Rethinking Land Use and Rural Livelihoods in Ethiopia's Agroecological Zones

Paper prepared for the 29th Annual Conference on Global Economic Analysis, 2026

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Abstract

The structural characteristics of the Ethiopian economy make it particularly vulnerable to the impacts of climate change, prompting the government to explore a range of adaptation and mitigation strategies. Land use shifts and livelihood diversification—through semi-intensive livestock systems, afforestation and tree crop development, and the pursuit of grain self-sufficiency—have been identified in policy documents as viable responses. However, the effectiveness of these strategies in achieving their intended objectives has not yet been assessed ex-ante. This study evaluates the individual and combined impacts of three key interventions: (i) shifting from traditional grain cultivation to tree crops and semi-intensive livestock farming in the degraded, drought-prone highlands; (ii) expanding commercial grain production in the moisture-reliable lowlands; and (iii) partially reallocating rural labor from agriculture to non-farm activities. The analysis examines a range of economic, social, and environmental outcome indicators and reveals significant spatial and distributional effects, with important trade-offs across sectors. Taken together, the policy shifts accelerate overall GDP growth by 1.5 percentage points and agricultural GDP by 0.3 percentage points, while also contributing to notable reductions in poverty and improvements in diet quality, particularly in rural areas. Moreover, the findings highlight the potential of these strategies to support Ethiopia's climate change mitigation and adaptation objectives by enhancing agricultural output per unit of greenhouse gas emissions and water use.

Key words: Climate change, adaptation, rural development, environmental sustainability, Ethiopia

1. Introduction

Agricultural and rural development remain essential pillars for Ethiopia's social and economic advancement, as rural activities form the backbone of the nation's economy—contributing approximately 36 percent to the gross domestic product (GDP) and sustaining the livelihoods of over 80 percent of the population (World Bank, 2025; IFPRI, 2024). However, the agricultural sector is marked by low productivity and significant yield gaps (van Dijk et al., 2020), resulting in persistently high poverty rates in rural areas (World Bank, 2023).

Ethiopia's heavy reliance on the agricultural sector renders its economy highly vulnerable to climate-related shocks. While floods and severe storms are not uncommon, droughts –

accompanied by land degradation, mainly in the densely populated highlands – remain the most devastating climatic events, posing significant economic and humanitarian challenges (Hill & Porter, 2017). For example, since 2000, the country has experienced eight major droughts (Nicholson, 2014; Palmer et al., 2023), with the 2015 drought alone leaving 10.2 million people in need of humanitarian assistance. Similarly, recurrent flooding affects lower basins, compounding the vulnerability of rural communities. These extreme events can also intensify the currently alarming rate of land degradation, which is estimated at 85 percent of Ethiopia's landmass (Gebreselassie et al., 2016; Solomon et al., 2024).

The consequences of climate change extend beyond household food insecurity, threatening broader economic stability. Projections suggest that by 2050, Ethiopia could suffer a GDP loss of up to 30 percent due to declining agricultural productivity (World Bank, 2020). Aragie et al. (2025) also assessed that extreme weather events could cumulatively cost Ethiopia up to 17 percent (or US$ 534.3 billion) in GDP between 2020 and 2040 compared to a no-climate change baseline.

To mitigate and adapt to the impacts of climate change, Ethiopia has integrated climate resilience strategies into key national policy frameworks, including the Agricultural Growth Program (AGP), the Livestock Master Plan (LMP), the Sustainable Land Management Program (SLMP), and the National Adaptation Plan (NAP). These frameworks promote a range of climate-smart agricultural practices such as the adoption of drought-resistant crop varieties, expansion of irrigation systems, resilient livestock management, early warning systems, and integrated natural resource management. In addition, Ethiopia has recently reaffirmed its commitment to a green development trajectory by updating its Nationally Determined Contribution (NDC), reinforcing both adaptation and mitigation efforts against the adverse effects of climate change.

Land use change and livelihood diversification—through semi-intensive livestock systems, afforestation and tree crop development, and the pursuit of grain self-sufficiency—are frequently cited in development programs as viable strategies warranting greater attention. Addressing the impacts of climate change on livestock farming is particularly critical for sustaining rural livelihoods and ensuring nutrition security. This calls for a transformation of the sector, including through the removal of key constraints such as limited access to quality feed and veterinary services. Enhancing the sector's resilience through the adoption of semi-intensive livestock practices is especially promising in Ethiopia's degraded highlands, where crop-livestock integration is common. Such an approach offers farmers more stable and diversified livelihood opportunities.

Beyond their role in regenerating degraded soils and reducing environmental footprints, tree crops and agroforestry offer a critical pathway for reintegrating livestock with crops and trees, thereby sustainably enhancing access to animal feed (Do et al., 2024; Lal, 2020). This integrated approach not only strengthens ecosystem resilience but also supports rural livelihoods by fostering interdependence within the farming system. Moreover, integrating tree crops with livestock production can significantly improve household food security by diversifying income sources and stabilizing food availability (Datta et al., 2024).

Increasing climate variability further underscores the urgent need to transform Ethiopia's agricultural system—both spatially and by reducing its heavy dependence on rain-fed practices. In addition to investing in new irrigation infrastructure at various scales, the adoption of efficient irrigation technologies such as drip and sprinkler systems can play a vital role in enhancing water use efficiency and climate resilience. In tandem with irrigation infrastructure development, the government is actively promoting the spatial expansion of grain production into the moist lowlands, particularly focusing on crops like wheat, to bolster national food security and achieve self-sufficiency in strategic staples.

However, the extent to which these strategies can achieve their intended objectives and the associated trade-offs have not yet been evaluated ex-ante. Such an analysis is essential for mobilizing the necessary political and economic resources to support their implementation—or to determine whether a strategic reassessment is required.

Under such a context, this study aims to assess the economic, social, and environmental implications of potential land use and livelihood transitions in Ethiopia's agricultural sector, with particular attention to the diverse opportunities and constraints across different agroecological zones. It specifically investigates the impacts of shifting from traditional grain cultivation to tree crops and semi-modern dairy farming in the degraded, drought-prone highlands, as well as the expansion of commercial grain production in the moisture-reliable lowlands. In addition, the study explores the broader implications of a partial reallocation of rural labor from agriculture to non-farm activities. These transformations are analyzed within an economywide framework to evaluate their effects on regional and national incomes, poverty levels, diet quality, and environmental sustainability.

The rest of the paper is organized as follows: Section 2 describes the current economic structure of Ethiopia together with a concise presentation of the policy context in light of achieving sustainable development. Section 3 presents the method of analysis, focusing on the modeling framework and scenario design. Section 4 discussed the main findings from the scenario analysis, while Section 5 forwards concluding remarks and policy recommendations.

2. Economy and Policy Context

2.1. The Structure of Ethiopian Economy

The agricultural sector in Ethiopia contributes over 36 percent of gross domestic product (GDP) and employs approximately 78 percent of the workforce (Table 1). It has served as the primary engine of economic growth, expanding by an average of 6 percent annually over the past two decades (World Bank, 2025). With the right policy reforms and targeted interventions, the sector holds substantial potential to further accelerate and sustain the country's overall economic performance. Meanwhile, the service sector—particularly trade and food services—is growing rapidly and emerging as a key contributor to both GDP and employment, rivaling agriculture in importance. Nevertheless, for the broader economy to maintain momentum, agriculture must continue to perform and undergo structural transformation.

Within agriculture, grain production is by far the dominant sub-sector, accounting for 18.0 percent of total GDP and 53.5 percent of total employment—equivalent to 50.7 percent of agricultural GDP and 68.9 percent of agricultural employment. Livestock follows, contributing 9.3 percent to GDP and 7.2 percent to employment at the national level. Despite Ethiopia's rich agroecological diversity and considerable potential, tree crops remain less practiced, contributing only about 3 percent to both agricultural GDP and employment.

Table 1: Current structure of Ethiopia's economy (2022)

	GDP		Employment	
	Value (bil. US$)	Share (%)	Workers (millions)	Share (%)
Total economy	**936.5**	**100.0**	**52.1**	**100.0**
Agriculture	**332.2**	**35.5**	**40.5**	**77.6**
Grains	168.5	18.0	27.9	53.5
Tree crops	11.5	1.2	1.2	2.2
Other crops	40.1	4.3	4.6	8.8
Livestock	87.4	9.3	3.8	7.2
Other agriculture	24.7	2.6	3.1	5.9
Mining	**5.9**	**0.6**	**0.1**	**0.2**
Manufacturing	**46.6**	**5.0**	**3.2**	**6.1**
Agro-processing	19.2	2.1	0.9	1.8
Services	**372.5**	**39.8**	**8.4**	**16.1**

Source: Authors' calculation based on the 2022 Social Accounting Matrix for Ethiopia (IFPRI, 2024).
Note: 'Other crops' include vegetables, roots, tubers, fibers, and species. 'Other agriculture' constitutes fishery, aquaculture, and forestry. Values are in 2022 US$.

Cereals and other grains are the primary sources of food and income for most Ethiopians, accounting for approximately 78 percent of total cultivated area and 75 percent of total agricultural production in tons in 2022 (ESS, 2022). Over the past five years, the area allocated to grain cultivation has grown at an average annual rate of 1.2 percent, significantly slower than the growth rate of overall grain production (FAO, 2025). In contrast, land dedicated to tree crops—including fruits, tea, and coffee—has been expanding rapidly, growing by over 6 percent annually since 2019. Tree crops now represent around 6 percent of total cultivated land. While fruit consumption has historically been very low, there are emerging signs of a gradual shift in food consumption patterns toward these higher-value products (Trübswasser et al., 2020).

Ethiopia's diverse agroecological zones exhibit significant variation in their contributions to both the total area under cultivation and overall agricultural production. Among these, two zones are of particular interest in this study: the degraded and drought-prone highlands, and the moisture sufficient lowlands. The degraded highlands are the most densely populated regions in the country. They also play a considerable role in Ethiopia's agricultural activity. Specifically, these highland areas account for approximately 27.8 percent of the nation's cultivated land under grain crops and 16.8 percent under tree crops (Table 2). In stark contrast, the moist lowlands contribute only 2.5 and 2.4 percent to the national totals for grain and tree crops, despite this agro-ecologies huge potential in relation to its landmass. A previous study by IFPRI (Schmidt and Thomas, 2020) estimates the potential for crop land expansion in the lowlands at 117 percent given the prevailing access to infrastructure and markets during the time of study. In terms of production shares, the degraded highlands contribute close to 24.2 and 14.9 percent of grains and tree crops production, respectively, whereas moisture sufficient lowlands produce a small 2.7 and 3.6 percent of grains and tree crops. This disparity underscores the central role of the highland regions in national food production, despite their environmental challenges.

Table 2: Share (%) of Ethiopia's agroecological zones in total cultivated land and production

	Cultivated area			Production		
	Grains	Tree crops	Other crops	Grains	Tree crops	Other crops
Dry highlands	27.8	16.8	16.1	24.2	14.9	8.6
Moist highlands – cereal	59.3	61.8	60.5	63.8	53.2	45.8
Moist highlands – *enset*	8.0	18.9	21.1	7.9	28.2	42.8
Dry lowlands	2.4	0.1	0.5	1.4	0.1	0.3
Moist lowlands	2.5	2.4	1.7	2.7	3.6	2.5

Source: Authors' compilation based on ESS (2022)

Ethiopia, ranking among the largest in Africa with a cattle population exceeding 60 million, exhibits a pronounced spatial disparity in livestock distribution. Nearly half of the country's cattle are concentrated in the cereal-based humid highlands, reflecting the dense rural population and strong crop-livestock integration in these areas. The drought-prone highlands follow distantly, accounting for 28 percent of the national cattle population (Aragie and Thurlow, 2024). Despite its large herd size, Ethiopia's cattle sector is marked by low productivity, underscoring the unsustainability of its current livestock production system. This is especially true when considering the emission (FAO, 2025) and water footprints (Mekonnen and Hoekstra, 2010a, 2010b) of the livestock system. These sources estimate the share Ethiopia's livestock in total agricultural emission at over 70 percent and in agricultural water footprint at 25 percent.

A significant portion of the labor force is still employed in agriculture, which is dominated by semi-subsistence operators. As such, the sector remains the largest source of livelihood for the majority of the population, mainly the poor. Agriculture also plays a predominant role for the country's foreign exchange earnings, especially through exports of coffee, spices, and other agricultural products, although surpassed significantly by receipts through remittances.

Accelerating growth and sustaining high employment levels have long been central development objectives for countries worldwide, and Ethiopia is no exception. With a poverty headcount rate of 23.5 percent in 2015 (World Bank, 2023) and notable deficiencies in dietary diversity, the Ethiopian government recognizes the formidable challenges it faces—particularly as it strives to achieve social progress through cleaner, more sustainable means (FDRE 2011, World Bank, 2020). Consequently, there is an increasing imperative to assess investment and development strategies not only through traditional economic and social lenses but also in terms of their environmental implications, which are becoming integral to policy discourse. In this regard, water and emission footprints of activities are worth exploring.

Greenhouse Gas (GHG) emissions are byproducts of human activities throughout the production and consumption process. Data synthesized from FAO (2025), Climate Wach (2025), and Poore and Nemecek (2018) shows GHG emission in Ethiopia reaches to about 159 million tons of CO_2 equivalent in 2022. The Ethiopia's agriculture is the dominant source of emissions, accounting for approximately 77 percent (123 million tons CO_2 equivalent) of total. Within the agricultural sector, livestock production is the primary driver, responsible for more than two-thirds of the sector's emissions.

To achieve the objective of sustainable development – by fulfilling human socio-economic needs while safeguarding the environment – cleaner technologies should be complemented by strategies that emphasize on plant-based carbon sequestration. Studies (e.g., Skrzypczak et al., 2025) show that planting 1000 trees per ha could capture 10 to 48 tons of CO_2 annually. As such, planting tree crops – especially in the degraded highlands of Ethiopia – can provide a double sward in the fight for climate change and in diversifying farmers livelihoods.

Freshwater is a vital resource essential for human survival and a strategic input in production. The water footprint data both in total m^3 and in m^3/ton obtained from the Water Footprint Network (Mekonnen and Hoekstra, 2010a, 201b) indicates that Ethiopia's agricultural sector again accounts for over 97 percent of the nation's total water footprint. This underscores the predominance of agriculture in the country's water usage. Within agriculture, crop production uses most of the water, reaching 75 percent as the sector contributes close to 70 percent of total agriculture GDP.

Practicing tree crops and improving vegetation covers can slow surface runoff and increase baseflow and soil moisture content (Mompremier et al., 2022; Xu et al., 2023; Castel et al., 2021; Farley et al., 2005). For instance, Mompremier et al. (2022) found in the case of Haiti that afforestation decreased direct runoff by 9-32 percent and increased baseflow by 2-9 percent, at the same time decreasing flow variability. Castel et al. (2021) further analyzed the impact of agroforestry interventions on agricultural productivity and human-wellbeing in low- and middle-income countries and reported a productivity gain of 35 percent as a result of aggressive agroforestry interventions. It is, thus, no wonder that Ethiopia is practicing a massive afforestation program and that the shift from grains to tree crops in degraded highlands is being considered by various stakeholders as a valid move to reduce soil erosion, improve soil health and moisture retention, and sequestrate carbon in playing its own part in the global drive to mitigate climate change.

2.2. Policies for Sustainable Development

Ethiopia's contribution to climate change is negligible (PDC,2021; Menghistu et al., 2021), but the country is highly vulnerable to climate change and weather risks. This is for a number of reasons. The main producers and employer sector in the economy – agriculture – is dominated by smallholder farmers who lack access to modern inputs, and heavily relies on rainfall. Further, a great majority of the population, mainly the poor, reside in rural areas with limited access to infrastructural and financial capital. Extreme weather events – especially droughts and floods – are common in the country, with predications indicating increasing frequency and duration (Godde et al., 2021; Palmer et al., 2023). This vulnerability of the economy to climate change has urged the Ethiopian government to design policies and strategies to achieve sustainable development and contribute to the fight against climate change.

Climate change mitigation and adaptation strategies have been already incorporated within Ethiopia's guiding policy documents, including the Agricultural Growth Program (AGP), the Livestock Master Plan (LMP), Sustainable Land Management Program (SLMP), and National Adaptation Plan (NAP). The AGP (MoA, 2020) aims at improving agricultural productivity and commercialization of smallholder farmers. The LMP (Shapiro et at., 2015) identifies investment strategies to increase the productivity of the livestock sector to enhance its economic contribution and ensure a shift from extensive to semi-intensive livestock activity. While the SLMP (MoA, 2019) bases itself on the safety net program and targets at accelerating green economy, the NAP (FDRE, 2019) aims at positioning climate change responses within the country's development policy framework.

Recently, Ethiopia has endorsed green development path and updated its Nationally Determined Contribution (NDC) to introduce various mitigation and adaption options to lessen the negative impacts of climate change. The updated NDC sets out plans to reduce 68 percent of the national greenhouse gas emission by 2030 (EFCCC, 2021). This is despite the fact that Ethiopia contributes only 0.02 percent of global emissions (PDC, 2021). The livestock and the land use and land cover sectors represent 83 percent of total business-as-usual emissions in 2030. Of the 83 percent, the land use change and forestry (LUCF) contribute 35 percent and livestock the rest 48 percent.

Hence, the updated NDC focuses its climate change adaptation and mitigation strategies on these land use and land cover sectors. The document underlines that land use change and forestry (LUCF) have the largest mitigation potential as a result of highly ambitious reforestation and forest restoration targets. This is to be achieved through massive reforestation and restoration, which aims at increasing the nation's forest cover to 30 percent by 2030, turning the agroforestry sector into a significant GHG sink. The promotion of tree crops in parts of Ethiopia can help in this effort. Another strategy that has been indicated in the NDC is to increase livestock productivity by adopting semi-intensive farming and decrease the size of the livestock herd.

The land use and land cover strategy emphasizes increasing the share of agricultural land under sustainable practices, reducing pre-harvest losses, and minimizing land conversion for agricultural infrastructure. Grassland improvement is a key focus, contributing to carbon sequestration. Promoting tree crops in degraded highlands can support this sustainable land management strategy by increasing green cover, sequestering carbon, and diversifying livelihoods. Meanwhile, the strategy for transforming Ethiopia's livestock sector focuses on enhancing efficiency and productivity in dairy, red meat, and poultry through targeted intervention packages. A key shift in this strategy includes prioritizing quality of cattle versus quantity and improving the milk and meat value chains. Additionally, improved feeding practices—such as incorporating oilseeds in feed—are promoted to lower emissions from enteric fermentation.

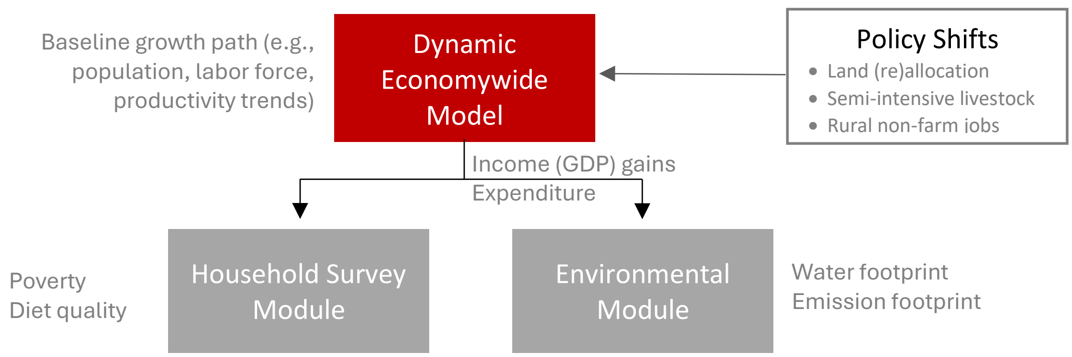
However, there are some missing links between Ethiopia's NDC and its food system both in plan and practice. Whereas the NDC rightly emphasizes on crop diversification while reducing the carbon footprint, less attention was given to promoting the production of nutrient-dense foods, including fruits and vegetables (EFSTN, 2024). It also didn't give much emphasis to reduce food waste and emission along the food system. As another sign of miss-match between policies stipulated in the NDC and other policy documents, data shows expansion in crop area (by 1.3 percent) and cattle herd size (2.6 percent) over the past decade (FAO, 2025).

3. Method of Analysis

3.1. Modeling Framework

This study assesses the economic, social, and environmental implications of potential land use and livelihood transitions within Ethiopia's agricultural sector, with a focus on the distinct opportunities and constraints across different agroecological zones. The analysis is conducted using IFPRI's RIAPA (Rural Investment and Policy Analysis) modeling system—an integrated framework that combines IFPRI's economywide model, household survey modules, and a resource use module (Figure 1). This comprehensive approach enables the evaluation of the impacts of policy shifts and interventions – including land policy, livestock interventions, and labor allocation – on a broad spectrum of development indicators, providing insights into economic growth, social well-being, and environmental sustainability.

Figure 1: A framework for modeling options for rural transformation in Ethiopia



Source: Authors' compilation

The economywide model

At the core of the integrated framework is IFPRI's CGE (Computable General Equilibrium) model. CGE models are widely utilized for economic policy formulation and analysis (Dixon and Parmenter, 1996; Devarajan and Robinson, 2010). They can effectively capture the interlinkages between sectors, households, and rural-urban economies, making them well-suited for assessing the economywide effects of various development policies and external shocks.

The Ethiopia model is calibrated to the 2022 Social Accounting Matrix (SAM) for Ethiopia (IFPRI 2024). The 2022 SAM represents the economy through a set of disaggregated sectors, encompassing 36 agricultural sub-sectors, which include 22 individual crops or groups of crops, six livestock production sectors, as well as forestry and fisheries. Additionally, the SAM incorporates 36 industrial sectors and 12 service sectors, many of which are closely related to agriculture. This includes 17 agro-processing activities within the industrial sector, along with trade and transport activities in the service sector. Providing such detailed representation of agricultural and non-agricultural sectors, the model tracks supply chains across various stages ranging from producers to final consumers.

The SAM was modified to accurately represent the regional features of agriculture in the country. This was achieved by integrating data from ESS (2022), which provides zonal-level information on crop and livestock production and land use. This spatial disaggregation was desirable to model the impacts of zone level interventions across the economy. Consequently, the revised SAM distinguishes 23 agricultural activities, including cattle, further disaggregated by agro-ecological zones.

Labor is disaggregated into rural and urban, and further by education/skill levels (no education, primary, secondary, and tertiary education). For rural labor allocation analysis purposes as will be detailed in section 3.2, rural labor is further split into farm and non-farm labor for each respective education/skill levels. Agricultural land, crop capital, and livestock capital in the SAM are disaggregated across five agroecological zones: (1) dry highlands, (2) moist highlands-cereal; (3) moist highlands-*enset*, (4) moist lowlands, and (5) dry lowlands (and pastoralists). The moist highlands account for over 70 percent of the national grain cultivation area and production (Table 2). Despite their limited potential due to continued land degradation, the dry highlands also contribute a significant share of cultivated areas and production.

The Ethiopia model also distinguishes 15 representative households, each of which is an aggregation of a group of households captured in the 2010/11 Ethiopian Household Consumption Expenditure (HCE) survey (CSA, 2012). These households are categorized into rural and urban, with rural households further divided into farm and non-farm groups based on their reliance on agriculture as a primary source of income. These households are further disaggregated by per capita expenditure quintiles to be able to analyze changes in poverty and distributional effects. In the model, households earn labor income and receive returns on their assets, which include land and capital, as well as domestic or foreign transfers. Whereas urban households principally earn labor income from non-agricultural employment, labor in rural areas enrage in both farm and non-farm activities. The Ethiopian model shows that under 10 percent of rural workers engage in non-farm employment.

The Ethiopian CGE model integrates a standard herd dynamics module (HDM) governing the livestock system that tracks annual herd size categorized by age, sex, breed, and agro-ecology. This HDM calculates changes in milk and meat yield caused by investments in feed (both traditional and improved) and shifts in breed composition and links the resultant change in milk and meat output to the corresponding sectors in the economic model. In turn, it utilizes data on consumer demand for animal products and prices and availability of livestock inputs derived from the economic model to recalibrate both new offtake levels and the remaining herd size (see Aragie and Thurlow, 2024).

The economywide model is a recursive dynamic CGE model that runs until 2030, solved using baseline growth path assumptions about population growth, labor force growth, change in sectoral productivity trends, and other macroeconomic fundamentals such as government spending. Climate actions and policy shifts such as those identified in Ethiopia's NDC, and other domestic and external shocks can force the economy deviate from its trend level of performance to a new growth trajectory, causing further changes in social and environmental sustainability outcomes.

The household survey module

While major economic indicators – changes in economic growth and job creation – are directly calculated from the core economywide model, assessing changes in social and environmental indicators necessitates specialized modules. To this end, the CGE model is linked top-down with household survey-based microsimulation modules measuring changes in poverty and diet deprivation. Real income changes for different household groups result in diverse effects on these social outcomes.

Changes in poverty are calculated by linking a poverty microsimulation module to the outcome variables of the CGE model—namely, household income, prices, and consumption—following the methodology of Arndt et al. (2012). The changes in real consumption across commodities, derived from the RIAPA model, are then applied to the corresponding households in the 2010/11 Household Consumption Expenditure (HCE) survey (CSA, 2012), which includes 15 representative household groups within the CGE model. The new poverty status is computed for all sampled households. The 2010/11 HCE survey encompassed 27,834 Ethiopian households, providing comprehensive information on various socio-economic variables, including income, consumption, and poverty levels.

Changes in diet quality follow a similar approach. A diet quality microsimulation module, recently developed by Pauw et al. (2023) for in-depth analysis of diet quality outcomes, was adapted for this study. This module utilizes data from all surveyed households and links them to their respective representative household groups in the CGE model. Dietary diversity is estimated across six major food group categories. This study applies the ReDD indicator, which serves as a multidimensional indicator of a household's diet quality, to track changes in the gap between a reference diet and the actual diet composition of households.

The environmental module

The environmental module uses information on water and emission intensities of sectors and calculates changes in total water and emission footprints of the economy over time as the economy evolves. The resulting resource footprint depends on which sector is expanding and driving the growth in the economy and the associated resource reallocation that occurs with it. For instance, as a water-intensive sector, such as rice expands, it potentially increases total water footprint in the cereal sector, but may also result in resource reallocation elsewhere possibly accelerating emission-intensive sector such as livestock.

The data used to operationalize the environmental module come from various sources. Whereas the water footprint data (m^3/ton) for various agricultural sectors – both crops and livestock – come from the Water Footprint Network (Mekonnen and Hoekstra, 2010a, 201b), this source only reports aggerate water footprint for sectors outside agriculture, namely industry and municipal water withdrawal. This aggerate industrial and municipal water withdrawal is distributed to the subcomponent sectors based on each component's contribution to sectoral output. We recognize the differences in water use by sector, but this was the most valid assumption we can make. In the end, the water footprint summed across all sectors at the baseline equals the extrapolated water footprint at economywide level.

Likewise, sectors differ in their emission intensities, i.e., emission generated associated with a ton of output. We use total emission data (in tons of CO_2 equivalent) obtained from FAO (2025) and Climate Watch (2025). FAO reports total emissions generated in the rice sector, other cereal in aggregate, and detailed livestock sub-sectors including milk and meat production. Climate Watch reports emissions generated by major manufacturing and service sectors that are also well-identified in Ethiopia's SAM. For the sake of completeness to attach emission factors for all agricultural sectors, we use global level estimates on emission per kg (CO_2 equivalent /kg) for a long list of commodities obtained from Poor and Nemecek (2018). These emission coefficients are then multiplied by the corresponding sectors' level of output obtained from FAO. We adjust the resultant emission by sub-sector until total emission in agriculture converges to the total reported for the sector.

Afforestation and tree crops can play a critical role in abating GHG emissions by sequestering carbon. As such, countries – including Ethiopia – are initiating massive tree planting initiatives and integrating tree cropping in their farming activities. Also, tree crops can help in maintaining soil moisture content and improving soil fertility, gradually improving agricultural productivity over the medium and long-run. Using information on the added values of tree crops on GHG sequestration from Skrzypczak et al. (2025) and on soil moisture content from Mompremier et al. (2022), this module is customized to reflect the impact of tree crops during the period of analysis, i.e., until 2030. Specifically, Skrzypczak et al. (2025) established that planting trees on an ha of land could capture 10 to 48 tons of CO_2 annually, while Mompremier et al. (2022) studied a case in Haiti and noted that afforestation increased baseflow by 2-9 percent, stabilizing water availability during dry periods.

3.2. Scenario Design

To analyze the implications of alternative land allocation and rural livelihood strategies, we first construct a baseline simulation (**Baseline**) and then model three alternative scenarios and two composite versions of these alternative scenarios to assess their overall impact as a package of strategies: (i) the tree crops and semi-intensive livestock in the degraded dry highlands scenario (**TCr+Liv_DH**), (ii) the grains in humid lowlands scenario (**Grn_ML**), (iii) the composite of these two (**Comb1**), (iv) the rural non-farm employment promotion scenario with implied farm and non-farm labor productivity (**RNF**), and (v) a scenario that combines all individual alternative policy shift scenarios (**Comb2**). We also split the **TCr+Liv_DH** scenario into its two components and design separate scenarios to understand the different impacts of the promotion of tree crops and semi-intensive livestock activities in the degraded highlands. Results from these scenarios, respectively identified as **TCr_DH** and **Liv_DH**, are reported in the annex tables.

Baseline scenario (Baseline): This is a business-as-usual scenario that mimics the recent past growth and structure of the economy and helps as a benchmark to compare the impacts of the alternative development strategies and policy shifts. In the baseline scenario, we assume the recent past growth trend is maintained, where agriculture, manufacturing, and services expand yearly by 4.0, 6.9, and 7.1 percent, respectively, resulting in an overall GDP growth of close to 6 percent. The model estimates the economic system up to 2030.

Tree crops and livestock in highlands scenario (TCr+Liv_DH): Estimates (Gebreselassie et al., 2016; Solomon et al., 2024) show that over 85 percent of Ethiopian landmass is heavily degraded, affecting productivity. This scenario emphasizes revitalizing the degraded highlands of Ethiopia by changing their vegetation landscapes and diversifying farmers livelihoods through the promotion of tree crops and semi-intensive livestock production focusing on dairy and red meat. In line with the size of grain land expansion in the **Grn_ML** scenario below, in the **TCr+Liv_DH** scenario, we assume 430,000 ha currently under grains cultivation in the degraded highlands is reallocated to tree crops, such as fruits, coffee, tea, cotton and nuts (Table 3). This is equivalent to an 11.7 percent reduction in land under grains in the region and a quadrupling of land under tree crops by 2030 from a mere 93,000 ha in 2022 (ESS, 2022). This shift in land use pattern is consistent with the country's strategy to improve the region's biophysical resources and reduces pressure on degraded highlands. As such, it is assumed, following Castel et al. (2021), that area under grains equivalent to that come under tree crops gains productivity by 35 percent. This amounts to nearly 16 percent of the grain land by 2030. This component of the **TCr+Liv_DH** scenario is considered as a separate scenario (**TCr_DH**) and is reported in the annex tables. Table 3 provides assumptions specific to the **TCr_DH** scenario.

Likewise, the **TCr+Liv_DH** scenario constitutes a livestock sector development strategy in the degraded highlands that focuses on improving breeds and feed systems to close the wide yield gap observed in the Ethiopia's livestock system. For instance, Abegaz (2022) and Duguma (2022) reports an average daily milk yield for local cows is approximately 1.5 liters, whereas improved systems can achieve 6 liters or more—a 4-fold difference. Meat yield per animal also shows considerable room for improvement with better feeding and breed quality (Abebe et al., 2022). To model the impact of improved livestock systems in Ethiopia's highlands, we assume a targeted 200 and 25 percent increase in milk and meat yield per animal, supported by adoption of improved dairy breeds and better herd management practices. This is also accompanied by a 50 percent increase in the production of improved feed by 2030 and a moderate increase in fodder production at a rate of one-third of the growth in tree crop land identified earlier in this scenario. This is supported by previous studies (Do et al., 2024, Lal, 2020) which established that tree crops and agroforestry can increase and sustain feed supply for livestock production. The changes to the livestock system are implemented within the HDM introduced in section 3.1. Again, this component of the scenario is also considered as a separate policy shift (**Liv_DH**) and results are reported in the annex. Again, Table 3 provides assumptions specific to the **Liv_DH** scenario.

Grains in lowlands scenario (Grn_ML): The **Grn_ML** scenario considers targeted expansion in grain production in moist lowlands of Ethiopia where an additional 430,000 ha of land is brought under grain cultivation by 2030 (Table 3). This is in line with the country's push to boost grain production and self-sufficiency and represents a 122 percent increase in farmland in the region dedicated to grain production, effectively doubling the overall area (grains and non-grains) of land under cultivation currently. Schmidt and Thomas (2020) estimated the potential for crop land expansion in the lowlands at 117 percent given the prevailing access to infrastructure and markets during the time of study. As access to infrastructure and markets expands through targeted investments, the region's potential can further expand. Since this land expansion is accompanied by irrigation development, in addition to the expansion in cultivated land, we also account for the yield effect of irrigation on new grain fields. With multiple harvesting seasons owing to irrigation, yields on the new grain fields are likely to double.

Rural non-farm scenario (RNF): Ethiopia's labor market reflects the characteristics of a typical low-income, agriculture-based economy, with farm labor dominating employment. Approximately 90 percent of rural jobs and 72 percent of national employment were in agriculture (World Bank, 2021; IFPRI SAM), indicating that rural non-farm activities employed only about 10 percent of the rural labor force. According to ILO (2025) data, the total labor force was estimated at 57 million in 2022. This scenario (**RNF**) models a policy-driven, accelerated shift from farm to non-farm employment in rural areas. Specifically, it assumes a doubling of the share of rural non-farm employment—an increase of 10 percentage points—by 2030 compared to 2022 levels. This shift results in a corresponding decline in farm employment of approximately 14 percent over the same period. To capture the potential productivity gains from labor transitioning out of agriculture, as well as the effects of complementary measures such as training and skills development, the scenario also assumes an annual increase of 1.6 percent in the productivity of rural farm and non-farm labor such that labor productivity becomes 10 percent higher by 2030. Such a complementary gain in productivity was also assumed in Dorosh et al. (2020).

Combined scenarios (Comb1 and Comb2): While **Comb1** jointly analyzes the policy interventions on degraded highlands (**TCr+Liv_DH**) and on most lowlands (**Grn_ML**) to examine the combined impacts of these agro-ecology-specific changes, **Comb2** expands this scope by integrating **Comb1** with **RNF** to evaluate the overall effects of the policy package across selected socio-economic and environmental outcomes.

Table 3: Land and labor allocation targets by 2030 compared with the allocation under the baseline scenario

Description	Scenarios	Land and Capital**		Labor supply		Productivity				
		Grains	Tree Crops	Rural Farm	Rural Non-Farm	Milk	Meat	Labor	Feed	Foder
Livestock in dry highlands*	Liv_DH					200.0%	25.0%		50.0%	
Tree crops in dry highlands	TCr_DH	-11.7%	463.3%							152.9%
Tree crops & livestock in dry highlands	TCr+Liv_DH	-11.7%	463.3%			200.0%	25.0%		50.0%	152.9%
Grains in moist lowlands	Grn_ML	100.0%								
Three above combined	Comb1	-11.7%, 100.0%	463.3%			200.0%	25.0%		50.0%	152.9%
Rural non-farm and skill	RNF			-14.2%	112.7%			15.3%		
Comb1 & RNF	Comb2	-11.7%, 100.0%	463.3%	-14.2%	112.7%	200.0%	25.0%	15.3%	50.0%	152.9%

Source: Authors' assumptions

Note: * Most of the dry highlands in Ethiopia are degraded due to centuries old practice of unsustainable farming. ** We assume there is a support to increase access to crop capital to the sectors with increases in land allocation at a rate half of the increase in land. Likewise, crop capital will be proportionately diverted from grains to tree crops in degraded highlands.

4. Discussion of Results

4.1. Macroeconomic effects

This section examines the impacts of alternative policy shifts on Ethiopia's macroeconomy, compared to the business-as-usual or baseline scenario. The baseline projects a robust 5.8% increase in national GDP, indicating stable economic growth (Table 4). This is accompanied by a comparable rate of growth in absorption and private consumption as well as a robust performance in the export sector, which is likely leading to the depreciation of the local currency.

Since some interventions are zone-specific, changes in macroeconomic indicators generally appear modest. However, implementing the policy shifts jointly could accelerate the annual GDP growth rate by 1.5 percentage points to 7.3 percent per year. The majority of this growth stems from the shift of labor out of agriculture into the rural non-farm sector, which boosts labor productivity and strengthens the link between agricultural and non-agricultural activities in rural areas. Among the agro-ecology-specific policies, those targeting the degraded, drought-prone highlands have slightly stronger effects on GDP, mainly driven by productivity gains in the livestock sector. In combination, the land use change scenarios in degraded highlands and moist lowlands together with semi-intensive livestock sector in the former (i.e., **Comb1**) contributes to a 0.1 percentage point faster growth in GDP per year, leading to a 0.4 percent bigger economy by 2030.

A major contributor to this GDP growth is the acceleration of export earnings, particularly under scenarios with an abundant rural labor supply in non-farm sectors. This labor shift enhances the performance of non-agricultural sectors and increases the production of tradable goods and services beyond agriculture. GDP growth is further reinforced by higher domestic absorption, reflecting increased internal demand, alongside a notable rise in private consumption. Additionally, the improved export performance leads to a significant depreciation of the exchange rate.

Table 4: Change in macroeconomic indicators GDP by 2030, annual growth

-	Baseline values (bil. US$)		Annual average growth rate (2024-2030)					
	2024	2030	Baseline	TCr+Liv_DH	Grn_ML	Comb1	RNF	Comb2
Absorption	145.8	200.6	5.47	5.50	5.49	5.52	6.76	6.81
Private consumption	99.7	134.9	5.17	5.23	5.21	5.26	6.18	6.27
Export	11.3	19.8	9.81	9.83	9.83	9.86	13.26	13.28
Import	(23.3)	(32.9)	5.92	5.94	5.94	5.95	7.98	8.00
GDP at factor cost	127.7	179.3	5.82	5.87	5.85	5.90	7.22	7.30
Exchange rate	1.0	1.0	0.76	0.72	0.75	0.71	0.59	0.55

Source: Model results
Note: Values are in 2022 US$. Exchange rate is normalized to 1.0 in 2024.

4.2. Sectoral level effects (national and agro-ecological levels)

Table 5 presents the effects of the various policy scenarios on national-level sectoral performance. This will be followed by a discussion of how the agricultural sector in different agroecological zones responds to the policy shifts under examination. As shown in Table 5, changes in land use combined with the partial reallocation of rural farm labor to outside agriculture can jointly raise agricultural sector annual growth by 0.3 percentage points over the 2025–2030 period, bringing the annual growth rate to 4.4 percent. This growth contributes to an increased supply of food and other agricultural products. However, the impact of this combined scenario varies across agricultural sub-sectors, reflecting the sector-specific nature of several of the combined policy interventions.

Most of the growth in agriculture is driven by agroecology-specific interventions—namely, land conversion to tree crops and livestock intensification in degraded highlands (**TCr+Liv_DH**) and land expansion for grain production in moist lowlands (**Grn_ML**). When these two interventions are implemented jointly, agricultural GDP grows 0.24 percentage points faster per year through 2030, growing by 4.3 percent. Under the **TCr+Liv_DH** scenario, the tree crop and livestock sectors grow at accelerated rates—1.9 and 0.5 percentage points above the baseline, respectively. In contrast, the gains under **Grn_ML** stem primarily from a 0.2 percentage point increase in the national annual growth rate of grain production. Overall, growth remains stagnant in agricultural sub-sectors not targeted by these land allocation shifts, such as roots and tubers, and vegetables.

Table 5: Change in GDP by 2030 - National level, average growth

-	Baseline values (bil. US$)		Annual average growth rate (2024-2030)					
	2024	2030	Baseline	TCr+Liv_DH	Grn_ML	Comb1	RNF	Comb2
Total economy	127.7	179.3	5.82	5.87	5.85	5.90	7.22	7.30
Agriculture	48.0	61.1	4.08	4.23	4.17	4.32	4.17	4.41
Grains	25.0	30.4	3.33	3.27	3.49	3.42	3.29	3.39
Tree crops	1.8	2.0	1.47	3.34	1.45	3.32	0.64	2.55
Other crops	6.1	7.1	2.63	2.54	2.64	2.55	2.66	2.58
Livestock	11.6	16.9	6.36	6.86	6.38	6.88	6.37	6.92
Other agriculture	3.5	4.7	5.05	4.99	5.06	5.00	6.63	6.57
Mining	0.8	1.1	6.29	6.26	6.30	6.27	8.52	8.50
Manufacturing	6.1	9.1	6.94	7.10	6.93	7.08	9.24	9.43
Agro-processing	2.7	3.6	5.10	5.15	5.11	5.16	6.37	6.47
Services	48.7	73.2	7.05	7.03	7.04	7.03	9.00	8.97

Source: Model results

Note: 'Other crops' include vegetables, roots, tubers, fibers, and species. 'Other agriculture' constitutes fishery, aquaculture, and forestry. Values are in 2022 US$.

Meanwhile, the overall effect on sectors outside agriculture is much stronger, with the manufacturing and services sectors each growing *roughly* by 9.0 percent per year compared with the 7.0 percent growth under the baseline scenario (Table 5). The **RNF** scenario is the primary driver of growth outside the agricultural sector. As shown in Table 5, shifting rural labor to non-farm sectors at the simulated levels accelerates manufacturing sector growth to 9.2 percent—92 percent of the growth observed under the **Comb2** scenario—compared to 6.9 percent in the baseline. The agro-processing sector, which plays a critical role in linking agriculture with the broader economy, also expands at a significantly faster rate, growing 1.3 percentage points above the baseline. Similarly, the service sector grows nearly 2 percentage points faster at nearly 9.0 percent, fueled by an increased and more affordable labor supply, as well as the strong performance of the manufacturing sector.

The impact of policy interventions on agricultural performance exhibits significant regional variation. These differences are closely tied to the sectoral focus of the interventions, as agro-ecological zones respond differently based on their local agricultural structures, labor dynamics, and land use patterns.

The **TCr+Liv_DH** intervention—aimed at shifting farmland from grain cultivation in degraded highlands to tree crops, alongside the promotion of semi-intensive livestock practices that rely on forage from expanded tree cropland—accelerates livestock GDP growth in dry highland (DH) regions by 1.9 percentage points annually, up from a baseline average of 6.3 percent (Table 6). Additionally, tree crop GDP in the region grows by 14.4 percent, compared to a modest 2.7 percent without the intervention. Together, these changes boost the region's overall agricultural GDP growth by 0.6 percentage points.

However, the overall impact on agricultural GDP remains modest due to the diversion of land away from grain cultivation, which offsets some of the gains in total output. As a result, grain production in the region—representing a key staple in Ethiopia—declines slightly by 0.3 percentage points relative to the baseline annual growth rate of 3.3 percent. This effect is marginal or negligible in other regions, underscoring the localized nature of livestock-focused policies. Yet, as shown in Table 5 under the **TCr+Liv_DH** scenario, national grain production remains slightly below the baseline level, placing upward pressure on cereal prices.

Meanwhile, grain intensification in moist lowlands (**Grn_ML**) causes a 3.0 percentage points faster growth in grain production in the region throughout the 2025-2030 period compared to the baseline growth of 2.4 percent. This contributes to a significant rise – from 3.9 percent growth to 5.5 percent – in overall agricultural performance in the moist lowland (ML) region, highlighting the strong potential this zone has to grain-related policy stimuli.

In comparison to the two earlier groups of policy shifts that specifically target the degraded highlands and moist lowlands, the **RNF** scenario promotes off-farm employment opportunities across the entire country. As shown in Table 6, rural non-farm strategies—coupled with dual productivity gains both on and off the farm—can help offset the potential negative effects of labor reallocation away from agriculture. These gains arise endogenously: agricultural productivity increases as underemployed workers exit the sector, while rural labor productivity improves through skill development in non-farm activities.

Meanwhile, when the interventions are implemented jointly, they accelerate annual agricultural GDP growth in DH and ML regions by between 0.6 and 1.4 percent per year to 4.5 and 5.3 percent, respectively. These GDP gains are contributed hugely by the expansion in the livestock and tree crop sectors in degraded highlands, and grain production in moist lowlands.

Table 6: Change in agriculture GDP by 2030 – Agro-ecological level, average growth

		Baseline values (bil. US$)		Annual average growth rate (2024-2030)					
		2024	**2030**	**Baseline**	**TCr_Liv_DH**	**Grn_ML**	**Comb1**	**RNF**	**Comb2**
DH	Agriculture	10.5	13.2	3.88	4.44	3.93	4.49	3.82	4.47
	Grains	6.4	7.8	3.29	3.03	3.37	3.11	3.23	3.05
	Tree crops	0.2	0.2	2.69	14.43	2.68	14.42	2.68	14.52
	Other crops	1.4	1.6	2.09	1.97	2.10	1.97	1.91	1.80
	Livestock	2.4	3.5	6.32	8.17	6.34	8.19	6.33	8.32
MHc	Agriculture	24.3	30.7	3.96	4.02	4.00	4.06	3.93	4.02
	Grains	15.5	18.9	3.42	3.43	3.47	3.49	3.40	3.48
	Tree crops	1.1	1.2	1.05	1.60	1.03	1.57	-0.04	0.45
	Other crops	2.5	3.0	2.70	2.62	2.71	2.63	2.72	2.66
	Livestock	5.2	7.6	6.55	6.68	6.58	6.71	6.60	6.76
MHe	Agriculture	6.0	7.6	4.03	4.09	4.06	4.11	4.06	4.14
	Grains	1.8	2.2	3.40	3.41	3.44	3.45	3.44	3.49
	Tree crops	0.5	0.5	1.54	2.08	1.53	2.07	0.75	1.27
	Other crops	2.0	2.4	2.89	2.81	2.91	2.82	3.06	2.99
	Livestock	1.7	2.5	6.51	6.65	6.53	6.67	6.56	6.72
DL	Agriculture	2.3	3.1	4.95	5.00	5.01	5.06	4.78	4.89
	Grains	0.5	0.5	2.11	2.00	2.34	2.22	1.63	1.73
	Tree crops	0.0	0.0	5.93	5.53	5.89	5.49	7.23	7.05
	Other crops	0.0	0.0	2.72	2.66	2.73	2.67	2.72	2.67
	Livestock	1.8	2.5	5.66	5.75	5.69	5.77	5.54	5.65
ML	Agriculture	1.5	1.9	3.95	3.95	5.50	5.49	3.83	5.34
	Grains	0.8	0.9	2.42	2.32	5.37	5.26	2.16	4.96
	Tree crops	0.1	0.1	2.80	3.12	2.79	3.10	2.71	3.06
	Other crops	0.1	0.1	2.89	2.80	2.91	2.82	3.11	3.04
	Livestock	0.5	0.7	6.50	6.62	6.53	6.65	6.49	6.64

Source: Model results

Note: DH = Degraded dry highlands, MHc = Moist highlands – cereal-based, MHe = Mosit highlands – *enset*-based, DL = Dry lowlands, and ML = Most lowlands. 'Other crops' include vegetables, roots, tubers, fibers, and species. 'Other agriculture' constitutes fishery, aquaculture, and forestry. Values are in 2022 US$.

4.3. Household level effects (real consumption expenditure, poverty, and diet quality)

This section examines the impacts of the selected policy shifts on key household-level outcome indicators, including consumption expenditure, poverty headcount rate, and diet diversity score. Table 7 compares the average growth in household expenditure under each policy scenario with the baseline outcome. Consistent with the change in private consumption reported in Table 3, implementing all scenarios jointly leads to an average household consumption growth of 6.3 percent—1.1 percentage points higher than the baseline growth of 5.2 percent. This improvement is driven by a faster increase in real income as a result of accelerated economic growth. Notably, the **RNF** intervention is the primary contributor to this rise in household consumption, while the land allocation scenarios have only a marginal impact. This limited effect is due to trade-offs between grain and tree crop sectors in the DHs and the relatively small contribution of grain production in the MLs to national output, despite regional expansion.

Rural households benefit strongly from each of the policy shifts, although the effect from the **RNF** option remains stronger, contributing greatly to the overall combined effect. Specifically, consumption growth for rural households increases by 1.5 percentage points compared to the 0.1 percentage points gain in consumption growth for urban households when all scenarios are implemented. The policy options considered further have stronger gains in consumption by poorer households (lower 40 percent in per capita expenditure), mainly when the **RNF** and composite scenarios are considered since most of the poor rely on upstream and downstream agri-food systems that are directly impacted by the interventions analyzed.

Table 7: Change in household expenditure by 2030, annual average

-	Baseline values (bil. Birr)		Annual average growth rate (2024-2030)					
	2024	2030	Baseline	TCr_Liv_DH	Grn_ML	Comb1	RNF	Comb2
National	99.7	134.9	5.17	5.23	5.21	5.26	6.18	6.27
Poor	21.7	29.6	5.36	5.44	5.41	5.48	7.10	7.22
Non-poor	78.0	105.3	5.12	5.17	5.15	5.20	5.92	6.00
Rural	71.0	95.5	5.07	5.14	5.11	5.18	6.43	6.55
Poor	20.8	28.3	5.30	5.38	5.35	5.43	7.10	7.23
Non-poor	50.2	67.1	4.97	5.04	5.01	5.08	6.15	6.26
Urban	28.7	39.4	5.43	5.43	5.45	5.45	5.53	5.56
Poor	0.9	1.3	6.65	6.67	6.68	6.71	6.98	7.04
Non-poor	27.8	38.1	5.39	5.39	5.41	5.41	5.49	5.51

Source: Model results

Note: The poor refer to the lower 40 percent of the population in per capita expenditure. Values are in 2022 US$.

With a population growth rate of approximately 2.4 percent, the economy's average growth rate of 5.8 percent (Table 3) is likely to have a significant impact on poverty reduction. Accordingly, the baseline scenario projects a potential 9.2 percent reduction in the national poverty rate by 2030 (Table 8). Notably, the majority of this decline is expected to occur in rural Ethiopia. The policy shifts under consideration further accelerate poverty reduction in both rural and urban areas. However, the impact is more pronounced in rural regions, where the poor benefit more directly from these interventions through income gains. When all policy options are implemented jointly, the poverty headcount rate at the national level is projected to decline by an additional 3.4 percentage points by 2030 to a total of 12.6 percentage point reduction. This reduction is comparable to the level of development gains that would be achieved under the **RNF** scenario alone. In contrast, the **TCr+Liv_DH** and **Grn_ML** scenarios jointly yield only a marginal reduction—0.29 percentage points—relative to the baseline, due to their limited overall impact on the economy.

Table 8: Changes in poverty and diet quality

-	Baseline			Percentage point change in poverty compared to the baseline trend by 2030				
	2024	**2030**	**Change**	**TCr_Liv_DH**	**Grn_ML**	**Comb1**	**RNF**	**Comb2**
Poverty								
National	21.35	12.14	-9.21	-9.41	-9.28	-9.50	-12.38	-12.58
Rural	23.21	13.20	-10.01	-10.23	-10.07	-10.34	-13.97	-14.19
Urban	13.78	8.32	-5.46	-5.61	-5.55	-5.63	-5.75	-5.90
Diet								
National	58.58	53.21	-5.37	-6.64	-5.44	-6.71	-5.69	-7.02
Rural	60.37	54.07	-6.30	-7.65	-6.38	-7.72	-7.44	-8.90
Urban	51.28	50.10	-1.17	-2.17	-1.22	-2.22	1.50	0.62

Source: Model results

The issue of diet quality is gradually assuming recognition as a key development challenge. Model results generate interesting insights (see lower panel of Table 8). Under the current growth dynamics, diet quality tends to improve faster in rural areas compared to urban areas since, as producers, rural households tend to increasingly have better access to food types to which both rural and urban households experience a consumption gap, including milk, meat, and horticulture products. The policy options considered in this study tend to further accelerate the improvements in diet quality, mainly in rural areas. This improvement is largely associated with the **TCr+Liv_DH** scenario, which increases the availability of nutrition dense animal products, fruits, and other tree crops. Meanwhile, the **RNF** option is likely to narrow access to quality and diversified diets in urban areas as under this scenario (i) agriculture grows slower and significantly so compared to the non-agricultural sector, and (ii) the price of food increases faster than the increase in income in this part of the country (Table 7).

4.4. Environmental effects (emissions and water)

Reports indicate that Ethiopia's GHG emissions were approximately 159 million tons of CO_2 equivalent, with the agricultural sector accounting for the majority—125 million tons. Using the environment module introduced in section 3.1, we estimate that emissions from agriculture reached 134 million tons of CO_2 equivalent in 2024 (Panel A, Figure 2). Under the baseline growth trajectory, emissions could rise to 173 million tons by 2030, assuming the economy grows at an average annual rate of 5.8 percent. This corresponds to an average annual emissions growth rate of 4.3 percent between 2024 and 2030.

The policy scenarios considered in this analysis alter emission levels relative to the baseline for several reasons. First, the economic growth rate differs from the baseline in each scenario, potentially leading to varying emission levels. Second, alternative scenarios change the sectoral composition of the economy, resulting in different emissions, as sectors vary in their emission intensities—that is, emissions per unit of output. Third, scenarios that promote increased vegetation cover, particularly by encouraging tree crops over annual grains, contribute to sustainability by enhancing carbon sequestration in soil and biomass. Based on estimates by

Skrzypczak et al. (2025), we assume that one hectare of land under tree crops sequesters 40 tons of carbon annually. This carbon capture rate is applied to each additional hectare of tree crop land across all scenarios—scenarios with greater expansion in tree crop area yield larger carbon sequestration benefits.

Panel B of Figure 2 supplements results reported in Panel A and illustrates the impact of the policy options by comparing total agricultural sector emissions in 2030 with those under the baseline scenario. As expected, promoting tree crops under the **TCr+Liv_DH** scenario results in the smallest increase in emissions—over 9 percent lower than the baseline level. As shown in Annex Figure A1, the emissions reduction is even greater when the livestock sector—traditionally the highest emitter of CO_2—is excluded from the DH interventions (i.e., under the **TCr_DH** scenario). In contrast, the **Grn_ML** scenario produces the highest emission levels among the alternatives, matching those of the baseline, despite its limited economic impact. Meanwhile, the **Comb2** scenario, despite its strong economic performance—raising average annual GDP growth by 0.3 percentage points—results in one of the smallest increases in emissions. This is largely due to modest shifts in the sectoral composition of the economy as it expands.

The lower panel of Figure 2 presents the water footprint impacts of various policy options relative to the baseline scenario. Water footprint is determined based on sector-specific water intensity, as assessed by Mekonnen and Hoekstra (2010a, 2010b). In addition, following Skrzypczak et al. (2025), we assume a 9 percent increase in net soil water content on farmlands under tree crops, which is treated as an improvement in the systems water use efficiency. Since the share of farmland under tree crops remains below 9 percent by 2030—even under the scenario that promotes tree crop expansion (**TCr+Liv_DH**)—rising from 6 percent in 2022 the water resource impact under this scenario remains modest. However, the potential impact could be substantial if the conversion of land from annual crops to tree crops is scaled up and sustained over time.

Under the current growth trajectory, the agricultural sector's water footprint is projected to increase by 4.17 percent by 2030, rising from nearly 200 billion m^3.[1] However, the combined implementation of interventions targeting the degraded highlands, moist lowlands, and rural non-farm activities—at the simulated levels—would raise the water footprint by only 0.8 percent in 2030 compared to the baseline. This increase is significantly lower than the 1.9 percent rise in agricultural GDP observed between the baseline and **Comb2** scenarios, indicating a more water-efficient growth pattern. As will be discussed further in Figure 3, the promotion of tree crops contributes to this relatively modest increase in water use by improving soil moisture retention in the degraded highlands—reducing runoff and enhancing baseflow recharge. This is further observed in Annex Figure A2 through a 0.6 percent reduction in water footprint under **TCr_DH** – which excluded the livestock sector expansion embodied in **Liv_TCr** – compared to the 2030 water footprint level under the baseline scenario. Notably, the RNF scenario shows potential for reducing the sector's water footprint, as the economy gradually and endogenously shifts away from water-intensive grain and horticulture production, despite a slight increase in overall agricultural GDP.

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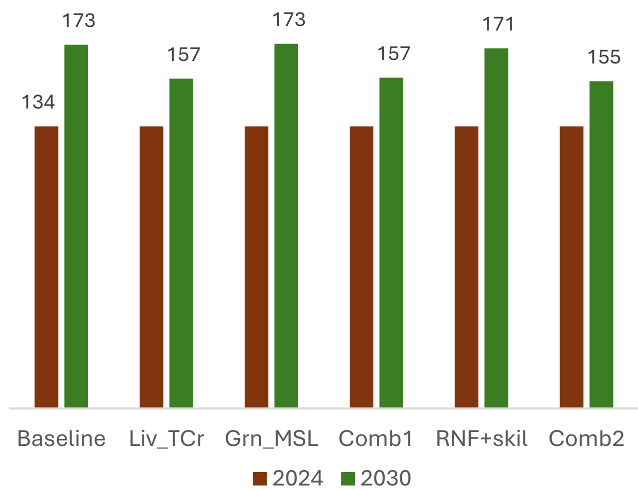
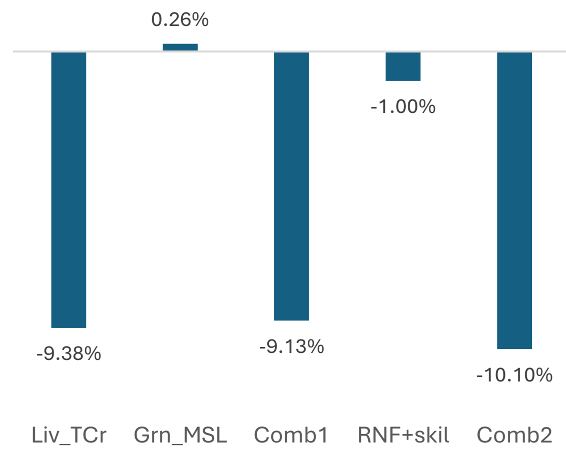
[1] Mekonnen and Hoekstra (2010a, 2010b) report water footprint of nations by 2005. We linearly increased the wafer footprint to the 2022 model baseline in this study by applying the economy growth rate between 2005 and 2022. This assumes no significant change in water use efficiency over the period.

Figure 2: Emission and water footprints in agriculture, by scenario

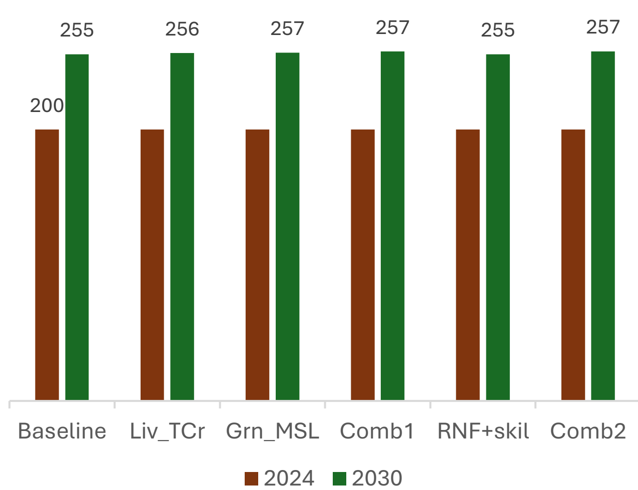
A) Emissions in agriculture (mil. of CO_2 equiv.)



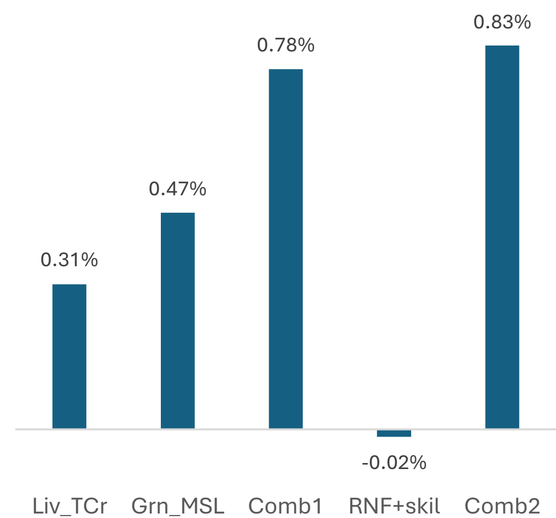
B) Annual growth in emissions in agriculture



C) Water footprint in agriculture (bil. of m^3)



D) Annual growth in water footprint in agriculture



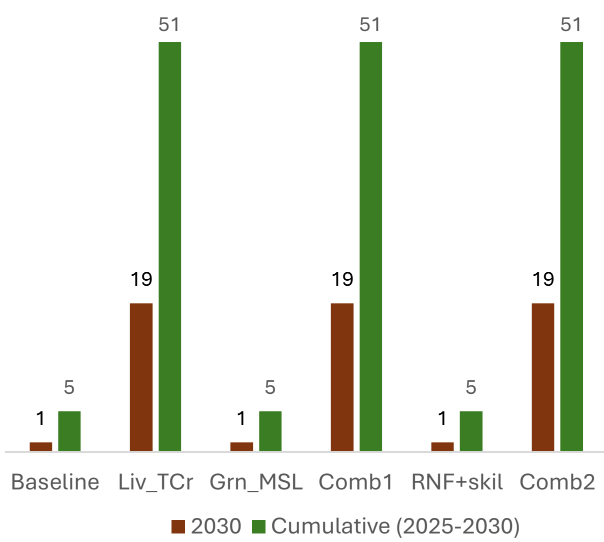
Source: Model results

Figure 3 quantifies and presents the additional carbon sequestration and soil water retention resulting from the widespread adoption of tree crops, particularly in the degraded highlands. These contributions directly support the emissions and water footprint reductions reported in Figure 2. Panel A of Figure 3 shows that tree crops have the potential to sequester 19 million tons of CO_2—equivalent to 11 percent of the projected 173 million tons of CO_2 equivalent emissions from agriculture by 2030 under the baseline (business-as-usual) scenario. Cumulatively, between 2025 and 2030, the development of farmland for tree crops could store approximately 51 million tons of CO_2, making a substantial contribution to Ethiopia's efforts to reduce net emissions while simultaneously rehabilitating degraded land. In contrast, the **Grn_ML** and **RNF** scenarios do not emphasize the expansion of tree crops; as a result, their carbon sequestration benefits remain minimal and closely align with emissions observed under the baseline scenario.

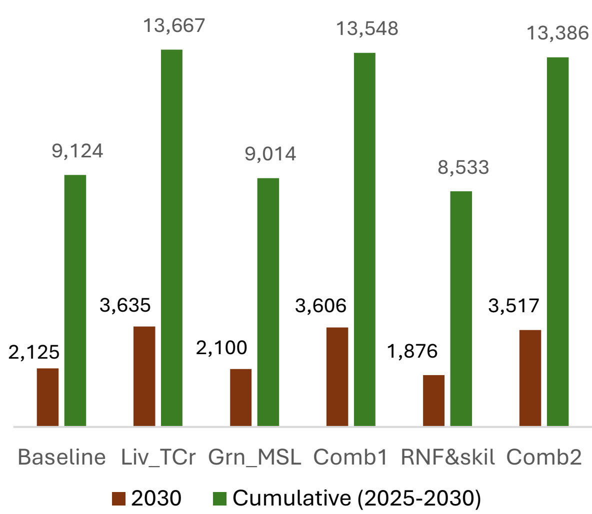
Panel B of Figure 3 illustrates the role of tree crops in restoring soil water content (moisture) in Ethiopia's degraded highlands. The increase in soil moisture under the baseline scenario is primarily attributed to the gradual expansion of farmland cultivated with tree crops over time. Expanding tree crop cultivation in the degraded highlands—under the **TCr+Liv_DH** scenario—would raise soil water content by 71 percent relative to the baseline, reaching 3.7 billion m^3 by 2030. The cumulative impact of this shift in cropping patterns is significant, especially in the context of land rehabilitation and water resource management. In contrast, the **Grn_ML** scenario yields water footprint outcomes that closely mirror the baseline, as it prioritizes land expansion for grain production and does not emphasize tree crop development. The Comb1 and Comb2 scenarios, which incorporate the same rate of tree crop expansion as **TCr+Liv_DH**, result in comparable improvements in soil water content. Although the **RNF** scenario demonstrates the lowest overall water footprint (Panel C, Figure 2), its impact on soil moisture content is limited and falls below that observed under the baseline. This indicates that the reduction in water footprint in the RNF scenario stems primarily from the economy's endogenous shift away from water-intensive agricultural activities, rather than from vegetation changes that enhance soil water retention.

Figure 3: Additional CO_2 sequestration and soil water content from tree crops, by scenario

A) CO_2 sequestration from tree crops (mil. tons)



B) Soil water content from tree crops (mil. m^3)



Source: Model results

5. Conclusions and Policy Implications

Agricultural and rural development remain essential pillars for Ethiopia's socio-economic advancement, as rural activities form the backbone of the nation's economy. However, these activities are marked by low productivity and significant yield gaps and are highly vulnerable to climate-related shocks such as droughts and flooding. To mitigate and adapt to the impacts of climate change, Ethiopia has integrated climate resilience strategies into key national policy frameworks. The country has also recently reaffirmed its commitment to a green development trajectory by updating its Nationally Determined Contribution (NDC), reinforcing both adaptation and mitigation efforts against the adverse effects of climate change.

Land use change and livelihood diversification—through semi-intensive livestock systems, afforestation and tree crop development, and the pursuit of grain self-sufficiency—are frequently cited in development programs as viable strategies warranting greater attention. However, the extent to which these strategies can achieve their intended objectives has not yet been evaluated ex-ante. Such an analysis is essential for mobilizing the necessary political and economic resources to support their implementation—or to determine whether a strategic reassessment is required.

This study aims to assess the economic, social, and environmental implications of potential land use and livelihood transitions in Ethiopia’s agricultural sector, with particular attention to the diverse opportunities and constraints across different agroecological zones. It specifically investigates the impacts of shifting from traditional grain cultivation to tree crops and semi-modern dairy farming in the degraded, drought-prone highlands, as well as the expansion of commercial grain production in the moisture-reliable lowlands. In addition, the study explores the broader implications of a partial reallocation of rural labor from agriculture to non-farm activities. These transformations are analyzed within an economywide framework to evaluate their effects on regional and national incomes, poverty levels, diet quality, and environmental sustainability.

Results from the Ethiopia model indicate that joint implementation of the policy shifts could accelerate annual GDP growth by 1.5 percentage points, with similarly strong gains in absorption and private consumption. The bulk of these gains stem from shifting labor out of agriculture into the rural non-farm sector. In contrast, the zone-specific nature of the remaining interventions and sectoral trade-offs—particularly between grains and tree crops—result in more modest macroeconomic impacts. Collectively, the policy shifts boost agricultural growth by 0.3 percentage points over the 2025–2030 period, relative to the baseline rate of 4.1 percent. Growth outside agriculture is even more pronounced, driven by efficiency-enhancing labor reallocation toward rural non-farm activities.

The impact of policy interventions on agricultural performance varies significantly across regions. In the degraded dry highlands, targeted interventions accelerate livestock GDP growth by 1.9 percentage points annually, up from a baseline of 6.3 percent. Similarly, tree crop GDP in the region rises sharply to 14.4 percent, compared to just 2.7 percent without intervention. Together, these improvements boost the region’s overall agricultural GDP growth by 0.6 percentage points, despite a 0.3 percentage point decline in grain production growth. In contrast, grain intensification in the moist lowlands leads to a 3.0 percentage point increase in grain GDP growth over the 2025–2030 period, relative to the baseline rate of 2.4 percent. This translates into a substantial improvement in the region’s overall agricultural performance, underscoring the strong responsiveness of this zone to grain-focused policy measures.

We also observed significant household-level impacts across the policy options. Their combined implementation results in average household consumption growth that is 1.1 percentage points higher than baseline growth. The rural non-farm intervention is the primary driver of this increase, while land allocation scenarios contribute only marginally due to sectoral trade-offs. Rural households and the poor experience the greatest consumption gains, reflecting their dependence on upstream and downstream segments of the agri-food system directly affected by the analyzed interventions. The proposed policy shifts further accelerate poverty reduction in both rural and urban areas, with more pronounced effects in rural regions due to a higher concentration of poor households. Diet diversity also improves significantly—particularly in rural areas—under the tree crops and semi-intensive livestock scenarios, which enhance the availability of nutrient-dense animal products, fruits, and other tree crops.

Promoting tree crops (jointly with semi-intensive livestock) in the degraded highlands results in the smallest increase in emissions—over 9 percent lower than the baseline level due to the carbon sequestration effects of the tree crops. In contrast, the grains in the moist lowlands scenario produces the highest emission levels among the alternatives, matching those of the baseline, despite its limited economic impact. Meanwhile, implementing all individual policy shifts jointly, despite its strong economic performance, causes the smallest increases in emissions. This is largely due to modest shifts in the sectoral composition of the economy as it expands.

We further noted from the water footprint effect that the combined implementation of interventions targeting the degraded highlands, moist lowlands, and rural non-farm activities—at the simulated levels—would raise the water footprint by only 0.8 percent in 2030 compared to the baseline, a rete significantly lower than the 1.9 percent rise in agricultural GDP observed between the baseline and combined scenario, indicating a more water-efficient growth pattern. Shifting farm labor to non-farm activities shows potential for reducing agriculture's water footprint, as the economy gradually and endogenously transitioning away from water-intensive grain and horticulture production, despite a slight increase in overall agricultural GDP.

In conclusion, the policy shifts examined in this study may result in significant spatial and distributional effects, highlighting important trade-offs across sectors. A more aggressive transition from grain cultivation to tree crops in the degraded highlands could contribute to vegetation restoration and long-term productivity gains. However, this shift may temporarily disrupt farmers' livelihoods until the tree crops begin to yield income, underscoring the need for short-term support mechanisms during the transition period. Furthermore, reducing grain cultivation in these areas could lead to a persistent shortfall in staple food supply unless offset by accelerated production in other regions—particularly the moist lowlands, where agricultural potential remains underutilized. The study also demonstrates the potential of these policy options to support Ethiopia's climate change mitigation and adaptation goals by increasing agricultural output per unit of greenhouse gas emissions and water usage.

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Annex

Table A1: Change in macroeconomic indicators GDP by 2030, annual growth – full scenarios

	Baseline values (bil. US$)		Annual average growth rate (2024-2030)							
	2024	2030	Baseline	Liv_DH	TCr_DH	TCr+Liv_DH	Grn_ML	Comb1	RNF	Comb2
Absorption	145.8	200.6	5.47%	5.51%	5.46%	5.50%	5.49%	5.52%	6.76%	6.81%
Private consumption	99.7	134.9	5.17%	5.24%	5.16%	5.23%	5.21%	5.26%	6.18%	6.27%
Export	11.3	19.8	9.81%	9.82%	9.82%	9.83%	9.83%	9.86%	13.26%	13.28%
Import	(23.3)	(32.9)	5.92%	5.93%	5.93%	5.94%	5.94%	5.95%	7.98%	8.00%
GDP at factor cost	127.7	179.3	5.82%	5.88%	5.82%	5.87%	5.85%	5.90%	7.22%	7.30%
Exchange rate	1.0	1.0	0.76%	0.76%	0.72%	0.72%	0.75%	0.71%	0.59%	0.55%

Source: Model results

Note: Values are in 2022 US$. Exchange rate is normalized to 1.0 in 2024.

Table A2: Change in GDP by 2030 - National level, average growth – full scenarios

	Baseline values (bil. US$)		Annual average growth rate (2024-2030)							
	2024	2030	Baseline	Liv_DH	TCr_DH	TCr+Liv_DH	Grn_ML	Comb1	RNF	Comb2
Total economy	127.7	179.3	5.8%	5.9%	5.8%	5.9%	5.9%	5.9%	7.2%	7.3%
Agriculture	48.0	61.1	4.1%	4.2%	4.1%	4.2%	4.2%	4.3%	4.2%	4.4%
Grains	25.0	30.4	3.3%	3.4%	3.2%	3.3%	3.5%	3.4%	3.3%	3.4%
Tree crops	1.8	2.0	1.5%	1.4%	3.4%	3.3%	1.5%	3.3%	0.6%	2.5%
Other crops	6.1	7.1	2.6%	2.6%	2.6%	2.5%	2.6%	2.5%	2.7%	2.6%
Livestock	11.6	16.9	6.4%	6.8%	6.4%	6.9%	6.4%	6.9%	6.4%	6.9%
Other agriculture	3.5	4.7	5.1%	5.0%	5.0%	5.0%	5.1%	5.0%	6.6%	6.6%
Mining	0.8	1.1	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	8.5%	8.5%
Manufacturing	6.1	9.1	6.9%	6.9%	7.1%	7.1%	6.9%	7.1%	9.2%	9.4%
Agro-processing	2.7	3.6	5.1%	5.1%	5.2%	5.2%	5.1%	5.2%	6.4%	6.5%
Services	48.7	73.2	7.0%	7.1%	7.0%	7.0%	7.0%	7.0%	9.0%	9.0%

Source: Model results

Note: ‘Other crops’ include vegetables, roots, tubers, fibers, and species. ‘Other agriculture’ constitutes fishery, aquaculture, and forestry. Values are in 2022 US$.

Table A3: Change in agriculture GDP by 2030 - Regional level, average growth – full scenarios

		Baseline values (bil. US$)		Annual average growth rate (2024-2030)							
		2024	**2030**	**Baseline**	**Liv_DH**	**TCr_DH**	**TCr+Liv_DH**	**Grn_ML**	**Comb1**	**RNF**	**Comb2**
DH	Agriculture	10.5	13.2	3.9%	4.4%	4.0%	4.4%	3.9%	4.5%	3.8%	4.5%
	Grains	6.4	7.8	3.3%	3.4%	3.0%	3.0%	3.4%	3.1%	3.2%	3.0%
	Tree crops	0.2	0.2	2.7%	2.7%	14.5%	14.4%	2.7%	14.4%	2.7%	14.5%
	Other crops	1.4	1.6	2.1%	2.0%	2.0%	2.0%	2.1%	2.0%	1.9%	1.8%
	Livestock	2.4	3.5	6.3%	8.0%	6.5%	8.2%	6.3%	8.2%	6.3%	8.3%
MHc	Agriculture	24.3	30.7	4.0%	4.0%	4.0%	4.0%	4.0%	4.1%	3.9%	4.0%
	Grains	15.5	18.9	3.4%	3.5%	3.4%	3.4%	3.5%	3.5%	3.4%	3.5%
	Tree crops	1.1	1.2	1.1%	1.0%	1.6%	1.6%	1.0%	1.6%	0.0%	0.4%
	Other crops	2.5	3.0	2.7%	2.6%	2.7%	2.6%	2.7%	2.6%	2.7%	2.7%
	Livestock	5.2	7.6	6.6%	6.7%	6.6%	6.7%	6.6%	6.7%	6.6%	6.8%
MHe	Agriculture	6.0	7.6	4.0%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%
	Grains	1.8	2.2	3.4%	3.5%	3.4%	3.4%	3.4%	3.4%	3.4%	3.5%
	Tree crops	0.5	0.5	1.5%	1.5%	2.1%	2.1%	1.5%	2.1%	0.8%	1.3%
	Other crops	2.0	2.4	2.9%	2.8%	2.9%	2.8%	2.9%	2.8%	3.1%	3.0%
	Livestock	1.7	2.5	6.5%	6.7%	6.5%	6.6%	6.5%	6.7%	6.6%	6.7%
DL	Agriculture	2.3	3.1	5.0%	5.0%	4.9%	5.0%	5.0%	5.1%	4.8%	4.9%
	Grains	0.5	0.5	2.1%	2.1%	2.0%	2.0%	2.3%	2.2%	1.6%	1.7%
	Tree crops	0.0	0.0	5.9%	5.9%	5.6%	5.5%	5.9%	5.5%	7.2%	7.1%
	Other crops	0.0	0.0	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
	Livestock	1.8	2.5	5.7%	5.8%	5.7%	5.7%	5.7%	5.8%	5.5%	5.6%
ML	Agriculture	1.5	1.9	3.9%	4.0%	3.9%	4.0%	5.5%	5.5%	3.8%	5.3%
	Grains	0.8	0.9	2.4%	2.4%	2.3%	2.3%	5.4%	5.3%	2.2%	5.0%
	Tree crops	0.1	0.1	2.8%	2.8%	3.2%	3.1%	2.8%	3.1%	2.7%	3.1%
	Other crops	0.1	0.1	2.9%	2.8%	2.9%	2.8%	2.9%	2.8%	3.1%	3.0%
	Livestock	0.5	0.7	6.5%	6.6%	6.5%	6.6%	6.5%	6.6%	6.5%	6.6%

Source: Model results

Note: DH = Degraded dry highlands, MHc = Moist highlands – cereal-based, MHe = Mosit highlands – *enset*-based, DL = Dry lowlands, and ML = Most lowlands. ‘Other crops’ include vegetables, roots, tubers, fibers, and species. ‘Other agriculture’ constitutes fishery, aquaculture, and forestry. Values are in 2022 US$.

Table A4: Change in household expenditure by 2030, annual average – full scenarios

	Baseline values (bil. US$)		Annual average growth rate (2024-2030)							
	2024	2030	Baseline	Liv_DH	TCr_DH	TCr+Liv_DH	Grn_ML	Comb1	RNF	Comb2
National	99.7	134.9	5.17%	5.24%	5.16%	5.23%	5.21%	5.26%	6.18%	6.27%
Poor	21.7	29.6	5.36%	5.44%	5.37%	5.44%	5.41%	5.48%	7.10%	7.22%
Non-poor	78.0	105.3	5.12%	5.19%	5.11%	5.17%	5.15%	5.20%	5.92%	6.00%
Rural	71.0	95.5	5.07%	5.15%	5.07%	5.14%	5.11%	5.18%	6.43%	6.55%
Poor	20.8	28.3	5.30%	5.38%	5.32%	5.38%	5.35%	5.43%	7.10%	7.23%
Non-poor	50.2	67.1	4.97%	5.05%	4.96%	5.04%	5.01%	5.08%	6.15%	6.26%
Urban	28.7	39.4	5.43%	5.46%	5.40%	5.43%	5.45%	5.45%	5.53%	5.56%
Poor	0.9	1.3	6.65%	6.67%	6.65%	6.67%	6.68%	6.71%	6.98%	7.04%
Non-poor	27.8	38.1	5.39%	5.42%	5.36%	5.39%	5.41%	5.41%	5.49%	5.51%

Source: Model results

Note: Values are in 2022 US$.

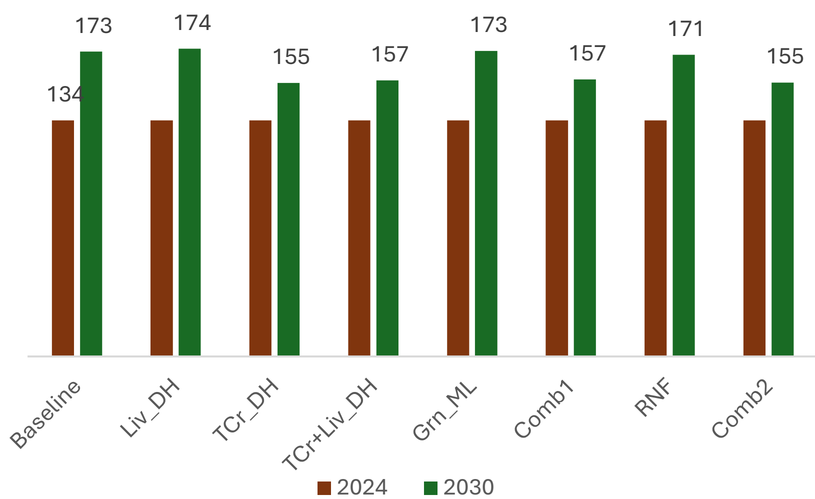
Table A5: Changes in poverty and diet quality – full scenarios

	Baseline			Percentage point change in poverty compared to the baseline trend by 2030						
	2024	2030	Change	Liv_DH	TCr_DH	TCr+Liv_DH	Grn_ML	Comb1	RNF	Comb2
Poverty										
National	21.35	12.14	-9.21	-9.29	-9.36	-9.41	-9.28	-9.50	-12.38	-12.58
Rural	23.21	13.20	-10.01	-10.09	-10.17	-10.23	-10.07	-10.34	-13.97	-14.19
Urban	13.78	8.32	-5.46	-5.55	-5.56	-5.61	-5.55	-5.63	-5.75	-5.90
Diet										
National	58.58	53.21	-5.37	-6.09	-6.00	-6.64	-5.44	-6.71	-5.69	-7.02
Rural	60.37	54.07	-6.30	-7.07	-6.97	-7.65	-6.38	-7.72	-7.44	-8.90
Urban	51.28	50.10	-1.17	-1.76	-1.64	-2.17	-1.22	-2.22	1.50	0.62

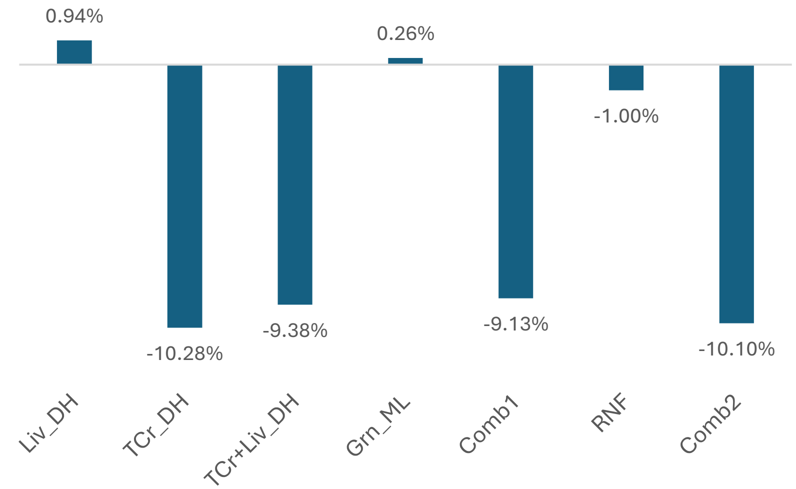
Source: Model results

Figure A1: Emission and water footprints in agriculture, by scenario -full scenarios

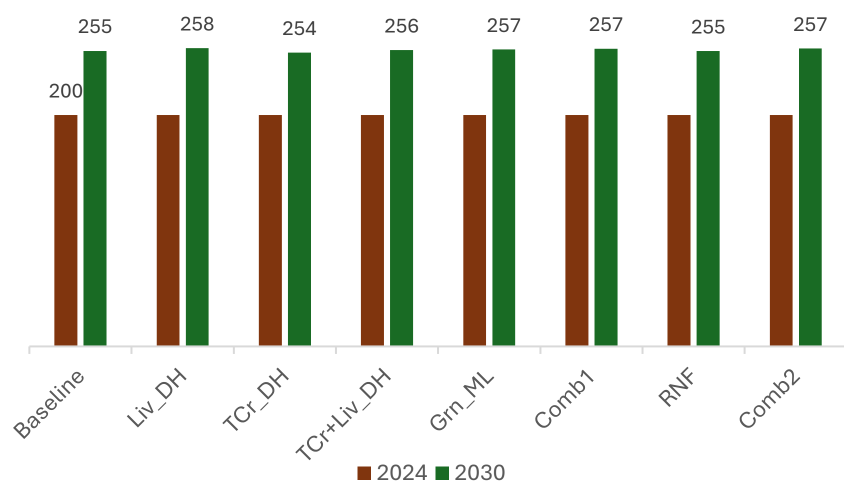
A) Emissions in agriculture (mil. of CO_2 equiv.)



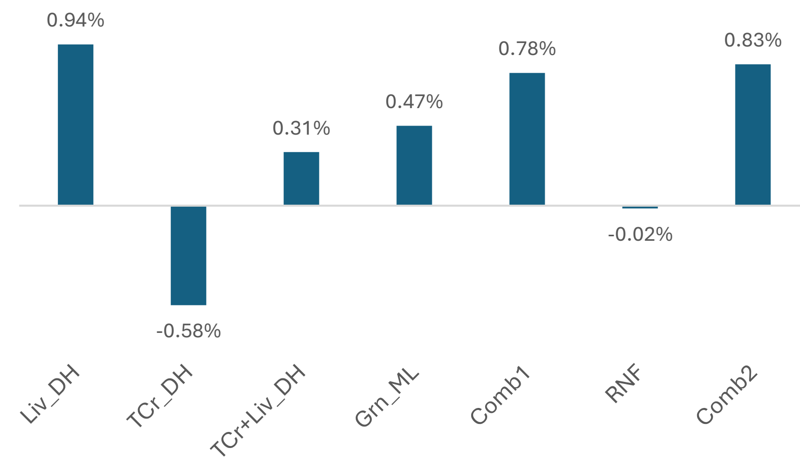
B) Annual growth in emissions in agriculture



C) Water footprint in agriculture (bil. of m^3)

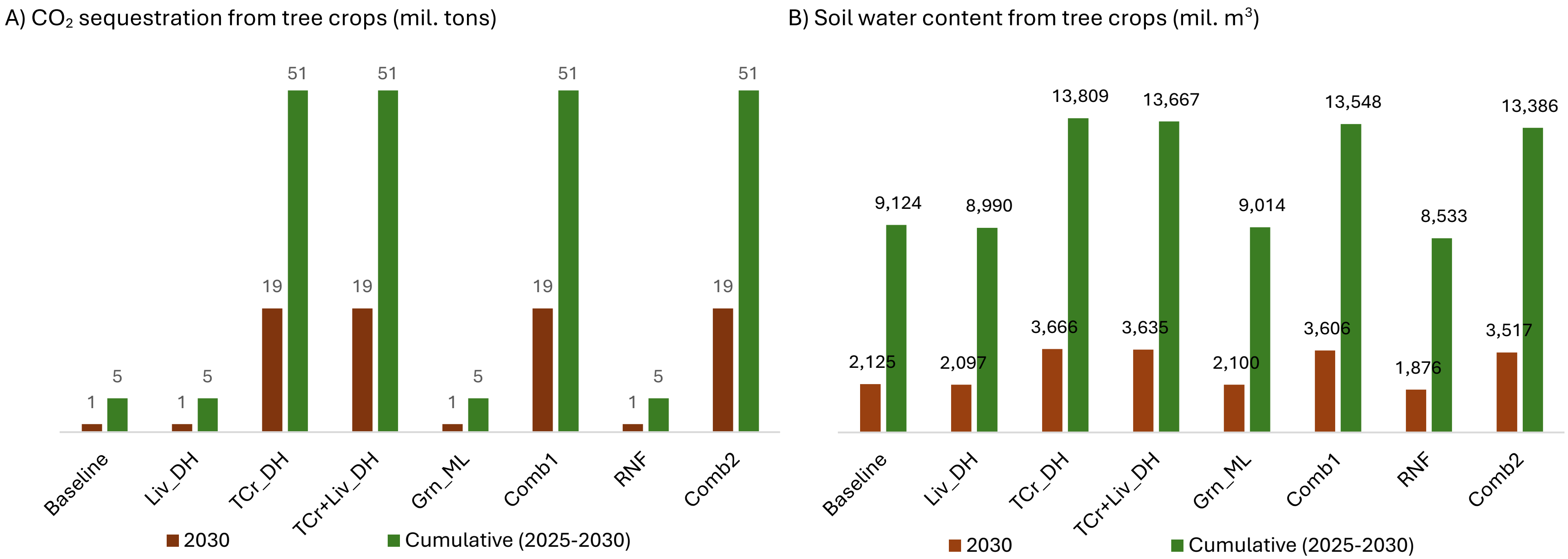


D) Annual growth in water footprint in agriculture



Source: Model results

Figure A2: Additional CO2 sequestration and soil water content from tree crops, by scenario – full scenarios



Source: Model results