Ethiopia should prioritize them. In the case of Colombia, the NDCs focus on CSA practices across various sectors, including cocoa, forestry, rice, and panela sugar production. In Ethiopia, the NDCs are designed to enhance food security by improving agricultural productivity in a climate-smart manner, including the production of barley, corn, teff, and wheat. In both countries, the CSA approaches consistently outperform BAU practices in terms of job creation across all crops.

Policy recommendations

The following policy recommendations aim to support the creation and maintenance of employment opportunities in the agricultural sector, with an emphasis on employment creation through the deployment of CSA practices. They aim to facilitate the operationalization of initiatives that further link and accelerate the achievement of climate targets and sectoral development strategies related to scaling up CSA practices. These recommendations are related to the findings of the research regarding climate policies driving CSA, education, employment quality, and the financing of CSA. They are divided into five objectives: 1. Bridge the gap between national and local level climate targets and agricultural development strategies, 2. Improve human capital skills and knowledge for the agricultural sector to allow the deployment of CSA agricultural practices 3. Increase employment quantity and quality in the agricultural sector linked to implementing CSA practices, 4. Unleash the potential of the women's labor force in the agricultural sector, and 5. Finance CSA practices at scale. Country-specific recommendations are provided based on existing examples of ongoing efforts that support the recommendation.

7.1 Colombia

1. Bridge the gap between national and local level climate targets and agricultural development strategies to accelerate the implementation of CSA practices.

1.1 Ensure the implementation of coordinated climate and agricultural development policies locally through greater involvement of local governments, rural communities, and inter-ministerial coordination.

National and regional coordination of agricultural development and climate policies is a cornerstone for identifying the most promising CSA practices, implementing related adaptation and mitigation responses, and enabling the deployment of CSA practices at scale. Colombia's Ministry of Agriculture and Rural Development (MADR) and National Planning Department (DNP) have continuously worked on integrating climate change into sectoral policies (Howland, F. et al., 2018). Moreover, Colombia has intensified its efforts to implement planning instruments for rural development that align national plans with local interests. However, no significant level of implementation or territorialization of these instruments has been observed to date (Sabourin, E. et al., 2019). Stakeholders agree that a coordination problem exists between national and territorial levels, which affects the quality of plans and lacks an integrated vision of development. For example, the effectiveness of the SISCLIMA—a tool for articulating climate change-related issues with sectoral bodies at the national and territorial levels that support CSA projects—is deemed ineffective so far by key stakeholders (OECD, 2022). Similarly, the National Climate Change Policy (NCCP) coordinates the creation of the Integrated Climate Change Management Plan (ICCMP) at both sectoral and territorial levels. For the agricultural sector, this is the mitigation and adaptation plan. FAO supports the adaptation component of this plan. At the territorial level, plans at different scales coexist (regional, departmental, municipal, and ecosystem). Some integrate the issue of adaptation and mitigation, and others only integrate the adaptation aspect. The DNP coordinates the sectors at the national level while the MADR coordinates at the territorial level (Sabourin, E. et. al., 2019). International organizations note that climate change management is mostly controlled at the national level, leaving local authorities with limited management and implementation authority (Howland, F. et al., 2018).

2. Improve human capital skills to allow the deployment of CSA agricultural practices.

2.1 Improve human capital capacities—skills and knowledge—at the territorial level to increase deployment of CSA practices whilst preserving and blending them with the use of TTT that are resilient to climate change.

Colombia has encountered a few notable barriers when implementing climate change initiatives, such as a lack of local capabilities, limited access to climate information, and a lack of ownership of initiatives at the territorial level. In addition to the lack of skills needed to implement CSA initiatives, the low levels of engagement with local farmers, their lack of knowledge, and the underutilization of agroecological approaches promoting conventional practices are considered primary barriers (Altieri et al., 2015). For CSA deployment, enabling and fostering social learning is fundamental, given the complexity of the topic and the unpredictable evolution of climate change's impacts on farming systems and local communities (FAO, 2013). The Colombian government strengthens local communities' involvement in land use management as a solution. For example, the UNDP-FAO support programme for "Scaling up Climate Ambition on Land Use and Agriculture through NDCs and NAPs" (SCALA Colombia) aims to support the development, articulation, and coordination of concrete strategies and actions towards a transformational change in the agricultural and land use sectors. Among other objectives, SCALA aims to recover and implement TTTs for adapting to climate change, while generating skills in adaptation for the agricultural sector related to loss and damage (L&D), management, reporting, and verification, as well as gender inclusion. Efforts to better prepare human capital—needed at the territorial level to implement CSA practices while preserving and blending them with the use of TTT—are essential to ensuring the sustainable transformation of the agricultural sector.

2.2. Ensure the identification and development of necessary technical skills for implementing CSA practices at the national level and their linkage with skills relevant to the 4th industrial revolution, such as digitalization.

Due to the uncertain and dynamic nature of climate change impacts, a transition towards CSA requires socio-institutional learning processes with a strategic approach to skills development for CSA at the country level, including strong engagement of national and local formal and informal education and training institutions (FAO, 2013). However, countries generally fail to establish strong connections between their environmental sustainability and skills development policies (Kizu et al., 2018). Challenges such as evolving green skills, undefined green job criteria, insufficient labor market data, and the need for stakeholder coordination hinder policymakers' efforts to align economy-wide skills policies to their climate sustainability strategies. Overcoming these challenges is crucial, as a green transition cannot occur without green jobs. In Colombia's job diagnostics, Casas et al. (2018) highlight the need to harmonize job training initiatives with the skills sought by employers and the current skill set of workers. The expansion of programs and coverage by Colombia's public training ecosystem must improve in terms of coordination and quality, resulting in the provision of more relevant educational courses in rural centers with updated curricula. Moreover, the country needs to better align the academic offer with the needs of rural economies and clarify communication and coordination for educational strategies to use digitalization as a partner in education provision.

2.3 Increase access to quality education at the territorial level and include CSA and related topics in the education curricula of rural schools from a basic level of education.

Low educational attainment in Colombian rural areas is a key driver of low labor productivity in the agricultural sector. Infrastructural barriers (e.g., underequipped schools), a lack of transport, and violence contribute to lower access to education in rural areas and hamper the attraction and retention of skilled service professionals. National plans to improve educational services and delivery in rural areas exist, but they need to be accelerated through sufficient financial and human capacity and a more comprehensive approach. Despite the existance of official programs that seek to improve access to education (e.g., the Special Plan for Rural Education [PEER] or Todos an aprender program), education policies and initiatives have relevant areas that are in need of improvement. The focus on education strategies and policies in rural areas is still limited, partly due to the centralization of decision-making, the weak alignment with local contexts, and the low involvement of local actors in policy design and implementation. In addition to the previously mentioned issues, there is no integration of CSA into the formal or vocational curriculum in Agronomy in Colombia; further reducing the rural sector's capacity to adapt to the new demands of the global environment and improve agricultural productivity in a sustainable way (Núñez-Rodríguez, Medina-Cruz & Jaimes (2024).

2.4 Leverage research and technology transfer so that human capital can access new knowledge and share its own to improve production systems through CSA with a focus on sustainability and management of climate change impacts.

Leveraging research and technology transfer is critical to empowering human capital to access innovative knowledge and share localized expertise, thereby fostering a dynamic cycle of learning that enhances agricultural production systems. The knowledge-sharing process creates diverse employment opportunities—from tech-driven roles in data analysis of farming systems to community-based positions in knowledge management for sustainable agribusiness and ecosystem restoration. The agrarian extension agent plays a central role in this knowledge transfer effort, providing a holistic understanding that bridges the gaps between research institutions and rural producers. These agents provide tailored guidance, helping farmers navigate transitions to CSA practices, adopt resource-efficient technologies, and access markets for climate-resilient goods. Their support ensures knowledge is contextualized, reducing risks for producers and fostering trust in innovation. As Colombia's agricultural sector shifts toward sustainability, this synergy between research, technology, and extension services stimulates job growth in rural areas, empowers youth and women through skill development, and strengthens value chains—positioning agriculture as a driver of inclusive economic growth and climate adaptation.

3. Increase employment quantity and quality in the agricultural sector linked to implementing CSA practices.

3.1 Accelerate the implementation of CSA practices as a way to increase agricultural productivity, better integrate agro-processing value chains, and increase attractive employment opportunities at the territorial level, which, as a result, will help retain well-prepared professionals in rural areas.

Despite the limited availability of stable and well-paying jobs in urban areas, the migration of Colombian workers from rural to urban settings is rising (Carranza et. al., 2022b). This is partially due to the lack of access to better educational services in urban areas, the urban-rural differences in expected earnings and the higher quality of jobs. For example, in 2019, only 7.6% of the working-age population in rural areas had a formal waged job, compared to 24% in urban areas. In addition, median workers in rural areas earned only about half the hourly income of median workers in urban areas, and earnings premiums were smaller in rural areas at all levels of education (Carranza et. al., 2022c). Productivity in rural areas must improve to curb the incentives that draw rural workers to urban areas in search of better opportunities. The use of CSA can improve agricultural productivity. Moreover, it can help better integrate agro-processing value chains. Therefore, increasing the use of CSA practices can result in human capital retention in the agricultural sector.

3.2 Increase visibility of employment opportunities linked to CSA adoption and promote labor mobility for agricultural workers through existing labor programs.

In order to increase employment opportunities for agricultural skill development in Colombia, it is crucial to enhance and broaden the reach of the relatively young Public Employment Service (SPE in Spanish), established in 2013. According to Carranza et. al. (2022), despite its national coverage, the service's concentration in urban areas limits access for job seekers based in rural regions. Additionally, promoting domestic labor mobility between rural areas could help agricultural workers relocate to other regions, thereby reducing unemployment during periods of reduced activity for specific crops. Labor mobility programs could include relocation and general job search subsidies within Colombia's MPC program (Mecanimos de Protección al Cesante in Spanish)[73]. The promotion of domestic mobility could also foster skill transferability within and across various occupations, helping reduce skills gaps in other industries beyond agriculture[74]. Moreover, new labor mobility trends—such as the Neocampesino[75] movement in Colombia—could help address specific skill gaps in the agricultural sector, including the adoption of digital technologies.

4.Unleash the potential of the women's labor force in the agricultural sector.

4.1 Enhance support for women entrepreneurs by increasing access to training, information, credits, and essential agricultural inputs.

In Colombia's rural areas, women lack access to financial products and education to build their businesses. International development agencies collaborate with local banks and governments to increase the provision of credit lines to support rural women, provide business and leadership training, and help more Colombian organizations incorporate gender policies into their operations. Examples of such projects include USAID, Microempresas de Colombia, UNI2 Microcrédito, Rural Microcredit Fund, etc. Entrepreneurship and access to finance projects directed towards women in agriculture could be enhanced by increasing the participation of private financial institutions in rural areas, providing agricultural insurance to support risk management along with credit lines, developing credit products that address (1) the lack of assets used as collateral, and (2) the limited credit history, and improving financial education of the rural women population. (Gutiérrez Eva, et. al. 2015).

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73 For Colombia, Barrera-Osorio et al. (2023) found that transportation and food subsidies increase the effectiveness of vocational training programs in terms of skills and labor-market outcomes.

74 This notion of the benefits of skills transferability among occupations is congruent with out own findings for Colombia's and Ethiopia's agricultural occupations, where there are significant overlaps of skills across different occupations.

75 Urban population who moves to rural areas.

4.2 Utilize new jobs created by CSA to reduce education gender gaps in the agricultural sector.

Although rural households in general face constraints in accessing quality education and formal credit, women encounter even greater challenges. Enhancing educational attainment and facilitating access to quality information and technical support can empower women to generate income, amass capital, and enhance their influence over household resource allocation (Pirela, R. et. al., 2022). Thus, Colombia could benefit from scaling-up capacity-building interventions provided by some development agencies on technical and financial education for women at the tertiary level should be scaled up.

5. Finance CSA at scale.

5.1 Accelerate efforts to develop an integral risk management strategy to increase the provision of agriculture insurance, resulting in increased access to finance the deployment of CSA practices, particularly for small- and medium-scale farmers.

CSA initiatives in Colombia are financed by multiple sources. National financial resources for CSA are received through government programs led by the Ministry of Environment and Sustainable Development (MADS), the Ministry of Agriculture and Rural Development (MADR), and national development banks such as the Fund for Agricultural Financing (FINAGRO), the Agricultural Bank (BANAGRARIO), the Business Development Bank (BANCOLDEX). In addition, Colombia benefits from international financial sources for CSA deployment, including bilateral programs from international partners such as the UK-DECC, UN Agency Programs (REDD and certain carbon markets), non-profit organizations, and multilateral institutions. Moreover, the private sector also finances CSA activities through cooperatives and informal credits (World Bank, 2014). Despite the high availability of financial support for agricultural development in Colombia, agricultural insurance is limited. Agricultural insurance can support CSA deployment by reducing small and semi-commercial farmers' risk aversion to investing in new technologies, and it can help improve access to formal agricultural credit, enabling farmers to purchase improved seeds and fertilizers and raising productivity and incomes (GIZ, 2022). Through an integral agricultural risk management strategy, Colombia could increase the demand and supply of agricultural insurance, overcoming the current market barriers—such as information asymmetries and high transactions—therefore improving the enabling environment for financing CSA practices (García Romero, H., & Molina, A. , 2015).

5.2 Scale up the utilization of payments for ecosystem services (PES) to finance CSA agroforestry and plantation management activities.

Since 2007, public and private environmental institutions, both at national and international levels, have collaborated on crafting a national strategy for Payment for Ecosystem Services (PES) in Colombia. This strategy seeks to integrate PES as a means to fulfill the goals of environmental policies and foster their alignment with current technical, economic, and legal frameworks. Despite these efforts, Colombia has yet to adopt the PES approach widely. Expanding PES initiatives and transforming them into established financial mechanisms capable of ensuring long-term sustainability is beneficial for supporting the deployment of CSA practices (CBD, n.a.).

7.2 Ethiopia

6. Bridge the gap between national and local level climate targets and agricultural development strategies to accelerate the implementation of CSA practices.

6.1 Recognize and address trade-offs between agricultural and climate policies in targets that might lead to future unintended consequences.

While Ethiopia's policies demonstrate considerable integration, conflicts between policy objectives could impede progress toward overarching national development goals—notably, efforts to enhance agricultural production clash with environmental objectives and commitments. For example, Sentinel (2022) explains that the primary strategies for increasing agricultural production in Ethiopia include enhancing the agricultural extension system, expanding irrigation, promoting the use of fertilizers and improved seeds, addressing land degradation, establishing agricultural commercialization clusters (ACCs) and farmers' production clusters (FPCs), and improving land tenure security through certification. While the traditional economic development approach outlined in the Climate Resilient Green Economy Strategy (2011) could theoretically meet the government's production goals, it would require extensive land expansion, potentially leading to deforestation, soil erosion, and increased greenhouse gas emissions. Recognizing the limitations of expansion alone, the national policy emphasizes that sustainable intensification should be the key strategy for boosting overall production, with support from forestry and environmental policies promoting CSA. However, there is a concern that intensification might inadvertently stimulate further land expansion—a phenomenon known as the rebound effect or Jevon's paradox—which is not addressed in current policy documents.[76]

7. Improve human capital skills to allow the deployment of CSA agricultural practices.

7.1Improve technical and vocational skills for the agricultural sector at the national level through apprenticeship opportunities.

In Ethiopia, the main institutional body for Technical and Vocational Education and Training (TVET) is governed by the Ministry of Education (MoE). Past assessments have deemed Ethiopia's competencies-based TVET system as lacking pertinence and quality, with high rates of instructor turnover and student dissatisfaction (Melesse et al., 2022; Yamada & Otchia, 2021; Allais, 2020; Woldetsadik & Lumadi, 2015; Abuel-Ealer, 2012). According to Melesse et al. (2022), Public-Private Partnerships (PPPs) improve TVET performance by

76 Sentinel Ethiopia Policy Disconnects briefing.pdf (sentinel-gcrf.org)

gearing curriculum development toward the actual needs and interests of partnered industries, enabling students to have hands-on experience with modern equipment, and adapting teacher-student relationships to local contexts. Along similar lines, apprenticeship programs can provide learning and income simultaneously, and have shown positive effects on both workers and businesses. Studies for developed countries show that one of the main benefits of apprenticeship programs is easing the transition from school to work, which can translate into a greater likelihood of finding a job in the future. These results also include a lower probability of unemployment and a shorter duration of unemployment. Apprentices also achieve higher pay increases compared to unskilled workers. The evidence for developing countries shows positive results in the short term (Attanasio et al., 2011; Card et al., 2011; Ibarrarán and Rosas, 2009), but the measurement of medium- and long-term results remains scarce (Fazio, Fernandez-Coto, and Ripani, 2016; Novella and Perez-Davila, 2017).

7.2 Improve the quality and availability of labor data in the agricultural sector to facilitate accurate skills assessment in the country.

Along with country-specific recommendations for skills development, the creation of labor market observatories that integrate various data sources is generally advised in skills assessment and anticipation literature (OECD, 2023; Carranza et al., 2022). One example of this is the real-time availability of detailed occupational data on specific skill requirements through job listings on job websites[77]. The capacity to derive labor-related metrics from high-frequency, large-scale data is vital for predicting shifts in job types and skills sought by businesses (Deming & Kahn, 2018). The presence of fresh data on labor demand within specific sectors can yield valuable insights into matters affecting jobs in the agricultural sector. Particularly, these forms of big data can assist Public Employment Services (PES) in providing personalized career orientation services to workers, and training prognostics to training institutions. In this regard, the OECD (2023) presents five cases in which big data and machine learning approaches are helping countries anticipate green skills demands.

8. Increase employment quantity and quality in the agricultural sector linked to implementing CSA practices.

8.1 Enhance the adoption of certifications to ensure the adoption of CSA practices along the agrifood value chain.

Policies that support CSA agriculture must also consider the different activities of the agrifood value chain (i.e., sourcing, production, and retailing). In this regard, Ethiopia can utilize existing market-based mechanisms such as certification schemes (e.g., Fair Trade protocols) to actualize its commitment to CSA agriculture. The adoption of certification reduces the likelihood of using practices that contribute to climate change (Akrong et al. 2023). The challenges associated with these sourcing strategies, however, have not been thoroughly examined. For these tasks, policies should prioritize mainstreaming ethical considerations at the end of the supply chain, including raising consumer awareness about the impact of CSA practices on soil conservation and economic development within producer communities.

8.2 Incorporate robust monitoring and evaluation mechanisms to review and proactively address the progress of identified issues.

Collaborative efforts among the government, agricultural organizations, and local communities are crucial to the successful adoption of CSA agriculture practices. In this context, agricultural planning authorities should reevaluate the role of their national top-down strategies to ensure optimal adaptation to local conditions rather than focusing solely on the best-performing regions or crops (e.g., Nikinake in Ethiopia, as discussed in Leta et al. 2018). These planning efforts should incorporate robust monitoring and evaluation mechanisms to review and proactively address the progress of identified issues. This suggestion aligns with the continual revision of the NDCs and National Adaptation Plans (NAPs), promoting a more agile and responsive strategy toward agricultural planning within the context of climate change.

9. Unleash the potential of the women's labor force in the agricultural sector.

9.1 Strengthen Ethiopia's gender budgeting initiatives by incorporating gender-focused goals into budgeting instruments and promoting gender balance in development programs —especially agriculture—to enhance agricultural production and sustainable food security.

9.2 Improve land tenure and resource rights for women.

Small farmers have not widely adopted CSA because of key barriers, including insecure land tenure and resource rights. This is because some (but not all) CSA practices involve significant initial investments tied to the land itself (e.g., establishing tassa planting pits, water diversion ditches, land terraces, or improved grass and fodder and fruit trees, and building fences to improve grazing land to support livestock production) (USAID, 2015). As a result, the extent to which CSA benefits have been realized and rural development outcomes improved is limited (FAO, 2013). Ensuring women's access to and control over land is paramount to addressing this issue. Ethiopia could replicate some successful interventions to promote land ownership among women, drawing on CSA practices from other countries. For example, focusing on marginalized women in Senegal, the Yaajeende conservation agriculture program, backed by USAID, collaborated with local communities to assign degraded and neglected land to women. These women undergo training and receive extension services to rehabilitate the land, rendering it fertile again. This initiative enhanced women's rights and equipped them with skills in conservation agriculture, enabling them to combat erosion through techniques such as cultivating low-maintenance, nutrient-rich crops and practicing crop rotation. Consequently, women are empowered to enhance land productivity and bolster resilience. (USAID, 2013).

77 Unconventional data does not replace official surveys but complements them, often providing the statistical strength to analyze real-time matters concerning skill supply and labor demand (Altamirano & Amaral, 2020).

Moreover, addressing land rights among women in the agricultural sector could lead to numerous additional advantages, such as reduced violence and abuse, increased income, savings, financial access, and enhanced participation in decision-making, all of which positively impact their children's education and health.

10. Finance CSA at scale.

10.1 Increase awareness of micro, small, and medium-sized farms about agricultural value chain finance (AVCF) opportunities linked to the use of climate-smart solutions.

New products to finance the adoption of CSA are being piloted in Ethiopia. For example, Africa Climate Risk Enterprise Ltd (ACRE) developed an insurance product that covers the entire value chain, including labor risks. Even so, Ethiopia's agricultural stakeholders' awareness of innovative applications of diverse models and tools for agricultural value chain finance opportunities (AVCF) linked to the use of CSA should be increased.

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Annexes

Annex 1 : Definitions

Green jobs

The study uses the policy definition of green jobs developed by the International Labour Organization (ILO) Green Jobs Programme (GJP).

"Green jobs are decent jobs that contribute to preserve or restore the environment, be they in traditional sectors such as manufacturing and construction, or in new, emerging green sectors such as renewable energy and energy efficiency.

Green jobs help:

a) Improve energy and raw materials efficiency,

b) Limit greenhouse gas emissions,

c) Minimize waste and pollution,

d) Protect and restore ecosystems,

e) Support adaptation to the effects of climate change.

At the enterprise level, green jobs can produce goods or provide services that benefit the environment, for example, green buildings or clean transportation. However, these green outputs (products and services) are not always based on green production processes and technologies. Therefore, green jobs can also be distinguished by their contribution to more environmentally friendly processes. For example, green jobs can reduce water consumption or improve recycling systems. Yet, green jobs defined through production processes do not necessarily produce environmental goods or services" (ILO 2016)[78].

This ILO-GJP definition emphasizes the difference between employment in producing environmental outputs and employment in environmental processes. Moreover, the ILO-GJP definition of green jobs includes only employment in environmental activities that fulfil decent work conditions[79]. Decent work conditions are measured using ten broad indicators established by the ILO (ILO, 2004).

The study recognizes that due to the broad definition of green jobs, individual countries must determine their own definition, potentially considering the environmental performance levels of each economic activity. Equally, each country must set its own targets for assessing decent work based on its current social and economic conditions, in compliance with the basic criteria of the ILO on decent jobs.

Green jobs definition in Colombia

The National Administrative Department of Statistics of Colombia (DANE) uses the ILO's green jobs definition. Therefore, Colombia's official green jobs estimation also measures two dimensions (DANE, 2022).

- Social Dimension: Follows ILO's definition of decent jobs.
- Environmental Dimension: This is based on the methodology of the System of Environmental and Economic Accounts (SCAE) from the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and the System of Environmental-Economic Accounting (Oleas-Montalvo, 2013; DANE, 2012). It recognizes as environmental activities those dedicated to environmental protection and resource management. For example, sustainable, productive activities that contribute to food security. It excludes those linked to the use of natural resources or the reduction of natural risks.

Green jobs definition in Ethiopia

Even though the Central Statistical Agency of Ethiopia has not officially adopted a green jobs definition to be used in a country-specific context, multiple national projects use the ILO definition of green jobs. For instance, the Engagement of Rural Young People in Tree-based Value Chains—a project in Southwest Ethiopia conducted by the Center for International Forestry Research (CIFOR) and the World Agroforestry (ICRAF)—adopts the term and applies it to the creation of green jobs for youth and women (Getahun, 2022a). Furthermore, the term is used in relation to the Green Legacy Initiative (GLI), which aims to plant trees in the country and has directly created 767,000 green jobs in the past four years, according to the Prime Minister Office release on 15 August 2022 (Getahun, 2022b). In Ethiopia's National Forest Sector Development Program (NFSDP)—a country-driven initiative used as the main guiding document for coordinating strategic policy interventions—it is stated that one of the emerging opportunities for forest sector development is the creation of green jobs, as defined by the ILO (Ethiopia, 2022).

Green jobs in the agriculture and forestry sector

The study considers green jobs in agriculture as those direct jobs producing agriculture, livestock, or forestry products using CSA practices. It considers direct jobs working in the following areas or using specific technologies related to them: soil conservation, water efficiency, organic growing methods, reducing farm-to-market distance, reforestation and afforestation, agroforestry, sustainable forestry management, and halting deforestation. (Jarvis et al., 2011).

78 ILO. (2023). Green jobs, green economy, just transition and related concepts: A review of definitions developed through intergovernmental processes and international organizations. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_883704.pdf.

79 The ILO defines decent work as "productive work for women and men in conditions of freedom, equity, security, and human dignity". Available at https://www.ilo.org/global/topics/decent-work/lang--en/index.htm

Informal employment

The study uses the statistical definition of informal employment endorsed by the Seventeenth International Conference of Labour Statisticians: "Employees are considered to have informal jobs if their employment relationship is, in law or practice, not subject to labor legislation, income taxation, social protection or entitlement to certain employment benefits (advance notice of dismissal, severances of pay, paid annual or sick leave, etc.)" (ILO, 2004)[80].

The study considers both classifications of informal employment defined by the ILO:

- Informal self-employment – this includes self-employment in informal enterprises, own-account workers in informal enterprises, unpaid family workers, and members of informal producers' cooperatives; and
- Informal wage employment – this includes employees without formal contracts, worker benefits or social protection, who are employed either in formal or informal enterprises.

Annex 2: Description of CSA practices assessed

Conservation agriculture

Conservation Agriculture (CA) is a farming system that can prevent losses of arable land while regenerating degraded lands. It promotes the maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency and to improved and sustained crop production.

https://www.fao.org/conservation-agriculture/overview/what-is-conservation-agriculture/en/

Risk management of crop and income loss

Crop insurance

Crop insurances are purchased by agricultural producers to protect their crops, either against loss due to natural disasters or the loss of revenue due to declines in the prices of agricultural commodities. The most common types of insurance are multiple-peril crop insurance (MPCI) and crop-hail insurance.

https://www.iii.org/article/understanding-crop-insurance

Income diversification

Income diversification is a potential strategy for risk management, food security, and welfare improvement, especially for rural households. Most rural smallholder farmers are highly dependent on agriculture-related activities for their livelihood and therefore are subject to different types of risks like drought, scarcity of irrigation water, non-availability of other income sources, etc.. Income diversification is a valuable strategy to cope with weather shocks and reduce the impact of weather disasters. https://www.researchgate.net/publication/335444046_The_Role_of_Income_Diversification_on_Risk_Management_and_Rural_Household_Food_Security_in_Ethiopia

Improve access to credit

Strengthening supportive institutions that can provide credit access to farmers has the potential to create financial capacities for their households to purchase agricultural inputs and other expenses.

https://agricultureandfoodsecurity.biomedcentral.com/articles/10.1186/s40066-022-00358-5#citeas

Strengthen household capacity (time allocation)

To promote smallholders' market participation and enhance farmers' livelihoods, strategies should aim at improving household capacity to produce surplus through optimal allocation of resources such as land, oxen, and time for non-farm activities. Haile, K., Gebre, E. & Workye, A. Determinants of market participation among smallholder farmers in Southwest Ethiopia: double-hurdle model approach. Agric & Food Secur 11, 18 (2022). https://agricultureandfoodsecurity.biomedcentral.com/articles/10.1186/s40066-022-00358-5#citeas

Educational campaigns and training acquisition

Through the implementation of educational campaigns and the assistance of smallholder farmers to acquire training, households can be better educated in terms of how to manage risks and diversify their livelihood from agricultural production. The level of education shows a positive influence on the decision to participate more in the market.

https://doi.org/10.1080/23311886.2019.1664193

Soil Conservation (Management of soil nutrients)

Natural fertilizers

Natural fertilizers include farmyard manure, compost, green manure, biofertilizers, and oil cakes. Farmyard manure usually includes a mixture of cattle dung, litter or bedding material, urine, a portion of fodder not consumed by cattle, and domestic wastes like ashes, etc. Compost can be defined as the rotting

80 https://www.ilo.org/public/english/bureau/stat/download/articles/2004-1.pdf

of animal and plant residues. Green manure crops are grown in the field itself, either as an intercrop or as a pure crop with the main crop buried in the same field before flowering. Biofertilizers contain nitrogen-fixing biological organisms that are of utmost importance in agriculture. Oil cakes are prepared from oilseeds. After the extraction of oil from them, the pulp is dried and used as a source of manure.

https://www.farmpractices.com/types-of-natural-fertilizers

Conservation tillage

At least 20% to 30% of the soil surface is covered in the previous year's crop residue after planting. The residue reduces wind velocity at the soil surface and breaks the impact of raindrops. Root systems hold the soil in place. If practiced across a slope, rows of stubble act as small dams to slow water as it runs downhill. Aside from erosion control, the other advantages of conservation tillage are increased water infiltration, a greater addition of organic matter to the soil, and savings of fuel and time for the farmer. Conservation tillage also enhances wildlife habitat for soil organisms, birds, and small animals like field mice and snakes.

https://www.johnstonnc.com/swc/content.cfm?pageid=wisc

No-till farming

No-till farming, also called zero tillage, is a way of growing crops or pastures from year to year without disturbing the soil through tillage. In zero tillage, crops are planted with minimum disturbance to the soil by planting the seeds in an unplowed field with no other land preparation. A typical zero-tillage machine is a heavy implement that can sow seed in slits 2–3 cm wide and 4–7 cm deep and also apply fertilizer in one operation.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Minimum tillage

Minimum tillage could be either strip tillage, which involves tilling the soil only in narrow strips with the rest of the field left untilled, or ridge tillage, which implies planting seeds in the valleys between carefully molded ridges of soil while the previous crop's residue is cleared off ridge-tops into adjacent furrows to make way for the new crop, or mulch-till, where residue is partially incorporated using chisels, sweeps, field cultivators or similar farming implements that leaves at least one-third of the soil surface covered with crop residue.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Contour farming

Contour farming involves tilling and planting along the contour, rather than up and down the slope. The furrows and rows of plants act as dams, which slow down the flow of water moving down the slope. Unless some type of contour farming is used, particularly on long slopes, serious field erosion can result. This CSA practice uses less fuel and power for tractors than others.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Intercropping

Intercropping is the practice of growing two or more crops on a piece of land. It requires careful planning, considering the soil, climate, crops, and varieties to ensure that crops do not compete with each other for physical space, nutrients, water, and sunlight.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Mixed intercropping

Mixed intercropping is the most basic form in which the component crops are mixed in the available space.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Row/Strip cropping

In row cropping, component crops are arranged in alternate rows. Variations include alley cropping, where crops are grown between rows of trees, and strip cropping, where multiple rows, or a strip, of one crop are alternated with multiple rows of another crop. Strip cropping involves alternating strips of small grain (e.g., rye) or forage crops (e.g., clover) with row crops like corn. It is used to control erosion by reducing the velocity of wind and water. The forage and cereal grain rows tend to trap sediment that may otherwise end up in watercourses.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Relay cropping

Relay cropping implies temporal separation; the second crop is sown during the growth of the first crop, often near the onset of reproductive development or fruiting, so that the first crop is harvested to make room for the full development of the second.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Windbreak or shelterbelt

Windbreaks are structures that break the wind flow and reduce wind speed. Shelterbelts are rows of trees or shrubs planted for the protection of crops against wind. Both provide a protective shelter against wind and possibly provide a suitable habitat for birds and honeybees. They prevent soil and wind erosion.

http://agropedia.iitk.ac.in/content/windbreaks-and-shelterbelts

Crop Rotation

Crop Rotation is an alternative to planting a field of the same crop, year after year (referred to as continuous mono-shelterbelts culture cropping). Instead, the main crop is rotated, ideally with cereal crops like winter wheat or forages such as clover and alfalfa.

Crop rotation provides several benefits. Rotation reduces the risk of insect and disease problems, thus decreasing pesticide dependency. Because the crop is changed each year, pests do not have enough time to become established in damaging numbers.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Straw incorporated

Straw incorporation is a common practice implemented to improve the soil fertility of rice paddies and increase rice yield. The global meta-analysis showed that straw incorporation increased the soil organic matter by 12.8%, total N by 11.1%, available P by 12.2%, and available K by 13.0%.

https://www.sciencedirect.com/science/article/pii/S2214514121000052#b0070

Transplanting of teff

Replacing planting methods like the broadcast method with row and transplanting methods, combined with optimized seeding densities and row spacing, shows potential to improve grain yield in Ethiopia.

https://acsess.onlinelibrary.wiley.com/doi/epdf/10.1002/agj2.20462

Cover crops

Cover crops can be broadly defined as any non-cash crop grown in addition to the primary cash crop. These crops are planted to increase soil organic matter and fertility, reduce erosion, improve soil structure, promote water infiltration, and limit pest and disease outbreaks. In many situations, cover cropping can lead to a decreased reliance on fossil fuels and improved agricultural productivity.

https://sarep.ucdavis.edu/sustainable-ag/cover-crops

Biopesticides

The intensive use of conventional pesticides over a long period causes pollution, biodiversity loss, the insurgence of secondary pests, and the elimination of natural/beneficial enemies. However, biopesticides and botanical pesticides can promote economic productivity and provide considerable advantages, like effective control of different species of agricultural pests, and are promising for use in sustainable agriculture. https://www.frontiersin.org/articles/10.3389/fsufs.2021.619058/full ; https://www.sciencedirect.com/science/article/abs/pii/S1470160X18302917

Natural fungicides

Sustainable types of fungicides can include new-generation fungicides, which are highly efficient even at low doses, natural and botanical fungicides, which are less toxic, stable, easily degradable, and maintain spoil properties, and are safe for the environment and humans. https://link.springer.com/chapter/10.1007/978-981-15-6275-4_11 ; https://link.springer.com/chapter/10.1007/978-981-15-3024-1_9; https://www.researchgate.net/publication/351283674_BOTANICAL_FUNGICIDES_CURRENT_STATUS_FUNGICIDAL_PROPERTIES_AND_CHALLENGES_FOR_WIDE_SCALE_ADOPTION_A_REVIEW

Biofumigation

Sustainable alternatives to chemical soil fumigants, like biofumigation, steam, solarization, and anaerobic soil disinfestation (ASD) using rice bran or mustard seed meal, resulting in better yields and outcompete conventional management. Typical synthetic fumigation content, like nematicide methyl bromide (MBr), poses risks to the environment and human health. Biofumigation, using plant material and naturally produced compounds to control pests, has been shown to be an increasingly feasible method of pest management. https://vegetableswest.com/2021/05/18/effective-non-chemical-soil-fumigants-for-organic-production/ ; https://www.sciencedirect.com/science/article/pii/S2095311919628170

Micro-dosing

Micro-dosing consistently increases yields. The practice includes seed coating and small packets. However, micro-dosing is time-consuming, laborious, and expensive.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Improved irrigation and water management

Sustainable irrigation needs to ensure that (1) water stocks (e.g., aquifers, rivers, or lakes) are not depleted by keeping withdrawal rates lower than those of natural replenishment; (2) withdrawals from water bodies do not lead to losses of aquatic habitat and irreversible ecosystem degradation; and (3) irrigation does not cause other forms of environmental damage (e.g., soil salinization) with associated losses of ecosystem services and functions, here collectively referred to as “natural capital” (e.g., de Perthuis and Jouvet, 2015).

Alternate wet and dry irrigation of rice (AWDI)

Alternate wet and dry irrigation of rice (AWDI) implies that rice fields are not kept continuously submerged but are intermittently dried during the rice growing stage. It is a potential method to reduce methane emissions (when rice fields are dried, oxygen becomes available in the root zone, and this reduces methane emissions).

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Intermittently flooded vs Continuously flooded

Intermittent flooding (IF) of rice has been encouraged as an approach to reduce water use and methane emissions compared with continuous flooding (CF). Conversion from CF to IF irrigation methods may well reduce the overall global warming potential of greenhouse gas emissions from rice production; however, yield penalties and nitrogen pollution are likely to increase as a result.

https://www.sciencedirect.com/science/article/abs/pii/S0167880921002759

Flood or furrow irrigation

Flood irrigation, also called surface irrigation, is any method of irrigation that delivers water to croplands using gravity and is not pressurized. This makes flood irrigation a low-tech, low-energy irrigation method implemented without the need for sophisticated machinery or expensive infrastructure. Furrow irrigation uses furrows between planted ridges. Fields may be of various shapes. First, the soil is prepared into vertical channels (furrows) and planting mounds. Then, water is released directly into each furrow, running down the furrow's length and seeping into the soil at the root level.

https://www.agrivi.com/blog/agronomy/modern-management-of-centennial-furrow-irrigation/

Bank stabilization

Bank stabilization consists of any measure used to hold soil in place on the bank or a watercourse. Here, waves, stream currents, ice, and surface runoff can scour away the soil.

The benefits of bank stabilization are reduced soil erosion, better water quality, and an increased aesthetic environment.

https://www.johnstonnc.com/swc/content.cfm?pageid=wisc

Buffer strip

A buffer strip is an area of land maintained in permanent vegetation that helps to control air, soil, and water quality, along with other environmental problems, dealing primarily with land that is used in agriculture. Buffer strips trap sediment and enhance filtration of nutrients and pesticides by slowing down runoff that could enter the local surface waters. Farmers can also use buffer strips to square off existing crop fields, providing safety for equipment while also farming more efficiently.

https://www.naturespots.net/habitats/agriculture/12665-buffer-strip

Grassed waterway

Grassed waterways are broad, shallow, and typically saucer-shaped channels designed to move surface water across farmland without causing soil erosion. The vegetative cover in the waterway slows the water flow and protects the channel surface from the eroding forces of runoff water. Left alone, runoff and snowmelt water will drain toward a field's natural draws or drainage ways. It is in these areas that grassed waterways are often established. Advantages of grassed waterways include that they can carry large flows, making them suited to safely carry runoff from large upstream watersheds, farm machinery can cross them, and once vegetation is established, maintenance is low.

https://www.ontario.ca/page/grassed-waterways

Drip irrigation

Drip irrigation, also known as trickle irrigation, micro irrigation, or localized irrigation, is an irrigation method that saves water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone. It is done through narrow tubes that deliver water directly to the base of the plant. The technology is quite expensive, but it can be implemented using low-cost alternatives.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

Modern irrigation systems

Modern methods of irrigation utilize cloud-automated and timed sprinkler systems, drip systems, and subsurface water lines. Using precise, high-resolution ET Everywhere weather data, smart irrigation controllers can create specific schedules to maintain landscape health, irrigating only when necessary, based on daily, site-specific runtime adjustments.

https://www.hydropoint.com/blog/modern-methods-of-irrigation/

Deficit irrigation

Deficit irrigation is irrigation that applies less water than the crop needs for full development. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8783.pdf

Irrigation scheduling (2 types)

Irrigations based on evapotranspiration (ET)

Evaporation is the loss of water from the soil, and transpiration is the amount of water used by plants for growth and other metabolic processes. Evapotranspiration is typically expressed in inches or millimeters of water per day. When it comes to efficient irrigation management, ET is an objective measurement that helps

determine how much water should be applied to the turf on a given day. It incorporates daily weather data—including solar radiation, wind speed, humidity, and temperature—and utilizes a crop coefficient to fine-tune the water requirement for a particular site and turf species.

https://gsrpdf.lib.msu.edu/?file=/article/jacobs-gross-irrigation-7-6-18.pdf

Irrigations based on soil water content/tension

Soil-water status (soil moisture) plays a critical role in determining the yield potential of crops. Soil water in the plant root zone must be maintained and balanced so that plants can optimize their transpiration (biomass/yield production process) as well as water, nutrient, and micronutrient uptake. Irrigation management requires the knowledge of "when" and "how much" water to apply to optimize crop production and increase and maintain a high level of water use efficiency. Soil moisture monitoring equipment can be used to measure how much moisture is in the soil.

https://cropwatch.unl.edu/2019/SWC-SMP-irrigation-trigger-values

Cross-slope barriers

Cross-slope barriers are measures on sloping lands in the form of earth or soil bunds, stone lines, and/or vegetative strips for reducing runoff velocity and soil loss, thereby contributing to soil, water, and nutrient conservation. This is achieved by reducing the steepness and/or length of the slope (FAO, 2011).

Management of genetic resources

Single seedling approach

Preserving rice seeds in a panicle and transplanting them as single seedlings can result in 100% germination, along with a statistically significant increase in root, shoot, and dry weight compared to market seeds. Furthermore, single seedlings require less irrigation and have a higher yield. https://www.researchgate.net/publication/347756016_Sustainability_of_preserving_seed_in_panicle_and_applying_single_seedling_to_minimise_production_cost_of_rice.

Modern varieties

In many cases, modern varieties are preferred over landraces because of their typically higher provisioning services like crop yields, but under non-optimal farming conditions, landraces often guarantee higher provisioning services as they can show high resilience under harsh environmental conditions and are a trusted source achieving stable crop yields, for example, under drought stress. Important to note is that both landraces and modern varieties have merit depending on the farmers' priorities and socioeconomic context. However, maintaining and restoring the diversity of landrace varieties is necessary for sustaining current and future needs. https://www.researchgate.net/publication/326932144_More_than_Yield_Ecosystem_Services_of_Traditional_versus_Modern_Crop_Varieties_Revisited

Use local climate-resilient and improved varieties

Farmers and other custodians of in situ and local crop diversity play a critical role in the sustainable use of PGRFA (Plant Genetic Resources for Food and Agriculture). Appropriate infrastructures, therefore, need to be established to support the continued cultivation of local crop varieties—ones that are genetically diverse due to repeated cycles of selection, seed saving, and replanting, which have resulted in their adaptation to local environmental conditions. Inventories provide the baseline information needed to understand the local crop diversity that exists and the array of associated social, economic, geographic, and environmental data. This knowledge is necessary to develop effective strategies that support the continued cultivation of local varieties, collect and conserve materials ex-situ, and monitor changes. https://www.fao.org/plant-treaty/tools/toolbox-for-sustainable-use/sustaining-local-crop-diversity/en/

Agroforestry

Agroforestry is a collective term for land-use systems and technologies where woody perennials (e.g., trees, shrubs, palms, and bamboo) are deliberately used on the same land-management units as crops and/or animals, in some form of spatial arrangement or temporal sequence.

Agrisilvicultural systems are a combination of crops and trees, such as alley cropping or home gardens.

Silvopastoral systems combine forestry and grazing of domesticated animals on pastures, rangelands, or on-farm.

The three elements—trees, animals, and crops—can be integrated into what are called agrosylvopastoral systems, which are illustrated by home gardens that involve animals as well as scattered trees on croplands used for grazing after harvests.

GGGI (2021). Compendium of Practices in Climate-Smart Agriculture and Solar Irrigation.

FAO (2015) https://www.fao.org/forestry/agroforestry/80338/en/

Cost reduction of transportation and storage

Building up local agro-processing plants

Building up local agro-processing plants as a strategy of lowering the costs of transportation and storage when farmers take their farm produce to distant manufacturers or processors is one factor that influences smallholder farmers' decisions to engage and participate more easily in the market. https://doi.org/10.1080/23311886.2019.1664193

Annex 3: Modeling Methodology

Coming from FAO's EX-ACT family of tools, the EX-ACT-VC model serves as the starting point for the definition of programs that, when introduced as CSA practices, are expected to generate additional employment. This tool not only allows users to establish a baseline given current conditions in each practice, but also permits the design of "what-if" scenarios which, in turn, allow for before-and-after comparison of results.

For this tool, most input variables come from EX-ACT-VC's socio-economic and off-farm GHG assessment modules. A sample of the central variables for designing a baseline scenario includes the number of holders/actors per practice, labor intensity per activity/link (e.g., person-day counts), wages, the share of unpaid (family) labor, current and prospective market prices (exchange rates, input prices, and fuel prices), on-farm results ((un)harvest, loss, GHG emissions per hectare).

Core or direct green jobs estimates rely on three bottom-up methods: i) case studies and sector-specific national and international literature, ii) labor markets and agricultural surveys and censuses, and iii) coefficients of input costs and labor intensity per upgrading practice. This approach is more accurate, albeit more time-consuming, than top-down approaches that rely on broad measures of labor intensity ratios or standard definitions of green jobs per economic activity (Jarvis et al., 2011).

These methods are complementary and for the most part interdependent: the number of jobs per hectare of wheat farming (labor intensity) may come from national or international case studies, baseline measures of employment can be taken from survey data, and finally, NDCs-defined goals for wheat farming can help extrapolate net job creation (which in turn could come from new jobs, labor substitution or labor transformation).

Some additional features were configured within the tool, for instance, the gendered distribution of labor. For this dimension, the model allows users to introduce a parameter that simulates linear growth in the participation of women in each project's respective activities. Using as a baseline the yearly average economy-wide increase in female labor participation from preceding official surveys (last two survey years), it also incorporates "pessimistic" and "optimistic" female labor participation scenarios. This parameter applies to the three levels of job creation (direct, indirect, and induced). Similarly, considering labor formality and the availability of living wages per sector of economic activity allows users to assess the share of new jobs that can be considered "decent work". A linear parametrization of both variables, based on recent country-level trends, would account for the future projections of these indicators across economic sectors.

The mapping of core job creation, Gross Production Value (GPV), and Value Added (VA) generated by each program lays the micro-foundations for the subsequent use of macroeconomic IO multipliers for the estimation of indirect and induced jobs. The tasks involved in this process are described in the following paragraphs.

IO modeling is used to estimate indirect and induced jobs and downstream sectoral added value. The input variable in the IO model is the variation (increase) in the total output of the selected sectors resulting from the policies and strategies considered in the scenarios proposed in the previous step. The variation in the total output will be estimated considering the sector's cost structure and investment multipliers of both countries. An increase in the total output of one of the selected sectors implies an increase in the inputs required for its production, including labor. The IO table presents the linear relations between the inputs and outputs from each sector, providing the information to estimate the additional inputs required from other sectors to increase the sector's production under consideration.

To evaluate the effects on indirect and induced employment, we employed a supply-driven model (Ghoshian) that delineates the relationships between inputs and outputs (Duran Lima & Banacloche, 2022; Oosterhaven, 2006). Considering an economy with I intermediate sectors, Q final sectors, and P primary sectors, the total output and total input identities are equal to:

$$x = Zi + Yi$$

$$x' = iZ + iV'$$

Where:

x = I - a vector with total input per sector,

Z = I×I matrix with intermediate inputs,

Y = I×Q matrix with final outputs

V = P×I matrix with primary inputs, and

i = vector of appropriate size with ones.

Considering the total input identity and complementing with the assumption of fixed output coefficients, the allocation coefficients are calculated by:

$$Z = \hat{x}B$$

$$Y = \hat{x}D$$

Where:

$x^\wedge$ = I × I diagonal matrix of total output per industry, and the final solution of the model is provided by:

$x' = v'I - B-1$

The primary supply (**v'**) is the exogenous driving force and determines the total inputs (**x'**), the intermediate inputs (**Z**), and the final outputs (**Y**).

To estimate the effects of a variation of the total output on employees' compensation, we start by considering that the total compensation of employees (**w**) as the ratio of the total output per industry is:

$W = x^\wedge w$

W also represents the direct effects of total output variations on the total employees' compensation. The effect of the increase in the total output of one particular sector on the total employees' compensation in the economy can be calculated by:

$Wtotal = Wx'$

Hence, the effect of the increase in the total output of one particular sector on the total employees' compensation in the country, excluding the direct impact, is:

$Windirect = Wtotal - W$

Considering the average annual wage per sector and the increase resulting in the total employees' compensation, excluding the direct impact, we can estimate the increase in indirect employment:

Lindirect = **Windirect /(**Average annual wage per sector)

Moreover, the induced employment can be estimated considering the increase in consumer demand (**c**) due to an increase in total outputs. Therefore, we start estimating the ratio of the consumer demand and total output as:

$C = x^\wedge c$

Finally, total induced employment is equal to the variation on consumer demand due to increases in total output (**Cx'**), divided by the average annual wage per economic activity:

Linduced=**Cx'**/Average annual wage per sector

Annex 2: NDC targets of selected sub-sectors

Table A2.1. Colombia NDC targets of selected sub-sectors

Sub-sector	2030 Target Unit: Ha	Target Type	Intervention	Note
Panela sugar	800	Mitigation	NAMA panela: develop a central planning strategy, institutional and financial management and articulation for development low in emissions and the contribution to the sustainable development of the panela production in the country. The NAMA seeks to support alternative technology transfer interventions (replacement of diesel engines with electric ones and the use more energy efficiency in the combustion of bagasse in the stoves), improve production practices (efficient use of synthetic fertilizers, reduced burning, lower spending energy in tilling the soil and wastewater management), the restoration of natural systems, the development of capabilities, and validation of a Monitoring, Reporting and Verification (MRV).	Technological conversion of 1,500 mills with 800 hectares of restoration as compensation to historical deforestation.
Irrigated rice	255,000	Mitigation	Mass adoption of technology (AMTEC 2.0) for production of irrigated rice: Implementation of a model of transference of technology based on sustainability and social responsibility, that tends towards organization, competitiveness and profitability of the producer, implementing technologies in a massive integral to increase yields and reduce costs production costs in rice cultivation. Includes forecasts of time - crop modeling, precision agriculture and the MIRI irrigation system.	> 255,000 hectares irrigated rice > 207,046 hectares dry rice
	207,046	Mitigation		
Cocoa	80,000	Mitigation	Strategies to reduce GHG emissions in the life cycle of cocoa production: increase in the area dedicated to cocoa cocoa cultivation under agroforestry systems, as well as its renovation and rehabilitation, to increase the stock of carbon.	> 80,000 hectares under renovation and rehabilitation > 150,000 hectares in systems agroforestry with timber
	150,000	Mitigation		
Forestry	368,836	Mitigation	Development and consolidation of the productive chain of the forest plantations for commercial purposes: Articulation technical and economic for the production of wood from forest plantations for commercial purposes with the plan of chain action.	Plantation of 27,282 hectares (300,000 hectares 2015-2030). foresees increased ambition for the year 2030 from the increase annual plantations to 34,165 ha (46,000 ha including scenario of reference), which would be equivalent to 368,836 Ha in plantations commercial foresters for the mitigation scenario to 2030.

Note: Colombia's updated NDC is available in Spanish only and has been translated.

Table A2.2: Ethiopia NDC targets of selected sub-sectors

Crop	2030 Target	Target Type	Intervention	Note
Wheat	45.9 quintals/Ha	Adaptation	Enhance food security by improving agricultural productivity in a climate-smart manner (promote yield increasing techniques)	Productivity of rain fed crop land (based on average for teff, wheat, barley and corn) > 45.9 quintals/Ha area under irrigation (based on corn, wheat, tomatoes and onions) > 225,913 Ha
	225,913 Ha	Adaptation		
Corn	45.9 quintals/Ha	Adaptation		
	225,913 Ha	Adaptation		
Teff	45.9 quintals/Ha	Adaptation		
	225,913 Ha	Adaptation		
Barley	45.9 quintals/Ha	Adaptation		
	225,913 Ha	Adaptation		
	16,200 Tons	Adaptation		

Annex 4: Data Inputs Source Tables

Within the models, the specifications for each country crop are primarily outlined in two sheets: Direct Jobs I and Direct Jobs II. Direct Jobs I offers a broad modeling perspective, encompassing aspects like land area, yields, and sustainable practices. Conversely, Direct Jobs II delves into crop-specific details, presenting indicators such as input costs per hectare (including labor for explicit cultivation activities, fertilizers, pesticides, etc.). As mentioned in the document, the information that feeds these points of data comes from both official statistics and labor and agriculture literature. The next tables detail the sources of data for Direct Jobs I and Direct Jobs II in both countries.

Table A4 1. Colombia: Data Inputs and Sources for Direct Jobs I

Input Name	Crop	Source
Number of Actors within Category	Cocoa	https://sioc.minagricultura.gov.co/cacao/Documentos/2021-06-30%20Cifras%20Sectoriales.pdf
	Rice	https://fedearroz.s3.amazonaws.com/media/documents/FINAL_CULTIVO_DEL_ARROZ_EN_COLOMBIA_1988-2016.pdf
	Forestry	https://microdatos.dane.gov.co/index.php/catalog/Agrop-Microdatos
	Panela sugar	https://microdatos.dane.gov.co/index.php/catalog/Agrop-Microdatos
Total Amount Harvested	Cocoa	https://sioc.minagricultura.gov.co/cacao/Documentos/2021-06-30%20Cifras%20Sectoriales.pdf
	Rice	https://sioc.minagricultura.gov.co/Arroz/Documentos/2021-06-30%20Cifras%20Sectoriales.pdf
	Forestry	https://sac.org.co/cuando-sera-la-hora-del-sector-forestal/ ; https://sioc.minagricultura.gov.co/Forestal/Documentos/2019-03-30%20Cifras%20Sectoriales.pdf
	Panela sugar	https://sioc.minagricultura.gov.co/CanaAzucar/Documentos/2020-09-30%20Cifras%20Sectoriales.pdf
Total Land used for Production	Cocoa	https://sioc.minagricultura.gov.co/cacao/Documentos/2021-06-30%20Cifras%20Sectoriales.pdf
	Rice	https://sioc.minagricultura.gov.co/Arroz/Documentos/2021-06-30%20Cifras%20Sectoriales.pdf
	Forestry	https://www.dane.gov.co/files/investigaciones/agropecuario/enda/ena/2019/boletin_ena_2019.pdf
	Panela sugar	https://sioc.minagricultura.gov.co/CanaAzucar/Documentos/2020-09-30%20Cifras%20Sectoriales.pdf
Total Emissions Associated with Production	Cocoa	Authors' estimates based on FAO's EXACT tool.
	Rice	http://www.scielo.org.co/pdf/ccta/v15n1/v15n1a04.pdf.pdf (scielo.org.co)
	Forestry	https://www.fao.org/fileadmin/templates/ex_act/images/EX-ACT_VC/Guideline_EX-ACT_B-VC__10082016.pdf
	Panela sugar	https://doaj.org/article/98a4cf5787314e78983b6363860bc0cc
Amount left unharvested (%)	Cocoa	https://microdatos.dane.gov.co/index.php/catalog/Agrop-Microdatos
	Rice	https://microdatos.dane.gov.co/index.php/catalog/Agrop-Microdatos
	Forestry	https://microdatos.dane.gov.co/index.php/catalog/Agrop-Microdatos
	Panela sugar	https://microdatos.dane.gov.co/index.php/catalog/Agrop-Microdatos
Amount lost during harvest (%)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1372669/
	Forestry	https://www.fao.org/fileadmin/templates/ex_act/images/EX-ACT_VC/Guideline_EX-ACT_B-VC__10082016.pdf
	Panela sugar	https://cengicana.org/files/20210802083131880.pdf
Amount consumed (%)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	N.A., asummed 0% of rice production is consumed by families.
	Forestry	https://www.fao.org/fileadmin/templates/ex_act/images/EX-ACT_VC/Guideline_EX-ACT_B-VC__10082016.pdf
	Panela sugar	N.A., asummed 0% of sugar cane production is consumed by families.
Amount lost during transport (pick up) (%)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/fileadmin/templates/ex_act/pdf/EXACT_VC/Case_study_rice_India_3008.pdf
	Forestry	https://www.fao.org/fileadmin/templates/ex_act/images/EX-ACT_VC/Guideline_EX-ACT_B-VC__10082016.pdf
	Panela sugar	https://www.gob.mx/cms/uploads/attachment/file/114371/Nota_T_cnica_Informativa_Diciembre_2015.pdf
Amount lost during storage and Amount lost during transport	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1372669/
	Forestry	N.A., asummed 0% of forestry production is lost during transport and storage.
	Panela sugar	https://www.ingeniorisaralda.com/es/almacenamiento-y-seguridad-PG55
Amount product sold (%)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	Amount sold to cooperative or market assumed at 100%.
	Forestry	https://www.fao.org/fileadmin/templates/ex_act/images/EX-ACT_VC/Guideline_EX-ACT_B-VC__10082016.pdf
	Panela sugar	Amount sold to cooperative or market assumed at 100%.
Days in storage (Days)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://ciencia.lasalle.edu.co/cgi/viewcontent.cgi?article=1268&context=ingenieria_agronomica
	Forestry	http://cybertesis.uach.cl/tesis/uach/2006/fift649e/doc/fift649e.pdf
	Panela sugar	https://www.gob.mx/cms/uploads/attachment/file/114371/Nota_T_cnica_Informativa_Diciembre_2015.pdf
Total volume of storage facility (m3)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://ciencia.lasalle.edu.co/cgi/viewcontent.cgi?article=1268&context=ingenieria_agronomica
	Forestry	https://sitios.claro.com.co/dekoart/venta-de-madera/cundinamarca/bogota/localidad-suba-zona-norte/pueblo-viejo/
	Panela sugar	https://www.intranox.com/silos-metalicos/silos-de-azucar
Electricity Used (kWh / day)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://researchoutput.csu.edu.au/ws/portalfiles/portal/8802118/PID28338postpub.pdf
	Forestry	https://www.fao.org/fileadmin/templates/ex_act/images/EX-ACT_VC/Guideline_EX-ACT_B-VC__10082016.pdf
	Panela sugar	https://www.redalyc.org/pdf/2231/223144218007.pdf

Table A4 2. Colombia: Data Inputs and Sources for Direct Jobs II

Input Name	Crop	Source
Total Amount of Manure Used (kg)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1372669/
	Forestry	https://www.fao.org/3/k1100E/k1100e01.htm#:~:text=60%20man%2Ddays/ha&text=This%20clearing%20and%20site%20preparation,cover%20the%20most%20common%20cases.
	Panela sugar	https://www.redalyc.org/journal/1799/179955074008/html/
Cost of Manure (COP/kg)	Cocoa	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Rice	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Forestry	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Panela sugar	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
Total Amount of Fertilizer Used (kg)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1372669/
	Forestry	https://data.worldbank.org/indicator/AG.CON.FERT.ZS
	Panela sugar	https://www.colpos.mx/wb_pdf/Veracruz/2016/2016_%2013.pdf
Cost of Fertilizer (COP/kg)	Cocoa	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Rice	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Forestry	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Panela sugar	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
Total Amount of Pesticides Used (kg)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1372669/
	Forestry	N.A.
	Panela sugar	https://www.ambientico.una.ac.cr/wp-content/uploads/tainacan-items/5/26302/252_13-28.pdf
Cost of Pesticides (COP/kg)	Cocoa	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Rice	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Forestry	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
	Panela sugar	https://sioc.minagricultura.gov.co/Boletines/BOLET%C3%8DN%20DE%20PRECIOS%20DE%20INSUMOS%20AGROPECUARIOS%20No.1%20de%202021.pdf
Cost of Fuel (COP/litre)	Cocoa	https://www.globalpetrolprices.com/Colombia/gasoline_prices/
	Rice	https://www.globalpetrolprices.com/Colombia/gasoline_prices/
	Forestry	https://www.globalpetrolprices.com/Colombia/gasoline_prices/
	Panela sugar	https://www.globalpetrolprices.com/Colombia/gasoline_prices/
Other Transportation Costs (COP)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/documents/card/en/c/cb3176en
	Forestry	https://www.fao.org/documents/card/en/c/cb3176en
	Panela sugar	https://www.fao.org/documents/card/en/c/cb3176en
Weeding / Treatment of Pesticides (labor days)	Cocoa	See table 11 in Annex -> https://scholarworks.uark.edu/cgi/viewcontent.cgi?article=1230&context=etd
	Rice	https://link.springer.com/article/10.1007/s12571-014-0351-7
	Forestry	https://scholarworks.uark.edu/cgi/viewcontent.cgi?article=1230&context=etd
	Panela sugar	Annex 2: https://www.bibalex.org/search4dev/files/289330/120295.pdf
Manure Application / Compost delivery (labor days)	Cocoa	See table 11 in Annex -> https://scholarworks.uark.edu/cgi/viewcontent.cgi?article=1230&context=etd
	Rice	Table 2, https://fabm.org.my/archive/1fabm2021/1fabm2021-17-22.pdf
	Forestry	https://www.fao.org/3/k1100E/k1100e01.htm#:~:text=60%20man%2Ddays/ha&text=This%20clearing%20and%20site%20preparation,cover%20the%20most%20common%20cases.
	Panela sugar	Annex 2: https://www.bibalex.org/search4dev/files/289330/120295.pdf
Input procurement (labor days)	Cocoa	See table 11 in Annex -> https://scholarworks.uark.edu/cgi/viewcontent.cgi?article=1230&context=etd
	Rice	Table 2, https://fabm.org.my/archive/1fabm2021/1fabm2021-17-22.pdf
	Forestry	https://www.fao.org/3/k1100E/k1100e01.htm#:~:text=60%20man%2Ddays/ha&text=This%20clearing%20and%20site%20preparation,cover%20the%20most%20common%20cases.
	Panela sugar	Annex 2: https://www.bibalex.org/search4dev/files/289330/120295.pdf
Harvesting (labor days)	Cocoa	http://centmapress.ilb.uni-bonn.de/ojs/index.php/fsd/article/view/931
	Rice	Table 2, https://fabm.org.my/archive/1fabm2021/1fabm2021-17-22.pdf
	Forestry	https://www.fao.org/3/k1100E/k1100e01.htm#:~:text=60%20man%2Ddays/ha&text=This%20clearing%20and%20site%20preparation,cover%20the%20most%20common%20cases.
	Panela sugar	Annex 2: https://www.bibalex.org/search4dev/files/289330/120295.pdf
Average Daily Wage (COP)	Cocoa	Gran Encuesta Integrada de Hogares (GEIH) 2022. DANE
	Rice	Gran Encuesta Integrada de Hogares (GEIH) 2022. DANE
	Forestry	Gran Encuesta Integrada de Hogares (GEIH) 2022. DANE
	Panela sugar	Gran Encuesta Integrada de Hogares (GEIH) 2022. DANE
% of Non-Remunerated (family) Labour	Cocoa	Gran Encuesta Integrada de Hogares (GEIH) 2022. DANE
	Rice	Gran Encuesta Integrada de Hogares (GEIH) 2022. DANE
	Forestry	Gran Encuesta Integrada de Hogares (GEIH) 2022. DANE
	Panela sugar	Gran Encuesta Integrada de Hogares (GEIH) 2022. DANE
Pruning clearning (labor days)	Cocoa	https://scholarworks.uark.edu/cgi/viewcontent.cgi?article=1230&context=etd
	Rice	Table 2, https://fabm.org.my/archive/1fabm2021/1fabm2021-17-22.pdf
	Forestry	https://www.fao.org/3/k1100E/k1100e01.htm#:~:text=60%20man%2Ddays/ha&text=This%20clearing%20and%20site%20preparation,cover%20the%20most%20common%20cases.
	Panela sugar	Annex 2: https://www.bibalex.org/search4dev/files/289330/120295.pdf
Threshing - drying/ Fermentation drying (labor days)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1372669/
	Forestry	https://www.fao.org/3/k1100E/k1100e01.htm#:~:text=60%20man%2Ddays/ha&text=This%20clearing%20and%20site%20preparation,cover%20the%20most%20common%20cases.
	Panela sugar	Annex 2: https://www.bibalex.org/search4dev/files/289330/120295.pdf
Pickup and transport (labor days)	Cocoa	https://www.fao.org/documents/card/en/c/cb3176en
	Rice	https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1372669/
	Forestry	https://www.fao.org/3/k1100E/k1100e01.htm#:~:text=60%20man%2Ddays/ha&text=This%20clearing%20and%20site%20preparation,cover%20the%20most%20common%20cases.
	Panela sugar	Annex 2: https://www.bibalex.org/search4dev/files/289330/120295.pdf
Selling Price (COP/Tonne)	Cocoa	https://agronet.gov.co/Noticias/Paginas/Precio-de-referencia-semanal-de-compra-de-cacao---Fuente-Industria.aspx
	Rice	https://www.fedearroz.com.co/es/fondo-nacional-del-arroz/investigaciones-economicas/estadisticas-arroceras/precios-del-sector-arrocero/
	Forestry	https://inta.gob.ar/sites/default/files/inta_concordia_planilla_de_precios_forestales_julio_2021.pdf
	Panela sugar	https://sioc.minagricultura.gov.co/CanaAzucar/Documentos/2021-06-30%20Cifras%20Sectoriales.pdf

Table A4 3. Ethiopia: Data Inputs and Sources for Direct Jobs I

Input Name	Crop	Source
Number of Actors within Category	Barley	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Corn	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Teff	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Wheat	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
Total Amount Harvested	Barley	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Corn	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Teff	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Wheat	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
Total Land used for Production	Barley	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Corn	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Teff	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
	Wheat	Agricultural Sample Survey 2021/21 (2013 EC) Volume 1, Report on Area and Production of Major Crops.
Total Emissions Associated with Production	Barley	https://www.researchgate.net/publication/264892275_Greenhouse_gas_emissions_from_oats_barley_wheat_and_rye_production
	Corn	https://www.frontiersin.org/articles/10.3389/fenvs.2021.710108/full
	Teff	https://www.frontiersin.org/articles/10.3389/fenvs.2021.710108/full
	Wheat	https://www.frontiersin.org/articles/10.3389/fenvs.2021.710108/full
Amount left unharvested (%)	Barley	Assumption of 5%.
	Corn	Assumption of 5%.
	Teff	Assumption of 5%.
	Wheat	Assumption of 5%.
Amount lost during harvest (%)	Barley	Assumption of 3%.
	Corn	Assumption of 3%.
	Teff	Assumption of 3%.
	Wheat	Assumption of 3%.
Amount consumed (%)	Barley	Assumption of 0%.
	Corn	Assumption of 0%.
	Teff	Assumption of 0%.
	Wheat	Assumption of 0%.
Amount lost during transport (pick up) (%)	Barley	Assumption of 0%.
	Corn	Assumption of 0%.
	Teff	Assumption of 0%.
	Wheat	Assumption of 0%.
Amount lost during storage and Amount lost during transport (%)	Barley	Assumption of 0%.
	Corn	Assumption of 0%.
	Teff	Assumption of 0%.
	Wheat	Assumption of 0%.
Amount product sold (%)	Barley	Assumption of 100% after net harvesting loses.
	Corn	Assumption of 100% after net harvesting loses.
	Teff	Assumption of 100% after net harvesting loses.
	Wheat	Assumption of 100% after net harvesting loses.
Days in storage (Days)	Barley	Assumption based on similar crops.
	Corn	Assumption based on similar crops.
	Teff	Assumption based on similar crops.
	Wheat	Assumption based on similar crops.
Total volume of storage facility (m3)	Barley	Assumption based on similar crops.
	Corn	Assumption based on similar crops.
	Teff	Assumption based on similar crops.
	Wheat	Assumption based on similar crops.
Electricity Used (kWh / day)	Barley	Assumption based on similar crops.
	Corn	Assumption based on similar crops.
	Teff	Assumption based on similar crops.
	Wheat	Assumption based on similar crops.

Annex 5: Job Opportunities in Colombian Agriculture: Standalone Analyses per Crop

This annex presents a series of standalone analyses assessing the job creation potential in key crops in Colombia, namely cocoa, rice, forestry, and panela sugar production. Each analysis delves into the specific crop's contribution to job growth, highlighting the socioeconomic impact of Colombia's agricultural practices and policies. Drawing from Colombia's NDCs that aim to promote sustainability and mitigate greenhouse gas emissions, these analyses evaluate employment opportunities across different stages of each crop's production cycle. Additionally, insights are provided on the integration of CSA practices, which can further boost job creation and environmental benefits. This section offers a comprehensive understanding of the unique dynamics and potential strategies for fostering job growth and overall economic and environmental sustainability in each of these critical agricultural sectors. To complement these analyses, the section also includes an overview of the skills required for selected occupations within each crop, providing insights for workforce planning and educational training in the agricultural sector.

Cocoa

Colombia's NDCs aim to rehabilitate 150,000 hectares of cocoa production and implement strategies to reduce greenhouse gas emissions throughout the cocoa production lifecycle. These strategies include expanding cocoa cultivation under agroforestry systems, as well as renewing and rehabilitating existing areas to increase carbon sequestration. Specifically, 80,000 hectares are dedicated to renewal and rehabilitation, while the remaining 70,000 hectares are designated for agroforestry systems (Govt. of Colombia, 2022).

We developed a tool to estimate the socioeconomic impact of Colombia's NDC targets on specific agricultural activities, including cocoa. This tool builds on top of FAO's EX-ACT-VC tool and uses employment intensities for sub-activities within a crop. In the case of cocoa, production involves stages including tree cultivation, pod harvesting, fermentation, drying, selling, transportation, and shipping. Farmers care for cocoa trees, harvest pods, ferment and dry the beans, which are then packed, sold to buying stations, transported to exporters, and stored until shipment to manufacturers. The baseline range of time required for these activities ranges between 25 and 85 days per hectare per year in low-productivity systems to between 65 and 287 days in medium and high-productivity systems (Cocoa Barometer, 2022; Singh et al., 2019; Torres et al., 2017; Curry et al., 2007; Mahrizal, 2011). Our own intensity factors range from a baseline of 80 person-days per hectare to 161 person-days including CSA agriculture practices.

Our estimates suggest that Colombia's Cocoa NDC strategy has the potential to add between 31,900 and 67,900 new jobs over the course of a decade (2022-2032) if CSA practices are implemented in the total targeted production area. For the upper-bound estimate, this includes approximately 26,800 direct jobs, 1,200 indirect jobs, and 3,900 induced jobs . This estimate includes 8,200 direct jobs stemming from sustainable agriculture, namely agroforestry and cross-slope barriers, practices known to increase yields and promote carbon sequestration (FAO, 2011; Hoff, 2017). Conversely, conventional cocoa production (i.e., the BAU scenario) would not only yield less employment creation over the decade (a total of 28,000 new jobs) but also significantly less carbon sequestration (-3.3 million MgCha versus -5.3 million MgCha) and production value (USD 165 million versus USD 185 million).

The majority of the 26,800 direct new jobs—assuming CSA practices are used—are derived from sub-activities in the production stage (19,000 jobs), followed by processing (3,600 jobs), transportation (3,000 jobs), and aggregation (1,200 jobs). Analogously, most indirect jobs would derive from production linkages of cocoa with manufacturing (405 jobs), other agricultural activities (289 jobs) and professional services (246 jobs). Sectoral inter-dependencies determine a similar distribution of induced jobs, with the bulk of new induced jobs concentrating in agriculture (2,600 jobs), manufacturing (535 jobs), and professional services (395 jobs).

Given the prevalence of labor informality and reduced female participation in cocoa production in Colombia, most of the jobs created would rely on male and informal labor. For example, out of our estimate of 26,800 new jobs created over a decade, only 7,800 and 2,000 correspond to female and formal labor, respectively. It is worth noting that these calculations utilize recent statistics to extrapolate the future growth of current sector-specific formality rates (7%) and female labor participation rates (27%) from official microdata. Additionally, over the decade, more than 6,200 jobs would come from non-remunerated household labor. These estimates highlight the need to promote both labor formalization policies and the integration of women into the country's agricultural labor markets.

Unit costs for the strategy increase to USD 5,085 per producer (USD 1,986 per hectare) without considering CSA agriculture and to USD 5,820 per producer (USD 2,274 per hectare) when introducing agroforestry and cross-slope barriers. Total yearly costs for a strategy that includes both CSA practices are USD 34.1 million, with a critical mass corresponding to inputs (80%). An internationally comparable measure is the number of jobs created per USD 1 million invested. In this regard, Colombia's NDC strategy for cocoa, including CSA practices, yields a yearly average of 142 jobs per USD 1 million invested (79 direct, 14 indirect, and 49 induced jobs). The model also incorporates information from the C for Colombia to account for the impacts of climate change on labor productivity. Based on the strategy proposed in this exercise and different scenarios, climate change is expected to result in a loss of between 1,100 and 2,600 FTE jobs from our estimate of 26,800 direct jobs.

Considering sensitivity scenarios regarding salaries, the number of total jobs per USD 1 million invested ranges from 107 to 302 per year, on average. Since microdata are available, the model allows users to define three sets of wages: the average wage, a lower bound wage (the average minus a standard deviation), and an upper bound wage (the average plus a standard deviation). For example, using wages one standard deviation below the mean, total employment rises to 67,900 jobs over the course of the decade (302 jobs per USD 1 million invested). The estimate decreases to 31,900 new jobs over the decade if using higher salaries (1 standard deviation above the mean) (107 jobs per USD 1 million in investments). Similarly, the model includes a learning rate, as a percentage that improves the crop's production over time. This rate can be interpreted as labor-augmenting knowledge that increases productivity in the production process. The baseline for this rate is set at 1%. When increasing this rate to 5%, for example, total net value added rises from USD 13 million to USD 20 million.

Skills-occupations dyads within cocoa

The following table presents an occupations-skills matrix for selected cocoa-related occupations, based on CEDEFOP-based Skill Labels and ISCO (International Standard Classification of Occupations) occupations. The matrix displays the percentage of different skills associated with each cocoa-related occupation. These skills are categorized into various domains, including accessing and analyzing digital data, analyzing and evaluating information, monitoring and evaluating performance, operating machinery and equipment, managing budgets and finances, collaborating and liaising, complying with health and safety procedures, planning production processes, negotiating contracts, and more. For instance, the occupation of a cacao beans cleaner requires a high percentage of skills related to operating food processing machinery, whereas an import export manager in coffee, tea, cocoa, and spices needs skills in negotiating contracts and agreements.

Furthermore, these skills can be classified into four tiers based on educational requirements: management, engineers, technicians, and non-professionals. The management tier encompasses skills related to planning, analyzing economic and financial data, and executing financial transactions, which are evident in occupations such as an import-export manager in coffee, tea, cocoa, spices, and a coffee, tea, cocoa, and spices distribution manager. The engineers tier involves skills in operating machinery and performing technical tasks, exemplified by the occupation of cacao press operator. The technicians' tier encompasses skills related to implementing procedures, monitoring, inspecting, and analyzing information, as shown in the percentages for import-export specialists and merchants in coffee, tea, cocoa, and spices. Lastly, the non-professionals tier comprises skills in physical tasks like operating machinery, cleaning, moving, and lifting, which are vital for roles such as cacao beans cleaner and cacao bean roaster. This hierarchical categorization provides valuable insights into the diverse educational prerequisites required for various cocoa-related professions. It assists in strategic workforce planning and the design of educational training initiatives tailored to the specific demands of the cocoa industry.

Table A6 1. Occupations-Skills matrix for selected cocoa occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations → (Managers, Engineers, Technicians, Elementary)	Cacao Beans Cleaner	Cacao Bean Roaster	Cocoa press operator	Import export manager in coffee, tea, cocoa and spices	Wholesale merchant in coffee, tea, cocoa and spices	Import export specialist in coffee, tea, cocoa and spices	Coffee, tea, cocoa and spices distribution manager
accessing and analysing digital data	0%	0%	0%	6%	6%	6%	5%
analysing and evaluating information and data	3%	0%	0%	0%	0%	0%	0%
analysing business operations	0%	0%	0%	0%	0%	0%	5%
analysing financial and economic data	0%	0%	0%	6%	6%	0%	0%
analysing scientific and medical data	0%	0%	0%	0%	0%	0%	5%
cleaning tools, equipment, workpieces and vehicles	0%	0%	5%	0%	0%	0%	0%
collaborating and liaising	5%	4%	5%	0%	0%	0%	0%
collecting and preparing specimens or materials for testing	0%	4%	0%	0%	0%	0%	0%
communicating with colleagues and clients	0%	0%	0%	0%	0%	6%	5%
complying with environmental protection laws and standards	3%	2%	3%	0%	0%	0%	0%
complying with health and safety procedures	5%	10%	10%	0%	0%	0%	0%
complying with operational procedures	10%	4%	10%	6%	0%	0%	5%
conducting academic or market research	0%	0%	0%	0%	6%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	6%	0%	0%	0%
developing operational policies and procedures	0%	0%	0%	0%	0%	6%	5%
developing professional relationships or networks	0%	0%	0%	0%	6%	0%	0%
developing solutions	0%	0%	0%	6%	0%	6%	5%
disposing of non-hazardous waste or debris	0%	0%	3%	0%	0%	0%	0%
engaging with others to identify needs	0%	0%	0%	0%	13%	0%	0%
ensuring compliance with legislation	10%	8%	10%	6%	0%	6%	10%
executing financial transactions	0%	0%	0%	0%	0%	0%	5%
fabricating food and related products	0%	4%	0%	0%	0%	0%	0%
following instructions and procedures	5%	2%	0%	0%	0%	0%	0%
gathering information from physical or electronic sources	0%	0%	0%	0%	0%	0%	5%
handling and disposing of hazardous materials	0%	4%	0%	0%	0%	0%	0%
identifying opportunities	0%	0%	0%	0%	13%	0%	0%
implementing new procedures or processes	0%	0%	0%	0%	0%	13%	5%
inspecting food safety and quality	0%	4%	5%	0%	0%	0%	0%
installing wooden and metal components	5%	4%	5%	0%	0%	0%	0%
liaising and networking	0%	0%	0%	0%	6%	0%	0%
maintaining operational records	0%	0%	0%	0%	0%	0%	5%
management skills	0%	0%	0%	11%	0%	0%	0%
managing budgets or finances	0%	0%	0%	0%	0%	6%	5%
managing transport and logistics activities	0%	0%	0%	6%	0%	6%	5%
marking materials or objects for identification	0%	2%	0%	0%	0%	0%	0%
measuring physical properties	5%	4%	5%	0%	0%	0%	0%
mediating and resolving disputes	0%	0%	0%	6%	0%	6%	0%
monitoring and evaluating the performance of individuals	0%	0%	0%	6%	0%	0%	0%
monitoring financial and economic resources and activity	0%	0%	0%	6%	6%	0%	0%
monitoring operational activities	5%	8%	5%	0%	0%	6%	0%
monitoring quality of products	5%	2%	3%	0%	0%	0%	0%
monitoring safety or security	0%	0%	0%	0%	0%	0%	0%
moving or lifting materials, equipment, or supplies	3%	0%	0%	0%	0%	0%	0%
negotiating and managing contracts and agreements	0%	0%	0%	0%	19%	0%	0%
operating food processing machinery	21%	4%	0%	0%	0%	0%	0%
operating kilns, furnaces and drying equipment	0%	4%	0%	0%	0%	0%	0%
operating machinery for the manufacture of products	0%	4%	0%	0%	0%	0%	0%
operating mixing and separating machinery	0%	0%	5%	0%	0%	0%	0%
operating petroleum, chemical or water processing systems or equipment	0%	0%	0%	0%	0%	0%	0%
performing risk analysis and management	0%	0%	0%	6%	6%	0%	14%
planning production processes	0%	0%	0%	0%	6%	6%	5%
preparing documentation for contracts, applications, or permits	0%	0%	0%	0%	0%	6%	0%
preparing financial documents, records, reports, or budgets	0%	0%	0%	11%	6%	0%	5%
preparing food and drinks	0%	8%	0%	0%	0%	0%	0%
protecting and enforcing	5%	0%	0%	0%	0%	0%	0%
repairing and installing mechanical equipment	0%	0%	5%	0%	0%	0%	0%
sorting materials or products	0%	0%	5%	0%	0%	0%	0%
storing goods and materials	5%	4%	5%	0%	0%	0%	0%
supervising a team or group	0%	0%	0%	0%	0%	0%	5%
technical or academic writing	0%	0%	0%	0%	0%	6%	0%
testing electrical and mechanical systems or equipment	5%	4%	5%	0%	0%	0%	0%
using foreign languages	0%	0%	0%	6%	0%	6%	0%
using precision measuring equipment	0%	0%	5%	0%	0%	0%	0%
verifying identities and documentation	0%	0%	0%	6%	0%	0%	0%
working in teams	0%	2%	3%	0%	0%	0%	0%
working with others	0%	0%	0%	6%	0%	6%	0%

Source: Own elaboration using ESCO's methodology.

Occupations-skills matrix for selected cocoa occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations → (Managers, Engineers, Technicians, Elementary)	Cacao Beans Cleaner	Cacao Bean Roaster	Cocoa press operator	Import export manager in coffee, tea, cocoa and spices	Wholesale merchant in coffee, tea, cocoa and spices	Import export specialist in coffee, tea, cocoa and spices	Coffee, tea, cocoa and spices distribution manager
accessing and analysing digital data	0%	0%	0%	6%	6%	6%	5%
analysing and evaluating information and data	3%	0%	0%	0%	0%	0%	0%
analysing business operations	0%	0%	0%	0%	0%	0%	5%
analysing financial and economic data	0%	0%	0%	6%	6%	0%	0%
analysing scientific and medical data	0%	0%	0%	0%	0%	0%	5%
cleaning tools, equipment, workpieces and vehicles	0%	0%	5%	0%	0%	0%	0%
collaborating and liaising	5%	4%	5%	0%	0%	0%	0%
collecting and preparing specimens or materials for testing	0%	4%	0%	0%	0%	0%	0%
communicating with colleagues and clients	0%	0%	0%	0%	0%	6%	5%
complying with environmental protection laws and standards	3%	2%	3%	0%	0%	0%	0%
complying with health and safety procedures	5%	10%	10%	0%	0%	0%	0%
complying with operational procedures	10%	4%	10%	6%	0%	0%	5%
conducting academic or market research	0%	0%	0%	0%	6%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	6%	0%	0%	0%
developing operational policies and procedures	0%	0%	0%	0%	0%	6%	5%
developing professional relationships or networks	0%	0%	0%	0%	6%	0%	0%
developing solutions	0%	0%	0%	6%	0%	6%	5%
disposing of non-hazardous waste or debris	0%	0%	3%	0%	0%	0%	0%
engaging with others to identify needs	0%	0%	0%	0%	13%	0%	0%
ensuring compliance with legislation	10%	8%	10%	6%	0%	6%	10%
executing financial transactions	0%	0%	0%	0%	0%	0%	5%
fabricating food and related products	0%	4%	0%	0%	0%	0%	0%
following instructions and procedures	5%	2%	0%	0%	0%	0%	0%
gathering information from physical or electronic sources	0%	0%	0%	0%	0%	0%	5%
handling and disposing of hazardous materials	0%	4%	0%	0%	0%	0%	0%
identifying opportunities	0%	0%	0%	0%	13%	0%	0%
implementing new procedures or processes	0%	0%	0%	0%	0%	13%	5%
inspecting food safety and quality	0%	4%	5%	0%	0%	0%	0%
installing wooden and metal components	5%	4%	5%	0%	0%	0%	0%
liaising and networking	0%	0%	0%	0%	6%	0%	0%
maintaining operational records	0%	0%	0%	0%	0%	0%	5%
management skills	0%	0%	0%	11%	0%	0%	0%
managing budgets or finances	0%	0%	0%	0%	0%	6%	5%
managing transport and logistics activities	0%	0%	0%	6%	0%	6%	5%
marking materials or objects for identification	0%	2%	0%	0%	0%	0%	0%
measuring physical properties	5%	4%	5%	0%	0%	0%	0%
mediating and resolving disputes	0%	0%	0%	6%	0%	6%	0%
monitoring and evaluating the performance of individuals	0%	0%	0%	6%	0%	0%	0%
monitoring financial and economic resources and activity	0%	0%	0%	6%	6%	0%	0%
monitoring operational activities	5%	8%	5%	0%	0%	6%	0%
monitoring quality of products	5%	2%	3%	0%	0%	0%	0%
monitoring safety or security	0%	0%	0%	0%	0%	0%	0%
moving or lifting materials, equipment, or supplies	3%	0%	0%	0%	0%	0%	0%
negotiating and managing contracts and agreements	0%	0%	0%	0%	19%	0%	0%
operating food processing machinery	21%	4%	0%	0%	0%	0%	0%
operating kilns, furnaces and drying equipment	0%	4%	0%	0%	0%	0%	0%
operating machinery for the manufacture of products	0%	4%	0%	0%	0%	0%	0%
operating mixing and separating machinery	0%	0%	5%	0%	0%	0%	0%
operating petroleum, chemical or water processing systems or equipment	0%	0%	0%	0%	0%	0%	0%
performing risk analysis and management	0%	0%	0%	6%	6%	0%	14%
planning production processes	0%	0%	0%	0%	6%	6%	5%
preparing documentation for contracts, applications, or permits	0%	0%	0%	0%	0%	6%	0%
preparing financial documents, records, reports, or budgets	0%	0%	0%	11%	6%	0%	5%
preparing food and drinks	0%	8%	0%	0%	0%	0%	0%
protecting and enforcing	5%	0%	0%	0%	0%	0%	0%
repairing and installing mechanical equipment	0%	0%	5%	0%	0%	0%	0%
sorting materials or products	0%	0%	5%	0%	0%	0%	0%
storing goods and materials	5%	4%	5%	0%	0%	0%	0%
supervising a team or group	0%	0%	0%	0%	0%	0%	5%
technical or academic writing	0%	0%	0%	0%	0%	6%	0%
testing electrical and mechanical systems or equipment	5%	4%	5%	0%	0%	0%	0%
using foreign languages	0%	0%	0%	6%	0%	6%	0%
using precision measuring equipment	0%	0%	5%	0%	0%	0%	0%
verifying identities and documentation	0%	0%	0%	6%	0%	0%	0%
working in teams	0%	2%	3%	0%	0%	0%	0%
working with others	0%	0%	0%	6%	0%	6%	0%

Source: Own elaboration using ESCO's methodology.

Irrigated rice

Colombia's NDCs allocate 255,000 hectares for irrigated rice cultivation and 207,046 hectares for rainfed rice cultivation. These areas will be the target of comprehensive technology adoption, aiming to increase productivity and efficiency in rice production. By implementing CSA practices and utilizing advanced technologies, Colombia aims to enhance the environmental and economic sustainability of rice farming. The AMTEC 2.0 model will be implemented to promote organization, competitiveness, and profitability for rice producers by integrating comprehensive technologies that boost yields and reduce production costs. This initiative includes weather forecasting, crop modeling, precision agriculture, and the MIRI irrigation system (Govt. of Colombia, 2022).

We developed a tool to estimate the socioeconomic impact of Colombia's NDC targets on specific agricultural activities, including irrigated rice. This tool builds on top of FAO's EX-ACT-VC tool and uses employment intensities for sub-activities within a crop. In the case of irrigated rice, production involves several stages, including land preparation, seedling cultivation, transplanting, irrigation, fertilization, pest control, harvesting, threshing, milling, selling, transportation, and storage. Farmers prepare the land for rice cultivation, grow rice seedlings, transplant them into the fields, provide irrigation and fertilization, control pests, harvest the mature rice plants, thresh the grains from the stalks, mill the rice to remove the husk, and then sell the milled rice to buyers. The harvested rice is then transported to processing facilities and stored until it is shipped to manufacturers or consumers (See Acharya, Table 2). The range of days required for these activities spans from a mean of 140 days per hectare per year in conventional systems, to an average of 70 days in mechanized systems (Acharya et al., 2021; Kinkingninhoun et al., 2020; Johnson, 1996) . Our intensity factors range from a baseline of 103 person-days per hectare to between 228 and 362 person-days, depending on the inclusion of CSA practices(including different irrigation systems).

Our estimates suggest that Colombia's Rice NDC strategy (25,500 hectares of new irrigated rice per year) has the potential to add between 267,600 to 289,300 new jobs over the course of a decade (2022-2032). For the upper-bound estimate, this includes approximately 264,500 direct jobs, 733 indirect jobs, and 2,400 induced jobs. The set of CSA practices considered for rice includes cross-slope barriers, straw mulching, and four different irrigation techniques: alternative wet and dry irrigation, furrow irrigation, solar-powered irrigation, and deficit irrigation. Each of these practices has specific effects on yields, input reduction, and carbon sequestration (see Ishfaq et al., 2020; WFP, 2021; El Baroudy et al., 2014; Ockerby & Fukai, 2011; FAO, 2011). Furthermore, our scenario modeling for CSA practices assumes combinations of cross-slope barriers and straw mulching with any of the four irrigation systems discussed in the literature. Among these irrigation systems, accompanied by the other two CSA practices, alternative wet and dry irrigation (AWDI) observed a higher labor intensity, resulting in a total job creation of 159,400 jobs. On the other hand, both furrow irrigation and solar-powered irrigation would demand 136,800 total new jobs over the decade, followed by deficit irrigation with 38,700.

Most of the 264,500 direct new jobs under the upper-bound of sustainable practices and AWDI come from sub-activities in the production stage (237,900 jobs), followed by processing (14,300 jobs), transport (10,200 jobs), and aggregation (2,000 jobs). Similarly, the majority of indirect jobs would derive from production linkages with rice production, including manufacturing (244 jobs), other agricultural activities (174 jobs), and professional services (149 jobs). Sectoral inter-dependencies determine a similar distribution of induced jobs, with the bulk of newly induced jobs concentrating in agriculture (1,500 jobs), manufacturing (323 jobs), and professional services (239 jobs).

Considering the high prevalence of informal employment and the lower involvement of women in rice production in Colombia, most employment opportunities generated would likely depend on male workers and informal labor. Out of the total of 264,500 newly generated direct jobs over ten years, only 30,900 can be attributed to female workers. Moreover, out of the 264,500, 48,900 are filled by formal employees. These calculations consider up-to-date statistics to project the future expansion of crop-specific formalization (17%) and female labor participation rates (10.8%), based on official microdata. Additionally, over the decade, over 2,600 jobs would come from non-remunerated household labor. These estimates highlight the importance of implementing policies that promote labor formalization and increase female participation in the country's agricultural labor markets.

The cost per producer for the strategy increases to USD 18,453 (USD 2,494 per hectare) without CSA agriculture and USD 22,988 (USD 3,106 per hectare) when incorporating straw mulching, cross-slope barriers, and labor-intensive irrigation systems (e.g., AWDI). The total annual cost for implementing these three CSA practices amounts to USD 79.2 million, with 28% corresponding to the cost of inputs. To gauge international comparability, a measure used is the number of jobs created per USD 1 million invested. In the case of Colombia's NDC strategy for rice, it generates an average of 397 jobs annually for every USD 1 million invested (334 direct, 14 indirect, and 49 induced jobs). The model considers the Climate Vulnerability Monitor for Colombia to account for the impact of climate change-related heat on labor productivity. Based on the strategy proposed in this exercise and different scenarios, climate change is expected to result in a loss of between 20,000 and 46,000 FTE jobs from our core estimate of 264,500 direct jobs.

Considering sensitivity scenarios regarding salaries, the number of total jobs per USD 1 million invested ranges from 362 to 558 per year, on average.[81] Since microdata are available, the model allows users to define three sets of wages: the average wage, a lower bound wage(the average minus a standard deviation), and an upper bound wage(the average plus a standard deviation). For

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example, using wages as one standard deviation below the mean, total employment rises to 289,300 over the decade (558 per USD 1 million invested). The estimate decreases to 267,600 new jobs over the decade if using higher salaries (1 standard deviation above the mean) (362 per USD 1 million in investments). Similarly, the model includes a learning rate, as a percentage that improves the crop's production over time. This rate can be interpreted as labor-augmenting knowledge that increases productivity in the production process. The baseline for this rate is set at 1%. When increasing this rate to 5%, for example, the total net value added shows an improvement.

Skills-occupations dyads within irrigated rice

The following table illustrates an occupations-skills matrix for selected occupations related to rice farming and agriculture, based on CEDEFOP skill labels and ISCO (International Standard Classification of Occupations). The matrix illustrates the percentage of different skills associated with each occupation. The skills are categorized into various domains, including cultivating land and crops, complying with health and safety procedures, conducting academic or market research, operating agricultural or forestry equipment, negotiating and managing contracts and agreements, tending and breeding animals, directing operational activities, promoting products, services, or programs, advising on business or operational matters, analyzing business operations, installing wooden and metal components, complying with environmental protection laws and standards, and more. Typically, various occupations share common skills; however, specific abilities may be more dominant in certain professions compared to others, and there is also partial overlap between certain skill sets across diverse occupations. For instance, the occupation of a farm manager is associated with a high percentage of skills related to planning production processes and directing operational activities, whereas an agricultural technician requires skills in conducting academic or market research and complying with health and safety procedures.

Based on the occupations-skills matrix for selected rice farming occupations, the skills associated with each occupation can be classified into four tiers based on educational requirements: management, engineers, technicians, and non-professionals. The management tier includes skills related to promoting products, services, or programs, planning production processes, estimating resource needs, developing objectives and strategies, and advising on financial, business, or marketing plans. These skills are particularly relevant for the occupation of farm manager, which shows a high percentage of skills in this category. The engineers' tier involves skills in maintaining electrical and mechanical equipment, designing industrial materials or products, and conducting academic or market research. These skills are observed in the occupation of agricultural engineer. The technicians' tier encompasses skills related to conducting academic or market research, analyzing financial and economic data, monitoring operational activities, and complying with health and safety procedures. The occupations of agricultural technician, agricultural inspector, and wholesale merchant require a significant percentage of skills from this tier. Lastly, the non-professionals tier comprises skills in physical tasks like in operating agricultural or forestry equipment, cultivating land and crops, cleaning tools and equipment, tending and breeding animals, and storing goods and materials. The occupations of mixed farmer and hop farmer align with these skills to a notable extent. This tiered classification provides valuable insights into the diverse educational qualifications required across various occupations in rice agriculture, thus facilitating effective workforce planning and educational training programs.

Occupations-skills matrix for selected rice farming occupations

Managers | Engineers | Technicians | Elementary

CEDEFOP-based Skill Labels ↓ per ISCO Occupations →	Mixed farmer	Agricultural Technician	Farm Manager	Agricultural Engineer	Agricultural Inspector	Wholesale merchant in agricultural raw materials, seeds and animal feeds	Hop Farmer
cultivating land and crops	9%	6%	9%	0%	2%	0%	31%
complying with health and safety procedures	18%	6%	6%	0%	5%	0%	5%
conducting academic or market research	0%	9%	0%	9%	12%	6%	0%
operating agricultural or forestry equipment	18%	0%	6%	0%	0%	0%	5%
negotiating and managing contracts and agreements	0%	0%	6%	0%	0%	19%	0%
tending and breeding animals	18%	0%	6%	0%	0%	0%	0%
directing operational activities	9%	0%	6%	0%	2%	0%	5%
promoting products, services, or programs	9%	0%	11%	0%	0%	0%	0%
advising on business or operational matters	0%	6%	0%	6%	2%	0%	5%
analysing business operations	0%	6%	0%	6%	5%	0%	0%
installing wooden and metal components	0%	0%	3%	6%	2%	0%	5%
complying with environmental protection laws and standards	0%	0%	3%	3%	2%	0%	7%
management skills	9%	0%	6%	0%	0%	0%	0%
monitoring safety or security	0%	0%	0%	0%	15%	0%	0%
analysing scientific and medical data	0%	11%	0%	0%	2%	0%	0%
technical or academic writing	0%	6%	0%	3%	5%	0%	0%
advising on environmental issues	0%	3%	0%	3%	2%	0%	5%
analysing financial and economic data	0%	0%	0%	6%	0%	6%	0%
identifying opportunities	0%	0%	0%	0%	0%	13%	0%
engaging with others to identify needs	0%	0%	0%	0%	0%	13%	0%
planning production processes	0%	0%	3%	3%	0%	6%	0%
planting, pruning and harvesting trees, crops and other plants	0%	0%	0%	0%	0%	0%	10%
using computer aided design and drawing tools	0%	0%	0%	9%	0%	0%	0%
designing systems and products	0%	0%	0%	9%	0%	0%	0%
disposing of non-hazardous waste or debris	9%	0%	0%	0%	0%	0%	0%
evaluating systems, programmes, equipment and products	0%	6%	0%	3%	0%	0%	0%
monitoring financial and economic resources and activity	0%	0%	0%	0%	2%	6%	0%
monitoring environmental conditions	0%	6%	0%	0%	2%	0%	0%
gathering information from physical or electronic sources	0%	6%	0%	0%	2%	0%	0%
purchasing goods or services	0%	0%	6%	0%	2%	0%	0%
performing calculations	0%	6%	0%	0%	0%	0%	2%
cleaning interior and exterior of buildings	0%	3%	0%	0%	0%	0%	5%
assessing land or real estate	0%	3%	0%	0%	0%	0%	5%
preparing financial documents, records, reports, or budgets	0%	0%	0%	0%	0%	6%	0%
performing risk analysis and management	0%	0%	0%	0%	0%	6%	0%
accessing and analysing digital data	0%	0%	0%	0%	0%	6%	0%
designing industrial materials, systems or products	0%	0%	0%	6%	0%	0%	0%
liaising and networking	0%	0%	0%	0%	0%	6%	0%
developing professional relationships or networks	0%	0%	0%	0%	0%	6%	0%
developing solutions	0%	0%	0%	6%	0%	0%	0%
tending and breeding aquatic animals	0%	6%	0%	0%	0%	0%	0%
maintaining electrical, electronic and precision equipment	0%	6%	0%	0%	0%	0%	0%
advising on design or use of technologies	0%	0%	6%	0%	0%	0%	0%
presenting general information	0%	0%	6%	0%	0%	0%	0%
monitoring operational activities	0%	3%	3%	0%	0%	0%	0%
maintaining operational records	0%	0%	0%	3%	2%	0%	0%
collecting and preparing specimens or materials for testing	0%	0%	0%	0%	5%	0%	0%
ensuring compliance with legislation	0%	0%	0%	0%	5%	0%	0%
advising on workplace health and safety issues	0%	0%	0%	0%	5%	0%	0%
responding to complaints	0%	0%	0%	0%	5%	0%	0%
storing goods and materials	0%	0%	0%	0%	0%	0%	5%
using hand tools	0%	0%	0%	0%	0%	0%	5%
calculating and estimating	0%	0%	0%	3%	0%	0%	0%
directing, supervising and coordinating projects	0%	0%	0%	3%	0%	0%	0%
developing policies and legislation	0%	0%	0%	3%	0%	0%	0%
developing operational policies and procedures	0%	0%	0%	3%	0%	0%	0%
maintaining mechanical machinery	0%	0%	0%	3%	0%	0%	0%
handling and disposing of hazardous materials	0%	0%	3%	0%	0%	0%	0%
cleaning tools, equipment, workpieces and vehicles	0%	3%	0%	0%	0%	0%	0%
reporting incidents and defects	0%	0%	3%	0%	0%	0%	0%
estimating resource needs	0%	0%	3%	0%	0%	0%	0%
developing objectives and strategies	0%	0%	3%	0%	0%	0%	0%
advising on products and services	0%	3%	0%	0%	0%	0%	0%
training on operational procedures	0%	0%	3%	0%	0%	0%	0%
implementing new procedures or processes	0%	0%	3%	0%	0%	0%	0%
monitoring, inspecting and testing	0%	0%	0%	0%	2%	0%	0%
monitoring health conditions of humans and animals	0%	0%	0%	0%	2%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	0%	2%	0%	0%
presenting information in legal proceedings	0%	0%	0%	0%	2%	0%	0%
positioning materials, tools or equipment	0%	0%	0%	0%	0%	0%	2%

Source: Own elaboration using ESCO's methodology.

Panela sugar

Colombia's NDCs focus on developing a central planning, management, and institutional coordination strategy to foster low-emission practices and contribute to the country's sustainable development of panela sugar production. The NDC aims to support interventions involving alternative technology transfer, such as replacing diesel engines with electric ones and adopting more energy-efficient bagasse combustion in furnaces. Additionally, the NDC seeks to improve production practices, including efficient use of synthetic fertilizers, reducing burning practices, optimizing energy consumption in soil cultivation, and managing wastewater. The plan also entails restoring natural systems and building capacities, as well as implementing a monitoring, reporting, and verification (MRV) system to validate progress and results. Through these strategies, the NDC aims to enhance the environmental sustainability of panela sugar production while reducing greenhouse gas emissions (Govt. of Colombia, 2022). Colombia's NDC does not specify the number of hectares allocated to this strategy. Our estimates assume an annual target of hectares equivalent to 10% of the current total production area, approximately 200,000 hectares (i.e., 20,000 hectares per year).

We developed a tool to estimate the socioeconomic impact of Colombia's NDC targets on specific agricultural activities, including panela sugar production. This tool builds on top of FAO's EX-ACT-VC tool and uses employment intensities for sub-activities within the crop. In the case of panela sugar production, workers are responsible for nurturing and maintaining the crops, conducting panela sugar harvesting operations, processing the harvested panela sugar, and transporting the processed products to the market or manufacturers. The processed panela sugar is then distributed to various downstream stakeholders or used to produce panela sugar or other sugar-based products. The baseline range of time required for these activities varies between 80 and 350 days per hectare per year (Ramírez, 2008; Rana et al., 2021; Sharma & Prakash, 2011). Our intensity factors range from a baseline of 133 person-days per hectare to 170 person-days incorporating CSA panela sugar practices into the production process.

According to our calculations, Colombia's panela sugar NDC strategy can create approximately 139,000 to 219,000 new jobs over the span of ten years (2022-2032). The average CSA estimate comprises the use of CSA practices and yields around 128,000 direct jobs, 6,000 indirect jobs, and 20,000 induced jobs. These estimates result from introducing agroforestry, cross-slope barriers and solar powered irrigation into panela sugar systems plantations. Moreover, the pertinent literature has shown that integrated agroforestry have positive effects on yields and carbon sequestration (Torres et al., 2017; FAO, 2011). In contrast, conventional panela sugar production in the BAU scenario would create 48,368 total jobs (22,605 direct, 5,847 indirect, and 19,916 induced). By adopting these CSA practices within panela sugar plantations, the NDC strategy boosts job creation, increases net value added to USD 383 million, and doubles CO_2 equivalent sequestration to 1.9 million tons (from 0.9 million), showcasing its socio-economic and environmental benefits.

The majority of the 128,000 direct new jobs under the upper-bound of sustainable panela sugar production comes from sub-activities in the production stage (122,800 jobs), followed by transportation (2,000 jobs), processing (1,700 jobs), and aggregation (1,000 jobs). Similarly, most of indirect jobs would derive from production linkages of panela sugar production with manufacturing (900 jobs), with other agricultural activities (600 jobs), and with professional services (500 jobs). Sectoral inter-dependencies determine a similar distribution of induced jobs, with the bulk of newly induced jobs concentrating in agriculture (5,800 jobs), manufacturing (1,200 jobs), and professional services (900 jobs).

Considering the high prevelance of informal employment and the lower involvement of women in panela sugar production in Colombia, most of the employment opportunities generated would depend on male workers and informal labor. Out of the total of 128,000 newly generated direct jobs over ten years, 16,300 can be attributed to female workers, while 16,900 are filled by formal employees. These calculations consider up-to-date statistics to project the future expansion of crop-specific formality (12.4%) and female labor participation rates (11.8%) based on official microdata. Additionally, over the decade, over 15,300 jobs would come from non-remunerated household labor. These projections underscore the significance of enacting policies that encourage the formalization of labor and increased female participation in the agricultural labor markets within the nation.

The cost per producer for the strategy increases to a yearly average of USD 38,168 (USD 1,509 per hectare) without CSA agriculture and to a yearly average of USD 53,773 when incorporating panela sugar (USD 2,125 per hectare). The total annual cost for implementing CSA commercial panela sugar amounts to USD 21.3 million, with 23% corresponding to inputs. To gauge international comparability, a measure used is the number of jobs created per USD 1 million invested. In the case of Colombia's NDC strategy for panela sugar—integrated commercial panela sugar—it generates an average of 665 jobs annually for every USD 1 million invested (602 direct, 14 indirect, and 49 induced jobs). The model considers the Climate Vulnerability Monitor for Colombia to account for the impact of climate change-related heat on labor productivity. Based on the strategy proposed in this exercise and different scenarios, climate change would result in a loss of between 6,800 and 15,700 FTE jobs from our core estimate of 131,000 direct jobs.

Considering sensitivity scenarios regarding salaries, the number of total jobs per USD 1 million invested ranges from 139 to 219 per year, on average. Since there is microdata availability, the model allows users to define three sets of wages: the average wage, a lower bound wage (the average minus a standard deviation), and an upper bound wage(the average plus a standard deviation). For example, using wages as one standard deviation below the mean, total employment rises to 219,000 jobs over the decade (825 jobs per USD 1 million invested). The estimate decreases to 139,000 new jobs over the decade if using higher salaries (1 standard deviation above the mean) (630 jobs per USD 1 million invested). Similarly, the model includes a learning rate, as a percentage that improves the crop's production over time. This rate can be interpreted as labor-augmenting knowledge that increases productivity in the production process. The baseline for this rate is set at 1%. When increasing this rate to 5%, for example, total value-added over the period rises to USD 400 million.

Skills-occupations dyads within panela sugar

The following table illustrates an occupations-skills matrix for selected occupations related to panela sugar plantations. The matrix is based on CEDEFOP skill Labels and ISCO (International Standard Classification of Occupations), showing the percentage of different skills associated with each occupation. The occupations-skills matrix for selected panela sugar-related high skilled occupations includes skills such as accessing and analyzing digital data, analyzing business operations, cleaning tools, equipment, workpieces, and vehicles, complying with health and safety procedures, collaborating and liaising, and engaging with others to identify needs, among others. In general, occupations share some common skills, but certain skills are more prevalent in one occupation compared to others, and there is also partial overlap between certain skills across different occupations. For instance, occupations like sugar refinery operator may require skills in operating food processing machinery and measuring dimensions and related properties, while wholesale merchant in sugar, chocolate, and sugar confectionery may necessitate skills in negotiating and managing contracts and agreements, and import export specialist in sugar, chocolate, and sugar confectionery requires expertise in ensuring compliance with legislation.

Moreover, upon analyzing the skills presented in the occupations-skills matrix, we can categorize them into four tiers based on educational requirements: management, engineers, technicians, and non-professionals. The management tier includes occupations such as sugar, chocolate, and sugar confectionery distribution manager who oversees the distribution and sales operations of panela sugar products, relying on skills such as performing risk analysis and management and ensuring compliance with legislation. Managers may execute financial transactions, manage budgets or finances, and develop financial, business, or marketing plans to drive the success of their distribution operations. Managerial occupations also include import export manager in sugar, chocolate, and sugar confectionery. They are involved in tasks such as monitoring and evaluating the performance of individuals and engaging with others to identify needs in the import-export processes of sugar, chocolate, and sugar confectionery products. The engineers tier involves occupations like sugar refinery operators, who are trained to work with sophisticated machinery and processes in sugar refineries. They operate food processing machinery, handle mixing and separating machinery, and may also be involved in installing wooden and metal components to ensure the smooth functioning of the refinery. The technicians' tier encompasses occupations such as wholesale merchant in sugar, chocolate, and sugar confectionery and import export specialist in sugar, chocolate, and sugar confectionery. These professionals are skilled in tasks such as complying with health and safety procedures, gathering information from physical or electronic sources, monitoring operational activities, and preparing financial documents, records, reports, or budgets related to the sugar and confectionery trade. This information can be useful for workforce planning and designing targeted training programs to support the panela sugar industry's growth and success.

Table A6 3. Occupations-Skills matrix for selected Panela sugar occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations → (Managers / Engineers / Technicians / Elementary)	Mixed farmer	Agricultural Technician	Farm Manager	Agricultural Engineer	Agricultural Inspector	Wholesale merchant in agricultural raw materials, seeds and animal feeds	Crop Production Manager	Crop production worker	Agronomic crop production team leader
cultivating land and crops	9%	6%	9%	0%	2%	0%	0%	0%	0%
complying with health and safety procedures	18%	6%	6%	0%	5%	0%	0%	0%	0%
conducting academic or market research	0%	9%	0%	9%	12%	6%	0%	0%	0%
operating agricultural or forestry equipment	18%	0%	6%	0%	0%	0%	0%	0%	0%
negotiating and managing contracts and agreements	0%	0%	6%	0%	0%	19%	0%	0%	0%
tending and breeding animals	18%	0%	6%	0%	0%	0%	0%	0%	0%
directing operational activities	9%	0%	6%	0%	2%	0%	0%	0%	0%
promoting products, services, or programs	9%	0%	11%	0%	0%	0%	0%	0%	0%
advising on business or operational matters	0%	6%	0%	6%	2%	0%	0%	0%	0%
analysing business operations	0%	6%	0%	6%	5%	0%	0%	0%	0%
installing wooden and metal components	0%	0%	3%	6%	2%	0%	0%	0%	0%
complying with environmental protection laws and standards	0%	0%	3%	3%	2%	0%	0%	0%	0%
management skills	9%	0%	6%	0%	0%	0%	5%	0%	2%
monitoring safety or security	0%	0%	0%	0%	15%	0%	0%	0%	0%
analysing scientific and medical data	0%	11%	0%	0%	2%	0%	0%	0%	0%
technical or academic writing	0%	6%	0%	3%	5%	0%	0%	0%	0%
advising on environmental issues	0%	3%	0%	3%	2%	0%	0%	0%	0%
analysing financial and economic data	0%	0%	0%	6%	0%	6%	0%	0%	0%
identifying opportunities	0%	0%	0%	0%	0%	13%	0%	0%	0%
engaging with others to identify needs	0%	0%	0%	0%	0%	13%	0%	0%	0%
planning production processes	0%	0%	3%	3%	0%	6%	0%	0%	0%
planting, pruning and harvesting trees, crops and other plants	0%	0%	0%	0%	0%	0%	0%	0%	0%
using computer aided design and drawing tools	0%	0%	0%	9%	0%	0%	0%	0%	0%
designing systems and products	0%	0%	0%	9%	0%	0%	0%	0%	0%
disposing of non-hazardous waste or debris	9%	0%	0%	0%	0%	0%	0%	0%	0%
evaluating systems, programmes, equipment and products	0%	6%	0%	3%	0%	0%	0%	0%	0%
monitoring financial and economic resources and activity	0%	0%	0%	0%	2%	6%	0%	0%	0%
monitoring environmental conditions	0%	6%	0%	0%	2%	0%	0%	0%	0%
gathering information from physical or electronic sources	0%	6%	0%	0%	2%	0%	0%	0%	0%
purchasing goods or services	0%	0%	6%	0%	2%	0%	0%	0%	0%
performing calculations	0%	6%	0%	0%	0%	0%	0%	0%	0%
cleaning interior and exterior of buildings	0%	3%	0%	0%	0%	0%	0%	0%	0%
assessing land or real estate	0%	3%	0%	0%	0%	0%	0%	0%	0%
preparing financial documents, records, reports, or budgets	0%	0%	0%	0%	0%	6%	0%	0%	0%
performing risk analysis and management	0%	0%	0%	0%	0%	6%	0%	0%	0%
accessing and analysing digital data	0%	0%	0%	0%	0%	6%	0%	0%	0%
designing industrial materials, systems or products	0%	0%	0%	6%	0%	0%	0%	0%	0%
liaising and networking	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing professional relationships or networks	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing solutions	0%	0%	0%	6%	0%	0%	0%	0%	0%
tending and breeding aquatic animals	0%	6%	0%	0%	0%	0%	0%	0%	0%
maintaining electrical, electronic and precision equipment	0%	6%	0%	0%	0%	0%	0%	0%	0%
advising on design or use of technologies	0%	0%	6%	0%	0%	0%	0%	0%	0%
presenting general information	0%	0%	6%	0%	0%	0%	0%	0%	0%
monitoring operational activities	0%	3%	3%	0%	0%	0%	0%	0%	0%
maintaining operational records	0%	0%	0%	3%	2%	0%	0%	0%	0%
collecting and preparing specimens or materials for testing	0%	0%	0%	0%	5%	0%	0%	0%	0%
ensuring compliance with legislation	0%	0%	0%	0%	5%	0%	0%	0%	0%
advising on workplace health and safety issues	0%	0%	0%	0%	5%	0%	0%	0%	0%
responding to complaints	0%	0%	0%	0%	5%	0%	0%	0%	0%
storing goods and materials	0%	0%	0%	0%	0%	0%	0%	0%	0%
using hand tools	0%	0%	0%	0%	0%	0%	0%	0%	0%
calculating and estimating	0%	0%	0%	3%	0%	0%	0%	0%	0%
directing, supervising and coordinating projects	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing policies and legislation	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing operational policies and procedures	0%	0%	0%	3%	0%	0%	0%	0%	0%
maintaining mechanical machinery	0%	0%	0%	3%	0%	0%	0%	0%	0%
handling and disposing of hazardous materials	0%	0%	3%	0%	0%	0%	0%	0%	0%
cleaning tools, equipment, workpieces and vehicles	0%	3%	0%	0%	0%	0%	0%	0%	0%
reporting incidents and defects	0%	0%	3%	0%	0%	0%	0%	0%	0%
estimating resource needs	0%	0%	3%	0%	0%	0%	0%	0%	0%
developing objectives and strategies	0%	0%	3%	0%	0%	0%	2%	0%	2%
advising on products and services	0%	3%	0%	0%	0%	0%	0%	0%	0%
training on operational procedures	0%	0%	3%	0%	0%	0%	0%	0%	0%
implementing new procedures or processes	0%	0%	3%	0%	0%	0%	0%	0%	0%
monitoring, inspecting and testing	0%	0%	0%	0%	2%	0%	0%	0%	0%
monitoring health conditions of humans and animals	0%	0%	0%	0%	2%	0%	0%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	0%	2%	0%	0%	0%	0%
presenting information in legal proceedings	0%	0%	0%	0%	2%	0%	0%	0%	0%
positioning materials, tools or equipment	0%	0%	0%	0%	0%	0%	0%	0%	0%
moving and lifting	0%	0%	0%	0%	0%	0%	9%	15%	8%
tending plants and crops	0%	0%	0%	0%	0%	0%	30%	38%	40%
cleaning	0%	0%	0%	0%	0%	0%	5%	6%	4%
documenting and recording information	0%	0%	0%	0%	0%	0%	5%	3%	4%
managing information	0%	0%	0%	0%	0%	0%	2%	3%	2%
organising, planning and scheduling work and activities	0%	0%	0%	0%	0%	0%	5%	0%	2%
supervising people	0%	0%	0%	0%	0%	0%	2%	0%	2%
allocating and controlling resources	0%	0%	0%	0%	0%	0%	5%	0%	4%
operating machinery for the manufacture of products	0%	0%	0%	0%	0%	0%	2%	3%	2%
using precision instrumentation and equipment	0%	0%	0%	0%	0%	0%	0%	3%	0%
operating mobile plant	0%	0%	0%	0%	0%	0%	9%	18%	13%
protecting and enforcing	0%	0%	0%	0%	0%	0%	9%	6%	8%
negotiating	0%	0%	0%	0%	0%	0%	2%	0%	2%
presenting information	0%	0%	0%	0%	0%	0%	2%	3%	0%
promoting, selling and purchasing	0%	0%	0%	0%	0%	0%	5%	3%	4%

Source: Own elaboration using ESCO's methodology. ESCO does not include occupations that explicitly refer to "Teff"; these occupations were selected to represent occupations closely related to occupations in teff production.

Occupations-skills matrix for selected sugarcane occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations → (Managers / Engineers / Technicians)	Sugar, chocolate and sugar confectionery distribution manager	Sugar refinery operator	Wholesale merchant in sugar, chocolate and sugar confectionery	Import export specialist in sugar, chocolate and sugar confectionery	Import export manager in sugar, chocolate and sugar confectionery
accessing and analysing digital data	5%	0%	6%	6%	0%
analysing business operations	5%	0%	0%	0%	0%
analysing financial and economic data	0%	0%	6%	0%	0%
analysing scientific and medical data	5%	0%	0%	0%	0%
cleaning	0%	5%	0%	0%	0%
cleaning tools, equipment, workpieces and vehicles	0%	5%	0%	0%	0%
collaborating and liaising	0%	5%	0%	0%	0%
communicating with colleagues and clients	5%	0%	0%	6%	0%
complying with environmental protection laws and standards	0%	3%	0%	0%	0%
complying with health and safety procedures	0%	11%	0%	0%	0%
complying with operational procedures	5%	5%	0%	0%	0%
conducting academic or market research	0%	0%	6%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	0%	0%
developing operational policies and procedures	5%	0%	0%	6%	0%
developing professional relationships or networks	0%	0%	6%	0%	0%
developing solutions	5%	0%	0%	6%	0%
disposing of non-hazardous waste or debris	0%	3%	0%	0%	0%
engaging with others to identify needs	0%	0%	13%	0%	6%
ensuring compliance with legislation	10%	11%	0%	6%	6%
executing financial transactions	5%	0%	0%	0%	6%
gathering information from physical or electronic sources	5%	0%	0%	0%	0%
identifying opportunities	0%	0%	13%	0%	0%
implementing new procedures or processes	5%	0%	0%	13%	0%
installing wooden and metal components	0%	5%	0%	0%	0%
liaising and networking	0%	0%	6%	0%	0%
maintaining operational records	5%	0%	0%	0%	0%
management skills	0%	0%	0%	0%	0%
managing budgets or finances	5%	0%	0%	6%	0%
managing transport and logistics activities	5%	0%	0%	6%	0%
measuring dimensions and related properties	0%	5%	0%	0%	0%
mediating and resolving disputes	0%	0%	0%	6%	0%
monitoring and evaluating the performance of individuals	0%	0%	0%	0%	11%
monitoring financial and economic resources and activity	0%	0%	6%	0%	0%
monitoring operational activities	0%	5%	0%	6%	6%
monitoring, inspecting and testing	0%	5%	0%	0%	6%
negotiating and managing contracts and agreements	0%	0%	19%	0%	6%
operating food processing machinery	0%	8%	0%	0%	6%
operating mixing and separating machinery	0%	11%	0%	0%	6%
performing risk analysis and management	14%	0%	6%	0%	0%
planning production processes	5%	0%	6%	6%	0%
preparing documentation for contracts, applications, or permits	0%	0%	0%	6%	6%
preparing financial documents, records, reports, or budgets	5%	0%	6%	0%	6%
repairing and installing mechanical equipment	0%	5%	0%	0%	6%
supervising a team or group	5%	0%	0%	0%	0%
technical or academic writing	0%	0%	0%	6%	0%
using foreign languages	0%	0%	0%	6%	0%
using precision measuring equipment	0%	3%	0%	0%	11%
verifying identities and documentation	0%	0%	0%	0%	6%
working in teams	0%	3%	0%	0%	6%
working with others	0%	0%	0%	6%	6%

Source: Own elaboration using ESCO's methodology.

Forestry

Colombia's NDCs aim to enhance sustainable forestry practices and mitigate greenhouse gas emissions. The NDCs focus on the development and consolidation of the productive chain of commercial forest plantations. This involves technical and economic coordination to produce timber from legal commercial forest plantations, aligned with the action plan for the forestry chain. The target is to establish new forest plantations covering 300,000 hectares between 2015 and 2030 (20,000 per year). The primary objectives are to increase carbon stocks, promote sustainable forest management, and contribute to the overall environmental and economic sustainability of Colombia's forestry sector (Govt. of Colombia, 2022).

We developed a tool to estimate the socioeconomic impact of Colombia's NDC targets on specific agricultural activities, including forestry. This tool builds on top of FAO's EX-ACT-VC tool and uses employment intensities for sub-activities within a crop. In the case of forestry production, various stages are covered, including tree planting and nurturing, timber harvesting, log transportation, processing, and distribution. Forestry workers are involved in nurturing and maintaining the trees, conducting timber harvesting operations, processing the logs, and transporting them to the market. The processed timber is then distributed to manufacturers or other downstream stakeholders. The baseline range of time required for these activities varies between 60 and 100 days per hectare per year (Alavalapati & Mercer, 2004; Rahman, 2011; Segerström, 1979). Our intensity factors range from a baseline of 93 person-days per hectare to 110 person-days incorporating sustainable forestry practices into the production process.

According to our calculations, Colombia's Forestry NDC strategy can create between 366,100 to 400,900 new jobs over ten years (2022-2032). The upper-bound estimate comprises the use of CSA practices and yields around 362,720 direct jobs, 660 indirect jobs, and 2,776 induced jobs. Specifically, these upper-bound results result from introducing agroforestry systems along commercial forest plantations. Furthermore, the literature has shown that agroforestry systems have positive effects on carbon sequestration (Torres et al., 2017; Hoff, 2017). In this regard, the BAU scenario of conventional forest production would create 82,039 total jobs (74,400 direct, 1,300 indirect, and 6,300 induced). The NDC strategy under BAU would generate USD 990 million in net value added for the decade. Finally, the integration of agroforestry doubles the estimate of CO_2 equivalent sequestration, from 5.9 million per decade under BAU to 8.9 million under agroforestry integration.

The majority of the 362,700 direct new jobs under the upper-bound of agroforestry integration comes from sub-activities in the production stage (337,900 jobs), followed by transportation (12,000 jobs), aggregation (8,000 jobs), and processing (4,800 jobs). Similarly, most indirect jobs would derive from production linkages of forestry production with other agricultural activities (424 jobs), transportation (91 jobs), and with professional services (58 jobs). Sectoral inter-dependencies determine a similar distribution of induced jobs, with the bulk of new induced jobs concentrating in agriculture (2,400 jobs), transportation (154 jobs), and professional services (110 jobs).

Considering the high prevelance of informal employment and lower involvement of women in forestry production in Colombia, most of the employment opportunities generated would depend on male workers and informal labor. Out of the total of 362,700 newly generated direct jobs over ten years, only 3,900 can be attributed to female workers, while 40,725 are filled by formal employees. These calculations utilize up-to-date statistics to project the future expansion of crop-specific formality (10.5%) and female labor participation rates (1%) based on official microdata. Additionally, over the decade, over 1,400 jobs are expected to come from non-remunerated household labor. These estimates highlight the importance of implementing policies that promote labor formalization and increase female participation in the agricultural labor markets within the country.

The cost per producer for the strategy increases to a yearly average of USD 251,535 (USD 2,966 per hectare) without CSA agriculture, and to a yearly average of USD 281,622 when incorporating agroforestry (USD 3,321 per hectare). The total annual cost for implementing sustainable commercial forestry amounts to USD 66.4 million, with 39% corresponding to inputs. To gauge international comparability, a measure used is the number of jobs created per USD 1 million invested. In the case of Colombia's NDC strategy for agroforestry-integrated commercial forestry, an average of 553 jobs is generated annually for every USD 1 million invested (547 direct, 1 indirect, and 6 induced jobs). The model considers the Climate Vulnerability Monitor for Colombia to account for the impact of climate change-related heat on labor productivity. Based on the strategy proposed in this exercise and different scenarios, climate change would result in a loss of between 31,100 and 71,800 FTE jobs from our core estimate of 362,700 direct jobs.

Considering sensitivity scenarios regarding salaries, the number of total jobs per USD 1 million invested ranges from 550 to 581 per year, on average. Since microdata is available, the model allows users to define three sets of wages: the average wage, a lower bound wage (the average minus a standard deviation), and an upper bound wage (the average plus a standard deviation). For example, using wages as one standard deviation below the mean, total employment rises to 400,900 over the decade (581 per USD 1 million invested). The estimate decreases to 366,100 new jobs over the decade if using higher salaries (1 standard deviation above the mean) (550 per USD 1 million invested). Also, the model includes a learning rate, as a percentage that improves the crop's production over time. This rate can be interpreted as labor-augmenting knowledge that increases productivity in the production process. The baseline for this rate is set at 1%. When increasing this rate to 5%, for example, total sale values rise to USD 1 billion (from USD 990 million).

Skills-occupations dyads within forestry

The following table presents an occupations-skills matrix for selected forestry occupations based on CEDEFOP skill labels and ISCO (International Standard Classification of Occupations). The matrix indicates the percentage of different skills associated with each forestry occupation. The skills are categorized into various domains, including moving and lifting, tending plants and crops, monitoring, and inspecting, analyzing, and evaluating information, using digital tools, organizing, and planning work, operating machinery, protecting, and enforcing, providing health care, advising, and consulting, and more. Commonly, different occupations share skills, but some specific abilities may be more prevalent in particular professions than in others. Additionally, there is a partial overlap in certain skill sets across a variety of occupations. For instance, the occupation of forester"is associated with a high percentage of skills related to planning, scheduling, and analyzing information, while forestry machinery technician is linked to skills in repairing mechanical and electrical equipment.

Furthermore, the skills presented in the occupations-skills matrix for selected forestry occupations can be classified into four tiers based on educational requirements: management, engineers, technicians, and non-professionals. The management tier includes skills related to developing objectives, strategies, and decision-making, as evident in the percentages associated with forester and forestry adviser occupations. The engineer's tier encompasses skills in operating machinery, maintaining equipment, and performing technical tasks, exemplified by the occupation of forestry machinery technician. The technicians' tier involves skills related to monitoring, inspecting, and analyzing information, as shown in the percentages for forestry inspector and forestry technician occupations. Lastly, the non-professionals tier comprises skills in physical tasks like moving and lifting, tending plants and crops, cleaning, and sorting and packaging goods, which are vital for forest workers, forest ranger, and forestry equipment operator roles. This tiered classification highlights the diverse educational qualifications needed across various forestry occupations, providing valuable insights for workforce planning and educational training programs in the forestry sector.

Table A6 4. Occupations-skills matrix for selected forestry occupations

Occupations-skills matrix for selected forestry occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations → (Managers, Engineers, Technicians, Elementary)	Forestry equipment operator	Forestry inspector	Forest worker	Forester	Forest ranger	Forestry machinery technician	Forestry adviser	Forestry technician
moving and lifting	5%	0%	4%	0%	0%	0%	0%	0%
tending plants and crops	24%	0%	29%	8%	8%	0%	3%	18%
cleaning	0%	0%	4%	0%	3%	0%	0%	0%
using hand tools	5%	0%	4%	0%	0%	7%	0%	0%
handling animals	0%	0%	0%	0%	3%	0%	0%	0%
sorting and packaging goods and materials	2%	0%	6%	0%	3%	0%	3%	0%
monitoring, inspecting and testing	7%	32%	4%	11%	16%	0%	20%	18%
documenting and recording information	3%	0%	2%	3%	3%	7%	3%	2%
analysing and evaluating information and data	5%	18%	0%	3%	5%	0%	5%	5%
measuring physical properties	3%	4%	0%	0%	0%	2%	0%	0%
conducting studies, investigations and examinations	0%	7%	0%	0%	0%	5%	3%	2%
calculating and estimating	0%	0%	0%	3%	0%	2%	5%	0%
accessing and analysing digital data	2%	0%	0%	0%	0%	0%	0%	0%
setting up and protecting computer systems	0%	0%	0%	0%	0%	5%	0%	0%
using digital tools for collaboration, content creation and problem solving	2%	0%	0%	3%	0%	0%	0%	2%
programming computer systems	0%	0%	0%	0%	0%	5%	0%	0%
working with computers	0%	0%	0%	0%	0%	5%	0%	0%
building and repairing structures	3%	0%	10%	0%	3%	19%	0%	7%
organising, planning and scheduling work and activities	2%	4%	0%	24%	0%	2%	10%	0%
developing objectives and strategies	7%	4%	2%	0%	5%	0%	3%	0%
supervising people	0%	4%	0%	8%	0%	0%	3%	9%
allocating and controlling resources	0%	0%	0%	3%	0%	0%	0%	0%
making decisions	0%	0%	2%	0%	5%	0%	5%	0%
management skills	0%	0%	0%	3%	0%	0%	0%	0%
installing, maintaining and repairing mechanical equipment	3%	0%	0%	0%	0%	0%	0%	0%
operating machinery for the extraction and processing of raw materials	3%	0%	0%	0%	0%	0%	0%	0%
driving vehicles	0%	0%	0%	0%	0%	5%	0%	0%
installing, maintaining and repairing electrical, electronic and precision equipment	0%	0%	0%	0%	0%	10%	0%	0%
operating mobile plant	16%	0%	8%	0%	0%	14%	0%	9%
protecting and enforcing	2%	14%	19%	8%	14%	7%	10%	5%
providing health care or medical treatments	2%	0%	0%	0%	3%	2%	0%	5%
providing information and support to the public and clients	0%	0%	0%	0%	5%	0%	0%	0%
advising and consulting	3%	7%	0%	11%	5%	0%	18%	9%
writing and composing	0%	7%	0%	5%	5%	0%	3%	0%
working with others	0%	0%	4%	0%	0%	2%	0%	2%
teaching and training	0%	0%	0%	0%	3%	0%	5%	0%
communication, collaboration and creativity	0%	0%	0%	3%	0%	0%	0%	0%
using more than one language	0%	0%	0%	0%	3%	0%	0%	0%
liaising and networking	0%	0%	0%	3%	8%	0%	5%	2%
promoting, selling and purchasing	0%	0%	0%	3%	0%	0%	0%	5%

Source: Own elaboration using ESCO's methodology.

Annex 6: Job Opportunities in Ethiopian Agriculture: Standalone Analyses per Crop

This section presents a series of standalone analyses assessing the job creation potential in key agricultural crops in Ethiopia, namely barley, corn, teff, and wheat production. Each analysis delves into the specific crop's contribution to job growth, highlighting the socioeconomic impact of Ethiopia's agricultural practices and policies. Drawing from Ethiopia's NDCs that aim to promote sustainability and mitigate greenhouse gas emissions, these analyses evaluate the employment opportunities across different stages of each crop's production cycle. Additionally, insights are provided on the integration of CSA practices, which can further boost job creation and environmental benefits. This section offers a comprehensive understanding of the unique dynamics and potential strategies for fostering job growth and overall economic and environmental sustainability in each of these critical agricultural sectors. To complement these analyses, the section also includes an overview of the skills required for selected occupations within each crop, providing insights for workforce planning and educational training programs in agriculture.

Barley

Ethiopia's NDCs aim to enhance food security by improving agricultural productivity in a climate-smart manner. The NDCs highlight the enhancement and expansion of the value chain for barley cultivation. This includes the promotion of yield-increasing techniques and economic coordination to boost barley production across the country, in line with the strategy for enhancing food security. The target is to cover more than 225,913 new hectares by 2030 for barley production (22,500 Hectares per year), which underpins the overarching objectives to increase food availability, promote CSA practices, and contribute to the overall environmental and economic sustainability of Ethiopia's agricultural sector (Govt. of Ethiopia, 2021).

To grasp the wider socioeconomic effects of barley farming, particularly in relation to Ethiopia's NDC objectives, a specific instrument inspired by the FAO's EX-ACT-VC was crafted. This instrument analyses job creation and other elements vital to the agricultural intricacies of barley growth. In the context of barley production in Ethiopia, the process includes various stages such as seed selection and sowing, plant nurturing, grain harvesting, processing, and distribution. Agricultural workers participate in planting and tending to the barley plants, overseeing the harvest, processing the grains, and ensuring their transportation to markets. The processed barley is subsequently distributed to manufacturers or other end users. The baseline range of time required for these activities varies between 50 and 70 days per hectare per year of productive cycle (Wollie, 2018; Khatun et al., 2018). Our intensity factors range from a baseline of 68 person-days per hectare to 103 person-days incorporating sustainable barley practices into the production process.

According to our calculations, Ethiopia's barley NDC strategy can create between 169,992 to 252,687 new jobs over the course of ten years (2022-2032). The upper-bound estimate comprises the use of sustainable practices, and yields around 69,431 direct jobs, 25,498 indirect jobs, and 75,063 induced jobs. Specifically, these upper-bound estimates result from introducing Integrated Soil Fertility Management (ISFM), furrow irrigation, and agroforestry practices within barley production. The literature has shown that these practices have positive effects on yields and carbon sequestration (Ockerby & Fukai, 2001; Torres et al., 2017). Conversely, the BAU scenario of traditional barley production would create 152,457 total jobs (65,000 direct, 23,000 indirect, and 64,000 induced jobs). The NDC strategy under BAU would generate USD 859 million in net value added over the course of the decade, versus USD 1,673 million when integrating sustainable practices. Also, these sustainable practices would increase the estimate of CO_2 equivalent sequestration, from 1.7 million tons per decade under BAU, to an estimated of 5.8 million tons over the decade.

The majority of the 69,000 direct new jobs under the upper bound comes from sub-activities in the production stage (49,600 jobs), followed by transportation (9,000 jobs), processing (5,400 jobs), and aggregation (5,400 jobs). Similarly, most indirect jobs would derive from production linkages of barley production with other agricultural activities (11,900 jobs), construction (11,000 jobs), and utilities (802 jobs). Sectorial inter-dependencies determine a similar distribution of induced jobs, with the bulk of new induced jobs concentrating in agriculture (59,700 jobs), construction (12,700 jobs), and utilities (924 jobs).

Given the prevelance of informal employment and the low levels of participation of women in Ethiopia's barley production, most job opportunities created would likely rely on male laborers and informal workers. Out of the total of 69,000 newly generated direct jobs over a ten-year period, 32,000 can be attributed to female workers, while 30,000 are filled by formal employees. These calculations utilize up-to-date statistics to project the future expansion of formality (40.1%) and female labor participation rates (43%) based on official microdata. Additionally, over the decade, over 21,000 jobs would come from non-remunerated household labor.

The cost per producer for the NDC strategy increases to a yearly average of USD 4,069 per hectare without sustainable agriculture and to a yearly average of USD 4,390 when incorporating sustainable practices. The total annual cost for implementing sustainable barley production amounts to USD 99 million, with 94% corresponding to inputs. To gauge international comparability, a measure used is the number of jobs created per USD 1 million invested. In the case of Ethiopia's NDC strategy for sustainable production of barley, it generates an average of 121 jobs annually for every USD 1 million invested (70 direct, 14 indirect, and 38 induced jobs). The model also considers the Climate Vulnerability Monitor for Ethiopia to account for the impact of climate change-related heat on labor productivity. Based on the strategy proposed in this exercise and different scenarios, climate change would result in a loss of between 1,400 and 6,900 FTE jobs from our core estimate of 69,000 direct jobs.

Considering sensitivity scenarios regarding salaries, the number of total jobs per USD 1 million invested ranges from 110 to 143 per year, on average. Since there is microdata availability, the model allows users to define three sets of wages: the average wage, a lower bound wage (the average minus a standard deviation), and an upper bound wage (the average plus a standard deviation). For example, using wages one standard deviation below the mean, total employment rises to 252,700 over the course of the decade (143 per USD 1 million invested). The estimate decreases to 169,900 new jobs over the decade if using higher salaries (1 standard deviation above the mean) (110 per USD 1 million invested). Similarly, the model includes a learning rate, as the percentage that improves the crop's production over time. This rate can be interpreted as labor-augmenting knowledge that increases productivity in the production process. The baseline for this rate is set at 1%. When increasing this rate to 5%, for example, the total net value added rises to USD 1,773 million (from USD 1,673 million).

Skills-occupations dyads within Barley

The following table presents an occupations-skills matrix for selected Barley occupations based on CEDEFOP skill labels and ISCO (International Standard Classification of Occupations). The matrix provides percentages representing the prevalence of various skills among different barley-centric occupations. Skills have been categorized into several domains, such as cultivating land and crops, complying with health and safety procedures, conducting academic or market research, and so on. Although many occupations share skills, certain abilities might be more pronounced in some professions than others. For instance, while the farm manager role involves skills like developing objectives and strategies, the agricultural engineer is more inclined towards abilities like using computer-aided design and drawing tools and designing systems and products.

Furthermore, the skills portrayed in the matrix for barley occupations can be broken down into four distinct tiers based on educational prerequisites. The management tier showcases skills like "developing objectives and strategies", which are evident in occupations such as farm manager and agronomic crop production team leader. The engineer's tier highlights skills like "designing systems and products" and "using computer-aided design and drawing tools", predominantly present in the agricultural engineer's role. The technician's tier exhibits skills related to "analyzing scientific and medical data", "evaluating systems, programs, equipment, and products", and "conducting academic or market research", observable in roles like the agricultural technician and agricultural inspector. Meanwhile, the non-professional tier is characterized by more hands-on tasks. Skills such as "moving and lifting", "tending plants and crops", and "cleaning" are predominant in occupations like crop production workers and agronomic crop production team leaders. Such classification provides a lucid understanding of the varying educational requirements across barley-related professions, offering invaluable insights for planning workforce and educational training in the industry.

Table A6 5. Occupations-skills matrix for selected barley occupations

Occupations-skills matrix for selected Barley* occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations → (Managers, Engineers, Technicians, Elementary)	Mixed farmer	Agricultural Technician	Farm Manager	Agricultural Engineer	Agricultural Inspector	Wholesale merchant in agricultural raw materials, seeds and animal feeds	Crop production manager	Crop production worker	Agronomic crop production team leader
cultivating land and crops	9%	6%	9%	0%	2%	0%	0%	0%	0%
complying with health and safety procedures	18%	6%	6%	0%	5%	0%	0%	0%	0%
conducting academic or market research	0%	9%	0%	9%	12%	6%	0%	0%	0%
operating agricultural or forestry equipment	18%	0%	6%	0%	0%	0%	0%	0%	0%
negotiating and managing contracts and agreements	0%	0%	6%	0%	0%	19%	0%	0%	0%
tending and breeding animals	18%	0%	6%	0%	0%	0%	0%	0%	0%
directing operational activities	9%	0%	6%	0%	2%	0%	0%	0%	0%
promoting products, services, or programs	9%	0%	11%	0%	0%	0%	0%	0%	0%
advising on business or operational matters	0%	6%	0%	6%	2%	0%	0%	0%	0%
analysing business operations	0%	6%	0%	6%	5%	0%	0%	0%	0%
installing wooden and metal components	0%	0%	3%	6%	2%	0%	0%	0%	0%
complying with environmental protection laws and standards	0%	0%	3%	3%	2%	0%	0%	0%	0%
management skills	9%	0%	6%	0%	0%	0%	5%	0%	2%
monitoring safety or security	0%	0%	0%	0%	15%	0%	0%	0%	0%
analysing scientific and medical data	0%	11%	0%	0%	2%	0%	0%	0%	0%
technical or academic writing	0%	6%	0%	3%	5%	0%	0%	0%	0%
advising on environmental issues	0%	3%	0%	3%	2%	0%	0%	0%	0%
analysing financial and economic data	0%	0%	0%	6%	0%	6%	0%	0%	0%
identifying opportunities	0%	0%	0%	0%	0%	13%	0%	0%	0%
engaging with others to identify needs	0%	0%	0%	0%	0%	13%	0%	0%	0%
planning production processes	0%	0%	3%	3%	0%	6%	0%	0%	0%
planting, pruning and harvesting trees, crops and other plants	0%	0%	0%	0%	0%	0%	0%	0%	0%
using computer aided design and drawing tools	0%	0%	0%	9%	0%	0%	0%	0%	0%
designing systems and products	0%	0%	0%	9%	0%	0%	0%	0%	0%
disposing of non-hazardous waste or debris	9%	0%	0%	0%	0%	0%	0%	0%	0%
evaluating systems, programmes, equipment and products	0%	6%	0%	3%	0%	0%	0%	0%	0%
monitoring financial and economic resources and activity	0%	0%	0%	0%	2%	6%	0%	0%	0%
monitoring environmental conditions	0%	6%	0%	0%	2%	0%	0%	0%	0%
gathering information from physical or electronic sources	0%	6%	0%	0%	2%	0%	0%	0%	0%
purchasing goods or services	0%	0%	6%	0%	2%	0%	0%	0%	0%
performing calculations	0%	6%	0%	0%	0%	0%	0%	0%	0%
cleaning interior and exterior of buildings	0%	3%	0%	0%	0%	0%	0%	0%	0%
assessing land or real estate	0%	3%	0%	0%	0%	0%	0%	0%	0%
preparing financial documents, records, reports, or budgets	0%	0%	0%	0%	0%	6%	0%	0%	0%
performing risk analysis and management	0%	0%	0%	0%	0%	6%	0%	0%	0%
accessing and analysing digital data	0%	0%	0%	0%	0%	6%	0%	0%	0%
designing industrial materials, systems or products	0%	0%	0%	6%	0%	0%	0%	0%	0%
liaising and networking	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing professional relationships or networks	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing solutions	0%	0%	0%	6%	0%	0%	0%	0%	0%
tending and breeding aquatic animals	0%	6%	0%	0%	0%	0%	0%	0%	0%
maintaining electrical, electronic and precision equipment	0%	6%	0%	0%	0%	0%	0%	0%	0%
advising on design or use of technologies	0%	0%	6%	0%	0%	0%	0%	0%	0%
presenting general information	0%	0%	6%	0%	0%	0%	0%	0%	0%
monitoring operational activities	0%	3%	3%	0%	0%	0%	0%	0%	0%
maintaining operational records	0%	0%	0%	3%	2%	0%	0%	0%	0%
collecting and preparing specimens or materials for testing	0%	0%	0%	0%	5%	0%	0%	0%	0%
ensuring compliance with legislation	0%	0%	0%	0%	5%	0%	0%	0%	0%
advising on workplace health and safety issues	0%	0%	0%	0%	5%	0%	0%	0%	0%
responding to complaints	0%	0%	0%	0%	5%	0%	0%	0%	0%
storing goods and materials	0%	0%	0%	0%	0%	0%	0%	0%	0%
using hand tools	0%	0%	0%	0%	0%	0%	0%	0%	0%
calculating and estimating	0%	0%	0%	3%	0%	0%	0%	0%	0%
directing, supervising and coordinating projects	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing policies and legislation	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing operational policies and procedures	0%	0%	0%	3%	0%	0%	0%	0%	0%
maintaining mechanical machinery	0%	0%	0%	3%	0%	0%	0%	0%	0%
handling and disposing of hazardous materials	0%	0%	3%	0%	0%	0%	0%	0%	0%
cleaning tools, equipment, workpieces and vehicles	0%	3%	0%	0%	0%	0%	0%	0%	0%
reporting incidents and defects	0%	0%	3%	0%	0%	0%	0%	0%	0%
estimating resource needs	0%	0%	3%	0%	0%	0%	0%	0%	0%
developing objectives and strategies	0%	0%	3%	0%	0%	0%	2%	0%	2%
advising on products and services	0%	3%	0%	0%	0%	0%	0%	0%	0%
training on operational procedures	0%	0%	3%	0%	0%	0%	0%	0%	0%
implementing new procedures or processes	0%	0%	3%	0%	0%	0%	0%	0%	0%
monitoring, inspecting and testing	0%	0%	0%	0%	2%	0%	0%	0%	0%
monitoring health conditions of humans and animals	0%	0%	0%	0%	2%	0%	0%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	0%	2%	0%	0%	0%	0%
presenting information in legal proceedings	0%	0%	0%	0%	2%	0%	0%	0%	0%
positioning materials, tools or equipment	0%	0%	0%	0%	0%	0%	0%	0%	0%
moving and lifting	0%	0%	0%	0%	0%	0%	9%	15%	8%
tending plants and crops	0%	0%	0%	0%	0%	0%	30%	38%	40%
cleaning	0%	0%	0%	0%	0%	0%	5%	6%	4%
documenting and recording information	0%	0%	0%	0%	0%	0%	5%	3%	4%
managing information	0%	0%	0%	0%	0%	0%	2%	3%	2%
organising, planning and scheduling work and activities	0%	0%	0%	0%	0%	0%	5%	0%	2%
supervising people	0%	0%	0%	0%	0%	0%	2%	0%	2%
allocating and controlling resources	0%	0%	0%	0%	0%	0%	5%	0%	4%
operating machinery for the manufacture of products	0%	0%	0%	0%	0%	0%	2%	3%	2%
using precision instrumentation and equipment	0%	0%	0%	0%	0%	0%	0%	3%	0%
operating mobile plant	0%	0%	0%	0%	0%	0%	9%	18%	13%
protecting and enforcing	0%	0%	0%	0%	0%	0%	9%	6%	8%
negotiating	0%	0%	0%	0%	0%	0%	2%	0%	2%
presenting information	0%	0%	0%	0%	0%	0%	2%	3%	0%
promoting, selling and purchasing	0%	0%	0%	0%	0%	0%	5%	3%	4%

Source: Own elaboration using ESCO's methodology. ESCO does not include occupations that explicitly refer to "Barley"; these occupations were selected to represent occupations closely related to occupations in barley production.

Corn

Ethiopia's NDCs aim to enhance food security by improving agricultural productivity in a climate-smart manner. The NDCs emphasize the development and augmentation of the productive chain for corn farming. This involves the promotion of yield-increasing techniques and economic coordination to boost corn production across the country, in line with the strategy for enhancing food security. The target is to cover more than 225,913 new hectares by 2030 for corn production (22,500 hectares per year), which underpins the overarching objectives to increase food availability, promote CSA practices, and contribute to the overall environmental and economic sustainability of Ethiopia's agricultural sector (Govt. of Ethiopia, 2021).

A tool has been developed to gauge the socioeconomic effects of Ethiopia's NDC goals on distinct agricultural endeavors, such as corn production. This instrument is built upon the FAO's EX-ACT-VC tool and factors in employment intensities for various tasks associated with a crop. For corn production, the process encompasses multiple stages: from seed planting, crop nurturing, and harvesting, to grain transportation, processing, and distribution. Corn farmers undertake tasks like planting, nurturing the crops, executing harvesting operations, processing the corn, and ensuring its transportation to the market. The refined corn is subsequently supplied to producers and consumers. The baseline range of time required for these activities varies between 35 and 110 days per hectare per year (Mafongoya & Jiri, 2015; Tarawali et al., 1987). Our intensity factors range from a baseline of 68 person-days per hectare to 104 person-days incorporating sustainable corn practices into the production process.

According to our calculations, Ethiopia's corn NDC strategy has the capacity to create between 83,900 to 97,200 new jobs over the span of ten years (2022-2032). The upper-bound estimate comprises the use of sustainable practices, and yields around 65,821 direct jobs, 3,293 indirect jobs, and 14,840 induced jobs. Specifically, these upper-bound estimates result from introducing Integrated Soil Fertility Management (ISFM), furrow irrigation, and agroforestry practices within corn production. The literature has shown that these practices have positive effects on yields and carbon sequestration (Ockerby & Fukai, 2001; Torres et al., 2017). Conversely, the BAU scenario of traditional corn production would create 79,265 total jobs (61,000 direct, 3,000 indirect, and 14,000 induced). The NDC strategy under BAU would generate USD 889 million in production value over the course of the decade, versus USD 1.1 billion when integrating sustainable practices. Also, these sustainable practices would increase the estimate of CO2 equivalent sequestration, from 1.7 million tons of emissions per decade under BAU, to a sequestration estimate of 714,800 tons over the decade.

The majority of the 65,000 direct new jobs under the upper bound comes from sub-activities in the production stage (46,800 jobs), followed by transport (9,000 jobs), processing (54,000 jobs), and aggregation (4,500 jobs). Similarly, most indirect jobs would derive from production linkages of corn production with construction (2,000 jobs), with other agricultural activities (750 jobs), and with utilities (151 jobs). Sectoral inter-dependencies determine a similar distribution of induced jobs, with the bulk of new induced jobs concentrating in agriculture (11,900 jobs), construction (2,400 jobs), and utilities (174 jobs).

Given the prevelance of informal employment and the low levels of participation of women in Ethiopia's corn production, most job opportunities created would likely rely on male laborers and informal workers. Out of the total of 65,000 newly generated direct jobs over ten years, 31,000 can be attributed to female workers, while 28,000 are filled by formal employees. These calculations consider up-to-date statistics to project the future expansion of formality (40.1%) and female labor participation rates (43%) based on official microdata. Additionally, over the decade, over 20,000 jobs would come from non-remunerated household labor.

The cost per producer for the NDC strategy increases to a yearly average of USD 5,213 per hectare without sustainable agriculture and to a yearly average of USD 5,571 when incorporating sustainable practices. The total annual cost for implementing sustainable corn production amounts to USD 126 million, with 94% corresponding to inputs. To gauge international comparability, a measure used is the number of jobs created per USD 1 million invested. In the case of Ethiopia's NDC strategy for sustainable production of corn, it generates an average of 73 jobs annually for every USD 1 million invested (52 direct, 4 indirect, and 17 induced jobs). The model also considers the Climate Vulnerability Monitor for Ethiopia to account for the impact of climate change-related heat on labor productivity. Based on the strategy proposed in this exercise and different scenarios, climate change would result in a loss of between 600 and 3000 FTE jobs from our core estimate of 65,000 direct jobs.

Considering sensitivity scenarios regarding salaries, the number of total jobs per USD 1 million invested ranges from 68 to 80 per year, on average. Since microdata is available, the model allows users to define three sets of wages: the average wage, a lower bound wage (the average minus a standard deviation), and an upper bound wage (the average plus a standard deviation). For example, using wages one standard deviation below the mean, total employment rises to 97,200 jobs over the course of the decade (80 jobs per USD 1 million invested). The estimate decreases to 83,900 new jobs over the decade if using higher salaries (1 standard deviation above the mean) (68 jobs per USD 1 million invested). Similarly, the model includes a learning rate, as a percentage that improves the crop's production over time. This rate can be interpreted as labor-augmenting knowledge that increases productivity in the production process. The baseline for this rate is set at 1%. When increasing this rate to 5%, for example, total sale values rise to USD 1.18 billion (from USD 1.14 billion).

Skills-occupations dyads within corn

The following table presents an occupations-skills matrix for selected corn occupations based on CEDEFOP skill labels and ISCO (International Standard Classification of Occupations). The matrix indicates the percentage of different skills associated with each corn-related occupation. The skills are categorized into various domains, including cultivating land and crops, complying with health and safety procedures, conducting academic or market research, operating agricultural equipment, and more. Commonly, different occupations share skills, but some specific abilities may be more prevalent professions than in others. For instance, the occupation of farm manager is associated with skills related to developing objectives and strategies, while the agricultural engineer occupation emphasizes using computer-aided design and drawing tools and designing systems and products.

Additionally, the skills detailed in the occupations-skills matrix for corn occupations can be grouped into four tiers rooted in educational requirements. The management tier encompasses skills like “developing objectives and strategies” with roles such as the farm manager and the agronomic crop production team leader exhibiting these abilities. The engineer’s tier is characterized by skills like “designing systems and products”, and “using computer-aided design and drawing tools” primarily evident in the agricultural engineer occupation. In the technician’s tier, skills associated with “analyzing scientific and medical data”, “evaluating systems, programs, equipment, and products” and “conducting academic or market research” are highlighted, as shown by the agricultural technician and agricultural inspector roles. The non-professional tier primarily involves more physical tasks. Skills like “moving and lifting”, “tending plants and crops”, and “cleaning” are predominant among crop production workers and agronomic crop production team leaders. This stratification by tiers offers a clear perspective on the variety of educational prerequisites across corn-related professions, providing invaluable insights for initiatives in workforce planning and educational training within the corn sector.

Table A6 6. Occupations-skills matrix for selected corn occupations

Occupations-skills matrix for selected Corn* occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations →
Managers | Engineers | Technicians | Elementary

CEDEFOP-based Skill Labels ↓ per ISCO Occupations →	Mixed farmer	Agricultural Technician	Farm Manager	Agricultural Engineer	Agricultural Inspector	Wholesale merchant in agricultural raw materials, seeds and animal feeds	Crop production manager	Crop production worker	Agronomic crop production team leader
cultivating land and crops	9%	6%	9%	0%	2%	0%	0%	0%	0%
complying with health and safety procedures	18%	6%	6%	0%	5%	0%	0%	0%	0%
conducting academic or market research	0%	9%	0%	9%	12%	6%	0%	0%	0%
operating agricultural or forestry equipment	18%	0%	6%	0%	0%	0%	0%	0%	0%
negotiating and managing contracts and agreements	0%	0%	6%	0%	0%	19%	0%	0%	0%
tending and breeding animals	18%	0%	6%	0%	0%	0%	0%	0%	0%
directing operational activities	9%	0%	6%	0%	2%	0%	0%	0%	0%
promoting products, services, or programs	9%	0%	11%	0%	0%	0%	0%	0%	0%
advising on business or operational matters	0%	6%	0%	6%	2%	0%	0%	0%	0%
analysing business operations	0%	6%	0%	6%	5%	0%	0%	0%	0%
installing wooden and metal components	0%	0%	3%	6%	2%	0%	0%	0%	0%
complying with environmental protection laws and standards	0%	0%	3%	3%	2%	0%	0%	0%	0%
management skills	9%	0%	6%	0%	0%	0%	5%	0%	2%
monitoring safety or security	0%	0%	0%	0%	15%	0%	0%	0%	0%
analysing scientific and medical data	0%	11%	0%	0%	2%	0%	0%	0%	0%
technical or academic writing	0%	6%	0%	3%	5%	0%	0%	0%	0%
advising on environmental issues	0%	3%	0%	3%	2%	0%	0%	0%	0%
analysing financial and economic data	0%	0%	0%	6%	0%	6%	0%	0%	0%
identifying opportunities	0%	0%	0%	0%	0%	13%	0%	0%	0%
engaging with others to identify needs	0%	0%	0%	0%	0%	13%	0%	0%	0%
planning production processes	0%	0%	3%	3%	0%	6%	0%	0%	0%
planting, pruning and harvesting trees, crops and other plants	0%	0%	0%	0%	0%	0%	0%	0%	0%
using computer aided design and drawing tools	0%	0%	0%	9%	0%	0%	0%	0%	0%
designing systems and products	0%	0%	0%	9%	0%	0%	0%	0%	0%
disposing of non-hazardous waste or debris	9%	0%	0%	0%	0%	0%	0%	0%	0%
evaluating systems, programmes, equipment and products	0%	6%	0%	3%	0%	0%	0%	0%	0%
monitoring financial and economic resources and activity	0%	0%	0%	0%	2%	6%	0%	0%	0%
monitoring environmental conditions	0%	6%	0%	0%	2%	0%	0%	0%	0%
gathering information from physical or electronic sources	0%	6%	0%	0%	2%	0%	0%	0%	0%
purchasing goods or services	0%	0%	6%	0%	2%	0%	0%	0%	0%
performing calculations	0%	6%	0%	0%	0%	0%	0%	0%	0%
cleaning interior and exterior of buildings	0%	3%	0%	0%	0%	0%	0%	0%	0%
assessing land or real estate	0%	3%	0%	0%	0%	0%	0%	0%	0%
preparing financial documents, records, reports, or budgets	0%	0%	0%	0%	0%	6%	0%	0%	0%
performing risk analysis and management	0%	0%	0%	0%	0%	6%	0%	0%	0%
accessing and analysing digital data	0%	0%	0%	0%	0%	6%	0%	0%	0%
designing industrial materials, systems or products	0%	0%	0%	6%	0%	0%	0%	0%	0%
liaising and networking	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing professional relationships or networks	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing solutions	0%	0%	0%	6%	0%	0%	0%	0%	0%
tending and breeding aquatic animals	0%	6%	0%	0%	0%	0%	0%	0%	0%
maintaining electrical, electronic and precision equipment	0%	6%	0%	0%	0%	0%	0%	0%	0%
advising on design or use of technologies	0%	0%	6%	0%	0%	0%	0%	0%	0%
presenting general information	0%	0%	6%	0%	0%	0%	0%	0%	0%
monitoring operational activities	0%	3%	3%	0%	0%	0%	0%	0%	0%
maintaining operational records	0%	0%	0%	3%	2%	0%	0%	0%	0%
collecting and preparing specimens or materials for testing	0%	0%	0%	0%	5%	0%	0%	0%	0%
ensuring compliance with legislation	0%	0%	0%	0%	5%	0%	0%	0%	0%
advising on workplace health and safety issues	0%	0%	0%	0%	5%	0%	0%	0%	0%
responding to complaints	0%	0%	0%	0%	5%	0%	0%	0%	0%
storing goods and materials	0%	0%	0%	0%	0%	0%	0%	0%	0%
using hand tools	0%	0%	0%	0%	0%	0%	0%	0%	0%
calculating and estimating	0%	0%	0%	3%	0%	0%	0%	0%	0%
directing, supervising and coordinating projects	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing policies and legislation	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing operational policies and procedures	0%	0%	0%	3%	0%	0%	0%	0%	0%
maintaining mechanical machinery	0%	0%	0%	3%	0%	0%	0%	0%	0%
handling and disposing of hazardous materials	0%	0%	3%	0%	0%	0%	0%	0%	0%
cleaning tools, equipment, workpieces and vehicles	0%	3%	0%	0%	0%	0%	0%	0%	0%
reporting incidents and defects	0%	0%	3%	0%	0%	0%	0%	0%	0%
estimating resource needs	0%	0%	3%	0%	0%	0%	0%	0%	0%
developing objectives and strategies	0%	0%	3%	0%	0%	0%	2%	0%	2%
advising on products and services	0%	3%	0%	0%	0%	0%	0%	0%	0%
training on operational procedures	0%	0%	3%	0%	0%	0%	0%	0%	0%
implementing new procedures or processes	0%	0%	3%	0%	0%	0%	0%	0%	0%
monitoring, inspecting and testing	0%	0%	0%	0%	2%	0%	0%	0%	0%
monitoring health conditions of humans and animals	0%	0%	0%	0%	2%	0%	0%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	0%	2%	0%	0%	0%	0%
presenting information in legal proceedings	0%	0%	0%	0%	2%	0%	0%	0%	0%
positioning materials, tools or equipment	0%	0%	0%	0%	0%	0%	0%	0%	0%
moving and lifting	0%	0%	0%	0%	0%	0%	9%	15%	8%
tending plants and crops	0%	0%	0%	0%	0%	0%	30%	38%	40%
cleaning	0%	0%	0%	0%	0%	0%	5%	6%	4%
documenting and recording information	0%	0%	0%	0%	0%	0%	5%	3%	4%
managing information	0%	0%	0%	0%	0%	0%	2%	3%	2%
organising, planning and scheduling work and activities	0%	0%	0%	0%	0%	0%	5%	0%	2%
supervising people	0%	0%	0%	0%	0%	0%	2%	0%	2%
allocating and controlling resources	0%	0%	0%	0%	0%	0%	5%	0%	4%
operating machinery for the manufacture of products	0%	0%	0%	0%	0%	0%	2%	3%	2%
using precision instrumentation and equipment	0%	0%	0%	0%	0%	0%	0%	3%	0%
operating mobile plant	0%	0%	0%	0%	0%	0%	9%	18%	13%
protecting and enforcing	0%	0%	0%	0%	0%	0%	9%	6%	8%
negotiating	0%	0%	0%	0%	0%	0%	2%	0%	2%
presenting information	0%	0%	0%	0%	0%	0%	2%	3%	0%
promoting, selling and purchasing	0%	0%	0%	0%	0%	0%	5%	3%	4%

Source: Own elaboration using ESCO's methodology. ESCO does not include occupations that explicitly refer to "Corn"; these occupations were selected to represent occupations closely related to occupations in corn production.

Teff

Ethiopia's NDCs aim to enhance food security by improving agricultural productivity in a climate-smart manner. The NDCs emphasize the development and augmentation of the productive chain for teff farming. This involves the promotion of yield-increasing techniques and economic coordination to boost teff production across the country, in line with the strategy for enhancing food security. The target is to cover more than 225,913 new hectares by 2030 for teff production (22,500 Hectares per year), which underpins the overarching objectives to increase food availability, promote CSA practices, and contribute to the overall environmental and economic sustainability of Ethiopia's agricultural sector (Govt. of Ethiopia, 2021).

To understand the broader socioeconomic impacts of teff production, especially in the context of Ethiopia's NDC goals, a specialized tool based on the FAO's EX-ACT-VC has been developed. This tool focuses on employment intensities and other associated factors crucial to the agricultural dynamics of teff cultivation. Teff, a staple grain in Ethiopia, is produced through a series of well-coordinated stages. Beginning with the careful selection and planting of seeds, farmers invest time in nurturing the crops, ensuring they grow to their optimal yield. Once the crops are mature, the harvesting phase commences, which requires a different set of skills and labor intensity. Post-harvest, the teff grains undergo a processing stage to refine them for consumption. This processed teff is then transported, distributed, and eventually reaches both producers and consumers. The baseline range of time required for these activities varies between 110 and 140 days per hectare per year of productive cycle (Vandercasteelen et al., 2018; Minten et al., 2016). Our intensity factors range from a baseline of 79 person-days per hectare to 114 person-days incorporating sustainable teff practices into the production process.

According to our calculations, Ethiopia's Teff NDC strategy has the capacity to create between 85,900 to 90,900 new jobs over the span of ten years (2022-2032) The upper-bound estimate comprises the use of sustainable practices and yields around 78,900 direct jobs, 1,244 indirect jobs, and 5,825 induced jobs. Specifically, these upper-bound estimates result from introducing Integrated Soil Fertility Management (ISFM), furrow irrigation, and agroforestry practices within teff production. The literature has shown that these practices have positive effects on yields and carbon sequestration (Ockerby & Fukai, 2001; Torres et al., 2017). Conversely, the BAU scenario of traditional teff production would create 76,815 total jobs (71,389 direct, 941 indirect, and 4,485 induced). The NDC strategy under BAU would generate USD 738 million in gross production values (e.g., sales) over the course of the decade, versus USD 1,209 million when integrating sustainable practices. Also, these sustainable practices would increase the estimate of CO2 equivalent sequestration, from 478,000 tons per decade under BAU, to an estimate of 4 million tons over the decade.

The majority of the 78,000 direct new jobs under the upper-bound comes from sub-activities in the production stage (59,900 jobs), followed by transport (9,000 jobs), processing (5,400 jobs), and aggregation (4,500 jobs). Similarly, most of indirect jobs would derive from production linkages of teff production with construction (956 jobs), other agricultural activities (71 jobs), and with utilities (70 jobs). Sectoral inter-dependencies determine a similar distribution of induced jobs, with the bulk of new induced jobs concentrating in agriculture (4,000 jobs), construction (1,000 jobs), and utilities (80 jobs).

Given the prevelance of informal employment and the low levels of participation of women in Ethiopia's teff production, most job opportunities created would likely rely on male laborers and informal workers. Out of the total of 78,000 newly generated direct jobs over a ten-year period, 37,000 can be attributed to female workers, while 34,000 are filled by formal employees. These calculations consider up-to-date statistics to project the future expansion of formality (40.1%) and female labor participation rates (43%) based on official microdata. Additionally, over the decade, over 24,000 jobs would come from non-remunerated household labor.

The cost per producer for the NDC strategy increases to a yearly average of USD 4,614 per hectare without sustainable agriculture and to a yearly average of USD 5,011 when incorporating sustainable practices. The total annual cost for implementing sustainable teff production amounts to USD 113 million, with 90% corresponding to inputs. To gauge international comparability, a measure used is the number of jobs created per USD 1 million invested. In the case of Ethiopia's NDC strategy for sustainable production of teff, an average of 77 jobs is generated annually for every USD 1 million invested (70 direct, 1 indirect, and 6 induced jobs). The model also considers the Climate Vulnerability Monitor for Ethiopia to account for the impact of climate change related heat on labor productivity. Based on the strategy proposed in this exercise and different scenarios, climate change would result in a loss of between 600 and 3,000 FTE jobs from our core estimate of 78,000 direct jobs.

Considering sensitivity scenarios regarding salaries, the number of total jobs per USD 1 million invested ranges from 76 to 80 per year, on average. Since microsdata is available, the model allows users to define three sets of wages: the average wage, a lower bound wage (the average minus a standard deviation), and an upper bound wage (the average plus a standard deviation). For example, using wages one standard deviation below the mean, total employment rises to 90,900 over the course of the decade (80 per USD 1 million invested). The estimate decreases to 85,900 new jobs over the decade if using higher salaries (1 standard deviation above the mean) (76 per USD 1 million invested). Similarly, the model includes a learning rate, as percentage that improves the crop's production over time. This rate can be interpreted as labor-augmenting knowledge that increases productivity in the production process. The baseline for this rate is set at 1%. When increasing this rate to 5%, for example, total net value added rises to USD 534 million (from USD 486 million).

Skills-occupations dyads within teff

The following table presents an occupations-skills matrix for selected teff occupations based on CEDEFOP skill labels and ISCO (International Standard Classification of Occupations). The matrix reveals the percentage of various skills associated with each occupation in the teff sector. The skills span multiple domains including cultivating land and crops, complying with health and safety procedures, conducting academic or market research, and operating agricultural equipment, among others. While many professions in the teff sector overlap in the skills they require, certain skills might be more dominant in one occupation than in others. For instance, the role of a farm manager is tied to "developing objectives and strategies" with a 3% association. On the other hand, the agricultural engineer profession is more inclined towards skills like "using computer-aided design and drawing tools" and "designing systems and products", both with a 9% association.

In the teff sector, skills delineated in the occupations-skills matrix are arranged into four hierarchical tiers based on their educational prerequisites. The management tier, for instance, includes skills like "developing objectives and strategies" which are predominantly seen in roles such as farm manager and agronomic crop production team leader, with both showcasing a 3% and 2% association, respectively. The engineering tier is characterized by capabilities for "designing systems and products" and "using computer-aided design and drawing tools" with the agricultural engineer role predominantly displaying these skills, both at 9%. The technician's tier emphasizes skills like "analyzing scientific and medical data" (11% in agricultural technician) and "conducting academic or market research" (9% in agricultural technician). Lastly, the non-professional tier is heavily oriented towards more hands-on activities. Skills like "moving and lifting" (15% in crop production worker), "tending plants and crops" (38% in crop production worker), and "cleaning" (6% in crop production worker) are most prevalent. This structured tiering provides a comprehensive understanding of the varying educational requirements across teff-related occupations, providing insights for strategies in workforce development and educational training in Ethiopia's teff industry.

Table A6 7. Occupations-skills matrix for selected teff occupations

Occupations-skills matrix for selected Teff* occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations → (Managers, Engineers, Technicians, Elementary)	Mixed farmer	Agricultural Technician	Farm Manager	Agricultural Engineer	Agricultural Inspector	Wholesale merchant in agricultural raw materials, seeds and animal feeds	Crop production manager	Crop production worker	Agronomic crop production team leader
cultivating land and crops	9%	6%	9%	0%	2%	0%	0%	0%	0%
complying with health and safety procedures	18%	6%	6%	0%	5%	0%	0%	0%	0%
conducting academic or market research	0%	9%	0%	9%	12%	6%	0%	0%	0%
operating agricultural or forestry equipment	18%	0%	6%	0%	0%	0%	0%	0%	0%
negotiating and managing contracts and agreements	0%	0%	6%	0%	0%	19%	0%	0%	0%
tending and breeding animals	18%	0%	6%	0%	0%	0%	0%	0%	0%
directing operational activities	9%	0%	6%	0%	2%	0%	0%	0%	0%
promoting products, services, or programs	9%	0%	11%	0%	0%	0%	0%	0%	0%
advising on business or operational matters	0%	6%	0%	6%	2%	0%	0%	0%	0%
analysing business operations	0%	6%	0%	6%	5%	0%	0%	0%	0%
installing wooden and metal components	0%	0%	3%	6%	2%	0%	0%	0%	0%
complying with environmental protection laws and standards	0%	0%	3%	3%	2%	0%	0%	0%	0%
management skills	9%	0%	6%	0%	0%	0%	5%	0%	2%
monitoring safety or security	0%	0%	0%	0%	15%	0%	0%	0%	0%
analysing scientific and medical data	0%	11%	0%	0%	2%	0%	0%	0%	0%
technical or academic writing	0%	6%	0%	3%	5%	0%	0%	0%	0%
advising on environmental issues	0%	3%	0%	3%	2%	0%	0%	0%	0%
analysing financial and economic data	0%	0%	0%	6%	0%	6%	0%	0%	0%
identifying opportunities	0%	0%	0%	0%	0%	13%	0%	0%	0%
engaging with others to identify needs	0%	0%	0%	0%	0%	13%	0%	0%	0%
planning production processes	0%	0%	3%	3%	0%	6%	0%	0%	0%
planting, pruning and harvesting trees, crops and other plants	0%	0%	0%	0%	0%	0%	0%	0%	0%
using computer aided design and drawing tools	0%	0%	0%	9%	0%	0%	0%	0%	0%
designing systems and products	0%	0%	0%	9%	0%	0%	0%	0%	0%
disposing of non-hazardous waste or debris	9%	0%	0%	0%	0%	0%	0%	0%	0%
evaluating systems, programmes, equipment and products	0%	6%	0%	3%	0%	0%	0%	0%	0%
monitoring financial and economic resources and activity	0%	0%	0%	0%	2%	6%	0%	0%	0%
monitoring environmental conditions	0%	6%	0%	0%	2%	0%	0%	0%	0%
gathering information from physical or electronic sources	0%	6%	0%	0%	2%	0%	0%	0%	0%
purchasing goods or services	0%	0%	6%	0%	2%	0%	0%	0%	0%
performing calculations	0%	6%	0%	0%	0%	0%	0%	0%	0%
cleaning interior and exterior of buildings	0%	3%	0%	0%	0%	0%	0%	0%	0%
assessing land or real estate	0%	3%	0%	0%	0%	0%	0%	0%	0%
preparing financial documents, records, reports, or budgets	0%	0%	0%	0%	0%	6%	0%	0%	0%
performing risk analysis and management	0%	0%	0%	0%	0%	6%	0%	0%	0%
accessing and analysing digital data	0%	0%	0%	0%	0%	6%	0%	0%	0%
designing industrial materials, systems or products	0%	0%	0%	6%	0%	0%	0%	0%	0%
liaising and networking	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing professional relationships or networks	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing solutions	0%	0%	0%	6%	0%	0%	0%	0%	0%
tending and breeding aquatic animals	0%	6%	0%	0%	0%	0%	0%	0%	0%
maintaining electrical, electronic and precision equipment	0%	6%	0%	0%	0%	0%	0%	0%	0%
advising on design or use of technologies	0%	0%	6%	0%	0%	0%	0%	0%	0%
presenting general information	0%	0%	6%	0%	0%	0%	0%	0%	0%
monitoring operational activities	0%	3%	3%	0%	0%	0%	0%	0%	0%
maintaining operational records	0%	0%	0%	3%	2%	0%	0%	0%	0%
collecting and preparing specimens or materials for testing	0%	0%	0%	0%	5%	0%	0%	0%	0%
ensuring compliance with legislation	0%	0%	0%	0%	5%	0%	0%	0%	0%
advising on workplace health and safety issues	0%	0%	0%	0%	5%	0%	0%	0%	0%
responding to complaints	0%	0%	0%	0%	5%	0%	0%	0%	0%
storing goods and materials	0%	0%	0%	0%	0%	0%	0%	0%	0%
using hand tools	0%	0%	0%	0%	0%	0%	0%	0%	0%
calculating and estimating	0%	0%	0%	3%	0%	0%	0%	0%	0%
directing, supervising and coordinating projects	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing policies and legislation	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing operational policies and procedures	0%	0%	0%	3%	0%	0%	0%	0%	0%
maintaining mechanical machinery	0%	0%	0%	3%	0%	0%	0%	0%	0%
handling and disposing of hazardous materials	0%	0%	3%	0%	0%	0%	0%	0%	0%
cleaning tools, equipment, workpieces and vehicles	0%	3%	0%	0%	0%	0%	0%	0%	0%
reporting incidents and defects	0%	0%	3%	0%	0%	0%	0%	0%	0%
estimating resource needs	0%	0%	3%	0%	0%	0%	0%	0%	0%
developing objectives and strategies	0%	0%	3%	0%	0%	0%	2%	0%	2%
advising on products and services	0%	3%	0%	0%	0%	0%	0%	0%	0%
training on operational procedures	0%	0%	3%	0%	0%	0%	0%	0%	0%
implementing new procedures or processes	0%	0%	3%	0%	0%	0%	0%	0%	0%
monitoring, inspecting and testing	0%	0%	0%	0%	2%	0%	0%	0%	0%
monitoring health conditions of humans and animals	0%	0%	0%	0%	2%	0%	0%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	0%	2%	0%	0%	0%	0%
presenting information in legal proceedings	0%	0%	0%	0%	2%	0%	0%	0%	0%
positioning materials, tools or equipment	0%	0%	0%	0%	0%	0%	0%	0%	0%
moving and lifting	0%	0%	0%	0%	0%	0%	9%	15%	8%
tending plants and crops	0%	0%	0%	0%	0%	0%	30%	38%	40%
cleaning	0%	0%	0%	0%	0%	0%	5%	6%	4%
documenting and recording information	0%	0%	0%	0%	0%	0%	5%	3%	4%
managing information	0%	0%	0%	0%	0%	0%	2%	3%	2%
organising, planning and scheduling work and activities	0%	0%	0%	0%	0%	0%	5%	0%	2%
supervising people	0%	0%	0%	0%	0%	0%	2%	0%	2%
allocating and controlling resources	0%	0%	0%	0%	0%	0%	5%	0%	4%
operating machinery for the manufacture of products	0%	0%	0%	0%	0%	0%	2%	3%	2%
using precision instrumentation and equipment	0%	0%	0%	0%	0%	0%	0%	3%	0%
operating mobile plant	0%	0%	0%	0%	0%	0%	9%	18%	13%
protecting and enforcing	0%	0%	0%	0%	0%	0%	9%	6%	8%
negotiating	0%	0%	0%	0%	0%	0%	2%	0%	2%
presenting information	0%	0%	0%	0%	0%	0%	2%	3%	0%
promoting, selling and purchasing	0%	0%	0%	0%	0%	0%	5%	3%	4%

Source: Own elaboration using ESCO's methodology. ESCO does not include occupations that explicitly refer to "Teff"; these occupations were selected to represent occupations closely related to occupations in teff production.

Wheat

Ethiopia's NDCs aim to enhance food security by improving agricultural productivity in a climate-smart manner. The NDCs highlight the enhancement and expansion of the value chain for wheat cultivation. This includes the promotion of yield-increasing techniques and economic coordination to boost wheat production across the country, in line with the strategy for enhancing food security. The target is to cover more than 225,913 new hectares by 2030 for wheat production (22,500 hectares per year), which underpins the overarching objectives to increase food availability, promote CSA practices, and contribute to the overall environmental and economic sustainability of Ethiopia's agricultural sector (Govt. of Ethiopia, 2021).

To grasp the wider socioeconomic effects of wheat farming, particularly in relation to Ethiopia's NDC objectives, a specific instrument inspired by the FAO's EX-ACT-VC was crafted. This instrument centers on job creation and other elements vital to the agricultural intricacies of wheat growth. In the context of wheat production in Ethiopia, the process includes stages such as seed selection and sowing, plant nurturing, grain harvesting, processing, and distribution. Agricultural workers participate in planting and tending to the wheat plants, overseeing the harvest, processing the grains, and ensuring their transportation to markets. The processed wheat is subsequently distributed to manufacturers or other end users. The baseline range of time required for these activities averages between 40 and 90 days per hectare per year of rainfed wheat production (Adgo, 2015; Hassena et al., 2000). Our own intensity factors range from a baseline of 87 person-days per hectare to 122 person-days incorporating sustainable wheat practices into the production process.

According to our calculations, Ethiopia's Wheat NDC strategy has the capacity to create between 227,398 to 343,365 new jobs over the span of ten years (2022-2032). The upper-bound estimate comprises the use of sustainable practices, and yields around 86,375 direct jobs, 35,757 indirect jobs, and 105,265 induced jobs. Specifically, these upper-bound estimates result from introducing Integrated Soil Fertility Management (ISFM), furrow irrigation, and agroforestry practices within wheat production. The literature has shown that these practices have positive effects on yields and carbon sequestration (Ockerby & Fukai, 2001; Torres et al., 2017). Conversely, the BAU scenario of traditional wheat production would create 208,769 total jobs (79,00 direct, 34,000 indirect, and 95,000 induced jobs). The NDC strategy under BAU would generate USD 1,997 million in net value added over the course of the decade, versus USD 2,999 million when integrating sustainable practices. Also, these sustainable practices would increase the estimate of CO2 equivalent sequestration, from 2.7 million tons per decade under BAU, to an estimate of 7.5 million tons over the decade.

The majority of the 86,000 direct new jobs under the upper-bound comes from sub-activities in the production stage (64,200 jobs), followed by transport (12,200 jobs), processing (5,400 jobs), and aggregation (4,500 jobs). Similarly, most of indirect jobs would derive from production linkages of wheat production with other agricultural activities (16,000 jobs), with construction (15,000 jobs), and with utilities (1,000 jobs). Sectoral inter-dependencies determine a similar distribution of induced jobs, with the bulk of new induced jobs concentrating in agriculture (83,000 jobs), construction (17,000 jobs), and utilities (1,000 jobs).

Considering the prevalence of informal employment and the low levels of involvement of women in Ethiopia's wheat production, most job opportunities generated would probably depend on male workers and those in informal sectors. Out of the total of 86,000 newly generated direct jobs over a ten-year period, 40,000 can be attributed to female workers, while 37,000 are filled by formal employees. These calculations utilize up-to-date statistics to project the future expansion of formality (40.1%) and female labor participation rates (43%) based on official microdata. Additionally, over the decade, over 26,000 jobs would come from non-remunerated household labor.

The cost per producer for the NDC strategy increases to a yearly average of USD 2,886 per hectare without sustainable agriculture and to a yearly average of USD 3,213 when incorporating sustainable practices. The total annual cost for implementing sustainable wheat production amounts to USD 73 million, with 90% corresponding to inputs. To gauge international comparability, a measure used is the number of jobs created per USD 1 million invested. In the case of Ethiopia's NDC strategy for sustainable production of wheat, it generates an average of 170 jobs annually for every USD 1 million invested (119 direct, 14 indirect, and 38 induced jobs). The model also considers the Climate Vulnerability Monitor for Ethiopia to account for the impact of climate change related heat on labor productivity. Based on the strategy proposed in this exercise and different scenarios, climate change would result in a loss of between 2,000 and 9,000 FTE jobs from our core estimate of 86,000 direct jobs.

Considering sensitivity scenarios regarding salaries, the number of total jobs per USD 1 million invested ranges from 159 to 192 per year, on average. Since microdata is available, the model allows users to define three sets of wages: the average wage, a lower bound wage (the average minus a standard deviation), and an upper bound wage (the average plus a standard deviation). For example, using wages one standard deviation below the mean, total employment rises to 343,400 jobs over the course of the decade (192 jobs per USD 1 million invested). The estimate decreases to 227,400 new jobs over the decade if using higher salaries (1 standard deviation above the mean) (159 jobs per USD 1 million in invested). Similarly, the model includes a learning rate, as percentage that improves the crop's production over time. This rate can be interpreted as labor-augmenting knowledge that increases productivity in the production process. The baseline for this rate is set at 1%. When increasing this rate to 5%, for example, total net value added rises to USD 3,140 million (from USD 2,999 million).

Skills-occupations dyads within wheat

The following table showcases an occupations-skills matrix for selected wheat occupations based on CEDEFOP skill labels and ISCO (International Standard Classification of Occupations). The matrix shows the percentage of different skills linked with each profession in the wheat sector. These skills go over several domains like cultivating land and crops, adhering to health and safety standards, conducting academic or market research, and handling agricultural or forestry equipment, to name a few. While there are commonalities in the skills across wheat professions, specific skills may stand out more in certain roles. For instance, in the wheat industry, the farm manager position prominently involves "developing objectives and strategies" with a 3% association. Conversely, the agricultural engineer role prominently showcases skills like "using computer-aided design and drawing tools" and "designing systems and products", both at a 9% association.

Within the wheat sector, the skills in the occupations-skills matrix are organized into four distinct hierarchical tiers, categorized by their educational prerequisites. The management tier highlights skills such as "developing objectives and strategies". Roles like farm manager and agronomic crop production team leader exhibit this skill with a 3% and 2% association, respectively. The engineering tier exemplifies competencies like "designing systems and products" and "using computer-aided design and drawing tools", primarily associated with the agricultural engineer role, both at 9%. The technician's tier underscores skills such as "analyzing scientific and medical data" (11% for agricultural technician) and "conducting academic or market research" (9% for agricultural technician). Meanwhile, the non-professional tier is skewed towards practical tasks, with "moving and lifting" being highlighted (15% in crop production worker), "tending plants and crops" (38% in crop production worker), and "cleaning" (6% in crop production worker) being the most prevalent. This tiered framework offers a holistic comprehension of the educational prerequisites spanning wheat-related professions, giving valuable insights for strategic planning in workforce development and educational programs in the global wheat sector.

Occupations-skills matrix for selected Wheat* occupations

CEDEFOP-based Skill Labels ↓ per ISCO Occupations → (Managers, Engineers, Technicians, Elementary)	Mixed farmer	Agricultural Technician	Farm Manager	Agricultural Engineer	Agricultural Inspector	Wholesale merchant in agricultural raw materials, seeds and animal feeds	Crop production manager	Crop production worker	Agronomic crop production team leader
cultivating land and crops	9%	6%	9%	0%	2%	0%	0%	0%	0%
complying with health and safety procedures	18%	6%	6%	0%	5%	0%	0%	0%	0%
conducting academic or market research	0%	9%	0%	9%	12%	6%	0%	0%	0%
operating agricultural or forestry equipment	18%	0%	6%	0%	0%	0%	0%	0%	0%
negotiating and managing contracts and agreements	0%	0%	6%	0%	0%	19%	0%	0%	0%
tending and breeding animals	18%	0%	6%	0%	0%	0%	0%	0%	0%
directing operational activities	9%	0%	6%	0%	2%	0%	0%	0%	0%
promoting products, services, or programs	9%	0%	11%	0%	0%	0%	0%	0%	0%
advising on business or operational matters	0%	6%	0%	6%	2%	0%	0%	0%	0%
analysing business operations	0%	6%	0%	6%	5%	0%	0%	0%	0%
installing wooden and metal components	0%	0%	3%	6%	2%	0%	0%	0%	0%
complying with environmental protection laws and standards	0%	0%	3%	3%	2%	0%	0%	0%	0%
management skills	9%	0%	6%	0%	0%	0%	5%	0%	2%
monitoring safety or security	0%	0%	0%	0%	15%	0%	0%	0%	0%
analysing scientific and medical data	0%	11%	0%	0%	2%	0%	0%	0%	0%
technical or academic writing	0%	6%	0%	3%	5%	0%	0%	0%	0%
advising on environmental issues	0%	3%	0%	3%	2%	0%	0%	0%	0%
analysing financial and economic data	0%	0%	0%	6%	0%	6%	0%	0%	0%
identifying opportunities	0%	0%	0%	0%	0%	13%	0%	0%	0%
engaging with others to identify needs	0%	0%	0%	0%	0%	13%	0%	0%	0%
planning production processes	0%	0%	3%	3%	0%	6%	0%	0%	0%
planting, pruning and harvesting trees, crops and other plants	0%	0%	0%	0%	0%	0%	0%	0%	0%
using computer aided design and drawing tools	0%	0%	0%	9%	0%	0%	0%	0%	0%
designing systems and products	0%	0%	0%	9%	0%	0%	0%	0%	0%
disposing of non-hazardous waste or debris	9%	0%	0%	0%	0%	0%	0%	0%	0%
evaluating systems, programmes, equipment and products	0%	6%	0%	3%	0%	0%	0%	0%	0%
monitoring financial and economic resources and activity	0%	0%	0%	0%	2%	6%	0%	0%	0%
monitoring environmental conditions	0%	6%	0%	0%	2%	0%	0%	0%	0%
gathering information from physical or electronic sources	0%	6%	0%	0%	2%	0%	0%	0%	0%
purchasing goods or services	0%	0%	6%	0%	2%	0%	0%	0%	0%
performing calculations	0%	6%	0%	0%	0%	0%	0%	0%	0%
cleaning interior and exterior of buildings	0%	3%	0%	0%	0%	0%	0%	0%	0%
assessing land or real estate	0%	3%	0%	0%	0%	0%	0%	0%	0%
preparing financial documents, records, reports, or budgets	0%	0%	0%	0%	0%	6%	0%	0%	0%
performing risk analysis and management	0%	0%	0%	0%	0%	6%	0%	0%	0%
accessing and analysing digital data	0%	0%	0%	0%	0%	6%	0%	0%	0%
designing industrial materials, systems or products	0%	0%	0%	6%	0%	0%	0%	0%	0%
liaising and networking	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing professional relationships or networks	0%	0%	0%	0%	0%	6%	0%	0%	0%
developing solutions	0%	0%	0%	6%	0%	0%	0%	0%	0%
tending and breeding aquatic animals	0%	6%	0%	0%	0%	0%	0%	0%	0%
maintaining electrical, electronic and precision equipment	0%	6%	0%	0%	0%	0%	0%	0%	0%
advising on design or use of technologies	0%	0%	6%	0%	0%	0%	0%	0%	0%
presenting general information	0%	0%	6%	0%	0%	0%	0%	0%	0%
monitoring operational activities	0%	3%	3%	0%	0%	0%	0%	0%	0%
maintaining operational records	0%	0%	0%	3%	2%	0%	0%	0%	0%
collecting and preparing specimens or materials for testing	0%	0%	0%	0%	5%	0%	0%	0%	0%
ensuring compliance with legislation	0%	0%	0%	0%	5%	0%	0%	0%	0%
advising on workplace health and safety issues	0%	0%	0%	0%	5%	0%	0%	0%	0%
responding to complaints	0%	0%	0%	0%	5%	0%	0%	0%	0%
storing goods and materials	0%	0%	0%	0%	0%	0%	0%	0%	0%
using hand tools	0%	0%	0%	0%	0%	0%	0%	0%	0%
calculating and estimating	0%	0%	0%	3%	0%	0%	0%	0%	0%
directing, supervising and coordinating projects	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing policies and legislation	0%	0%	0%	3%	0%	0%	0%	0%	0%
developing operational policies and procedures	0%	0%	0%	3%	0%	0%	0%	0%	0%
maintaining mechanical machinery	0%	0%	0%	3%	0%	0%	0%	0%	0%
handling and disposing of hazardous materials	0%	0%	3%	0%	0%	0%	0%	0%	0%
cleaning tools, equipment, workpieces and vehicles	0%	3%	0%	0%	0%	0%	0%	0%	0%
reporting incidents and defects	0%	0%	3%	0%	0%	0%	0%	0%	0%
estimating resource needs	0%	0%	3%	0%	0%	0%	0%	0%	0%
developing objectives and strategies	0%	0%	3%	0%	0%	0%	2%	0%	2%
advising on products and services	0%	3%	0%	0%	0%	0%	0%	0%	0%
training on operational procedures	0%	0%	3%	0%	0%	0%	0%	0%	0%
implementing new procedures or processes	0%	0%	3%	0%	0%	0%	0%	0%	0%
monitoring, inspecting and testing	0%	0%	0%	0%	2%	0%	0%	0%	0%
monitoring health conditions of humans and animals	0%	0%	0%	0%	2%	0%	0%	0%	0%
developing financial, business or marketing plans	0%	0%	0%	0%	2%	0%	0%	0%	0%
presenting information in legal proceedings	0%	0%	0%	0%	2%	0%	0%	0%	0%
positioning materials, tools or equipment	0%	0%	0%	0%	0%	0%	0%	0%	0%
moving and lifting	0%	0%	0%	0%	0%	0%	9%	15%	8%
tending plants and crops	0%	0%	0%	0%	0%	0%	30%	38%	40%
cleaning	0%	0%	0%	0%	0%	0%	5%	6%	4%
documenting and recording information	0%	0%	0%	0%	0%	0%	5%	3%	4%
managing information	0%	0%	0%	0%	0%	0%	2%	3%	2%
organising, planning and scheduling work and activities	0%	0%	0%	0%	0%	0%	5%	0%	2%
supervising people	0%	0%	0%	0%	0%	0%	2%	0%	2%
allocating and controlling resources	0%	0%	0%	0%	0%	0%	5%	0%	4%
operating machinery for the manufacture of products	0%	0%	0%	0%	0%	0%	2%	3%	2%
using precision instrumentation and equipment	0%	0%	0%	0%	0%	0%	0%	3%	0%
operating mobile plant	0%	0%	0%	0%	0%	0%	9%	18%	13%
protecting and enforcing	0%	0%	0%	0%	0%	0%	9%	6%	8%
negotiating	0%	0%	0%	0%	0%	0%	2%	0%	2%
presenting information	0%	0%	0%	0%	0%	0%	2%	3%	0%
promoting, selling and purchasing	0%	0%	0%	0%	0%	0%	5%	3%	4%

Source: Own elaboration using ESCO's methodology. ESCO does not include occupations that explicitly refer to "Wheat"; these occupations were selected to represent occupations closely related to occupations in Wheat production.

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