3V Scientific Publishing House

Trends in Ecological and Indoor Environmental Engineering

RESEARCH ARTICLE **OPEN ACCESS**
https://doi.org/10.62622/TEIEE.026.4.3.01-16 **ISSN 2956-9761**

LAND DEGRADATION AND AGRICULTURAL PRODUCTIVITY IN BURKINA FASO: INTEGRATING SOIL EROSION MODELLING AND ECONOMY-WIDE IMPACT ASSESSMENT USING A CGE FRAMEWORK

Abdoul Rahmane Ouedraogo[1]
[1]Department of Economics, Center for Economic and Social Studies, Documentation and Research, Thomas SANKARA University, Ouagadougou, Burkina Faso
*Corresponding email: ouedraabdoul93@gmail.com

Received: 07.05.2026; ***Accepted:*** 10.06.2026; ***Available online:*** 28.06.2026; ***Published:*** 30.09.2026

Cite this article: Ouedraogo, A. R. (2026). Land Degradation and Agricultural Productivity in Burkina Faso: Integrating Soil Erosion Modelling and Economy-Wide Impact Assessment Using a CGE Framework. *Trends in Ecological and Indoor Environmental Engineering*, 4(3), 1–16.

Background: Land degradation represents a major environmental and development challenge in Sub-Saharan Africa, where agricultural systems remain highly dependent on natural soil fertility and rain-fed production. Soil erosion and declining land quality reduce ecosystem services and threaten food security, rural livelihoods, and economic stability. Burkina Faso is particularly affected due to high exposure to climatic variability and intensive land use pressure. **Objectives:** This study aims to assess the impact of land degradation on agricultural productivity in Burkina Faso and to evaluate its economy-wide consequences using an integrated biophysical and computable general equilibrium modelling framework. **Methods:** The study combines the Revised Universal Soil Loss Equation (RUSLE) model with a recursive dynamic computable general equilibrium (CGE) model. The RUSLE model is used to estimate spatial soil erosion and derive land productivity loss coefficients across agricultural regions. These coefficients are then introduced as exogenous productivity shocks into the CGE model calibrated on the 2016 Social Accounting Matrix of Burkina Faso. The CGE framework captures interactions among production sectors, households, government, and external trade. It allows assessment of direct and indirect effects of land degradation on agricultural production, income distribution, and macroeconomic performance under different scenarios. **Results:** The RUSLE results indicate that approximately 28% of agricultural land in Burkina Faso is affected by degradation, corresponding to an estimated economic loss of 321.34 billion CFA francs. Crop-specific results show that staple crops such as maize, millet, sorghum, and groundnuts are the most affected. CGE simulations demonstrate that land productivity losses lead to significant declines in agricultural output, reduced household income, and contraction in macroeconomic indicators. Under the baseline scenario, GDP declines by approximately 27%, while pessimistic conditions lead to even larger reductions. Rural households are disproportionately affected due to their dependence on agriculture. Results also show strong heterogeneity across crop types and regions, reflecting spatial variation in land degradation intensity. **Conclusion:** Land degradation significantly constrains agricultural productivity and economic performance in Burkina Faso. Integrated biophysical and CGE modelling highlights the importance of sustainable land management policies to mitigate soil erosion impacts and improve agricultural resilience, food security, and rural welfare.

Keywords: land degradation; soil erosion; RUSLE; computable general equilibrium (CGE); integrated assessment modelling; agricultural productivity; sustainable land management; food security; Sub-Saharan Africa.

INTRODUCTION

Agricultural productivity remains a central determinant of food security, rural welfare, and structural transformation in sub-Saharan Africa, where agriculture continues to employ a large share of the population and contributes significantly to national income (Szangolies et al., 2023; Hu et al., 2021). Agricultural productivity is commonly defined as the efficiency with which natural resources are transformed into agricultural outputs. Despite its strategic importance, productivity growth in sub-Saharan Africa has remained persistently low compared to other developing regions. While South Asia has achieved substantial yield increases exceeding 100% over recent decades, productivity gains in sub-Saharan Africa have been comparatively modest, with output growth still largely driven by land expansion rather than intensification (Ritchie, 2022). This persistent lag raises concerns about the sustainability of current agricultural trajectories and their implications for long-term food security.

From a theoretical perspective, the relationship between land quality and agricultural output has long been established in classical political economy. Ricardo (1817) introduced the concept of differential rent, demonstrating that heterogeneity in soil fertility generates systematic differences in land productivity and economic returns. Marx (1894) developed the concept of absolute rent within his broader theory of ground rent, suggesting that land quality and the intensity of capital investment are key factors shaping agricultural surplus. These theoretical foundations remain highly relevant in contemporary contexts where land degradation alters the productive capacity of agricultural ecosystems.

Land degradation is widely recognized as a global environmental and economic challenge defined as the long-term decline in land productivity and ecosystem service provision (MEA, 2005; ELD, 2015; FAO, 2021). It affects approximately one-third of global land resources and exposes more than 2.6 billion people to increased vulnerability (ELD, 2015). Beyond biophysical impacts, land degradation undermines soil fertility, water regulation, biodiversity, and agricultural productivity (Li et al., 2021; Nedd & Anandhi, 2024; Mirzabaev & von Braun, 2022). The Economics of Land Degradation (ELD) Initiative estimates that soil erosion alone generates annual global losses exceeding USD 127 billion, with Africa bearing a disproportionate share of these costs, estimated between 4% and 12% of GDP (Berry et al., 2003).

In Africa, these impacts are amplified by high dependence on rain-fed agriculture, limited adaptive capacity, and strong exposure to climate variability. Land degradation is driven by interacting anthropogenic and climatic factors, including unsustainable farming practices, deforestation, and rainfall variability in semi-arid regions (Pimentel et al., 2004; Zhang et al., 2007; Wang et al., 2016). These processes contribute to soil erosion, nutrient depletion, and declining yields, reinforcing cycles of poverty and environmental degradation (Gambella et al., 2021).

Burkina Faso provides a particularly relevant case study for analysing these dynamics. Approximately 34% of agricultural land is already degraded, with degradation expanding from 113,000 hectares per year (1983–1992) to 469,000 hectares per year (2002–2013) (MAAH, 2018). The country also experiences substantial economic losses associated with land degradation, estimated at 21% of GDP in 2008, including 4.7% attributable specifically to land and forest degradation (sba-Ecosys-CEDRES, 2010). These losses directly affect agricultural production costs, input efficiency, and rural livelihoods (Dugué et al., 2024).

Socioeconomic vulnerability further amplifies these effects. According to INSD (2022), more than half of the rural population lives in vulnerable conditions compared to 13.1% in urban areas. Projections indicate continued yield declines due to environmental stressors, ranging from 5.5% to 8% by the end of the century (Adam et al., 2020; Arumugam et al., 2023). Empirical evidence further estimates annual cereal losses between 5 and 20 million tonnes due to soil erosion, while biophysical modelling suggests production losses of up to 3.83 million tonnes (ELD, 2015; Sartori et al., 2019). Despite policy interventions such as PNGT, SCADD, and PNDES, land degradation persists, suggesting limited effectiveness of past mitigation strategies (MEEVCC, 2016).

The existing literature has extensively documented the negative relationship between land degradation and agricultural productivity (Dia & Sarpong, 2011; Panagos et al., 2021; Mirzabaev & von Braun, 2022; Dugué et al., 2024). However, three key gaps remain. First, most studies focus either on biophysical impacts or farm-level productivity effects, with limited integration of economy-wide transmission mechanisms. Second, although spatial degradation patterns are increasingly documented, their macroeconomic implications through sectoral interdependencies remain insufficiently quantified. Third, for Burkina Faso specifically, existing evidence remains fragmented and largely descriptive, lacking integrated modelling frameworks capable of linking spatial degradation processes to national economic outcomes in a consistent analytical structure.

These gaps are particularly important because land degradation does not only affect agricultural output directly, but also propagates through input markets, factor reallocation, household income channels, and consumption dynamics. As a result, ignoring economy-wide transmission may significantly underestimate the total economic cost of land degradation. Moreover, spatial heterogeneity in degradation intensity implies that economic impacts are unevenly distributed across regions and production systems, which has important implications for targeted policy design.

To address these limitations, there is a need to develop an integrated analytical framework combining a biophysical land degradation model based on the Revised Universal Soil Loss Equation (RUSLE) with a computable general equilibrium (CGE) model. This approach is intended to enable the estimation of both direct productivity losses and indirect economy-wide effects, thereby providing a more comprehensive assessment of the potential economic consequences of land degradation in Burkina Faso.

The study is expected to contribute to the literature in three main ways. First, it aims to provide a spatially explicit estimation of land productivity losses using a standardized erosion-based framework. Second, it seeks to quantify the economy-wide effects of land degradation through a multisectoral general equilibrium model, capturing indirect transmission beyond agriculture. Third, it is intended to evaluate the mitigating potential of sustainable land management practices under alternative scenarios, linking environmental degradation to policy-relevant interventions.

The central hypothesis of the study is that land degradation is expected to have a statistically and economically significant negative effect on agricultural productivity, and that these effects may propagate non-linearly through intersectoral linkages, leading to amplified reductions in GDP, household income, and consumption. It is further hypothesized that these macroeconomic impacts are likely to be heterogeneous across regions and crop systems, and that sustainable land management practices may partially offset these losses, with stronger effects expected in highly degraded agroecological zones.

Accordingly, the aim of this study is to analyse the effects of land degradation on agricultural productivity in Burkina Faso. To achieve this, the study integrates a biophysical land degradation model based on the Revised Universal Soil Loss Equation (RUSLE) with a computable general equilibrium (CGE) framework. Specifically, it seeks to identify the magnitude and transmission channels through which soil erosion and land quality decline affect agricultural production systems, and to assess the extent to which sustainable land management practices may mitigate these biophysical and socio-economic impacts.

MATERIALS AND METHODS

Study area

This study focuses on Burkina Faso, a landlocked country located in the Sudano-Sahelian zone of West Africa, where agriculture constitutes the main source of livelihood for more than 80% of the population (MEEVCC, 2016; INSD, 2022). The country's economy remains highly dependent on rain-fed agriculture, making it particularly vulnerable to environmental degradation and climate variability.

Burkina Faso has experienced recurrent climatic shocks, including severe drought episodes during 1973–1974 and 1983–1984, as well as major flooding events in 2009, all of which significantly affected agricultural systems, ecosystems, and rural livelihoods (MEEVCC, 2016). These climatic pressures are compounded by ongoing land degradation, soil erosion, deforestation, and declining soil fertility.

According to Hien and CILSS (2015), approximately 34% of cultivated land in Burkina Faso is degraded. The Economics of Land Degradation initiative (ELD, 2015) further estimates annual cereal yield losses caused by soil erosion at between 5 and 20 million tonnes. Land degradation therefore constitutes a major constraint on agricultural productivity, food security, and rural household welfare.

The country also presents strong spatial heterogeneity in terms of agroecological conditions, agricultural systems, rainfall patterns, and land-use pressure, making it an appropriate case study for analysing the economic effects of land degradation. In addition, previous studies have highlighted the importance of sustainable land management practices in improving agricultural productivity and resilience in Burkina Faso.

Given the economic importance of agriculture and the increasing pressure on natural resources, Burkina Faso provides a relevant analytical framework for assessing the direct and indirect impacts of land degradation on agricultural productivity and the broader economy.

Analytical framework and estimation strategy

This study employs an integrated biophysical–economic modelling framework to quantify the impacts of land degradation on agricultural productivity and the broader economy of Burkina Faso. The approach combines the

Revised Universal Soil Loss Equation (RUSLE), widely used for spatial assessment of soil erosion (Renard et al., 1997; Panagos et al., 2021), with a recursive dynamic Computable General Equilibrium (CGE) model, which enables the evaluation of economy-wide consequences of environmental shocks through intersectoral linkages and market interactions (Alfsen et al., 1996; Diao & Sarpong, 2011; Decaluwé et al., 2013).

The analytical framework consists of two sequential stages.

In the first stage, annual soil erosion rates are estimated using the RUSLE model for the year 2017. Spatial datasets describing rainfall erosivity, soil erodibility, topography, land cover, and conservation practices are integrated within a GIS environment to calculate mean annual soil loss for each raster cell. The resulting erosion estimates are subsequently aggregated to the regional level and used to identify severely eroded agricultural areas (SEA) according to a threshold of >11 t ha^{-1} yr^{-1}, following Panagos et al. (2018). This threshold has been validated in numerous studies applying the RUSLE model and provides a readily interpretable criterion for identifying severely eroded agricultural land.

In the second stage, the proportion of severely eroded agricultural land is converted into a land productivity loss coefficient (LPL), following the approach proposed by Panagos et al. (2018). The LPL coefficient represents the reduction in effective agricultural land productivity attributable to soil degradation and is calculated separately for each region and crop category.

The estimated LPL coefficients are subsequently introduced into the CGE model as exogenous land-productivity shocks affecting agricultural production activities. Specifically, land degradation is represented through a reduction in the efficiency parameter associated with the land factor in agricultural production functions. This procedure enables the transmission of biophysical degradation effects into the economic system and allows assessment of both direct productivity losses and indirect impacts on production, factor markets, household welfare, government revenues, trade flows, and gross domestic product.

The CGE model is calibrated using the 2016 Social Accounting Matrix (SAM) for Burkina Faso obtained from the Partnership for Economic Policy (PEP) and simulated using 2017 as the reference year.

Estimation of land productivity loss using the RUSLE model

Land degradation was assessed using the Revised Universal Soil Loss Equation (RUSLE), one of the most widely applied empirical models for estimating long-term average annual soil loss caused by water erosion under varying climatic, topographic, and land-use conditions (Renard et al., 1997; Panagos et al., 2021). The model was implemented within a Geographic Information System (GIS) environment to generate spatially explicit estimates of soil erosion across Burkina Faso.

Annual soil loss was estimated as:

$$A = R \times K \times LS \times C \times P \qquad (1)$$

where A represents annual soil loss (t ha^{-1} yr^{-1}); R is the rainfall erosivity factor; K is the soil erodibility factor; LS is the slope length and slope steepness factor; C is the cover-management factor; P is the support practice factor.

Spatial datasets and pre-processing

The RUSLE factors were derived from harmonized geospatial datasets covering the study area for the year 2017.

The rainfall erosivity factor (R) was estimated from precipitation data obtained from data collected at national meteorological stations using the methodology proposed by Renard et al. (1997).

The soil erodibility factor (K) was derived from soil physical and chemical properties obtained from DGAHDI (2017). Soil texture, organic matter content, soil structure, and permeability variables were used to calculate erodibility according to Renard et al. (1997).

The topographic factor (LS) was generated from a Digital Elevation Model (DEM) obtained from the Shuttle Radar Topography Mission (SRTM) dataset with a spatial resolution of 30 m (DGAHDI, 2017). Slope gradient and flow accumulation layers were calculated and subsequently used to derive the LS factor following the procedure described by Renard et al. (1997) and Panagos et al. (2018).

The cover-management factor (C) was estimated using land-use and vegetation-cover information. Land-cover classes were reclassified into corresponding C-factor values according to coefficient values reported by Renard et al. (1997) and subsequent applications in Sub-Saharan African environments.

The support-practice factor (P) was assigned following the approach proposed by Panagos et al. (2018). In the absence of spatially explicit conservation-practice data, a value of P = 1 was applied, consistent with previous regional RUSLE applications (Panagos et al., 2021).

All spatial datasets were projected to a common coordinate reference system (CRS) and resampled to a uniform spatial resolution of 30 m. Continuous variables were resampled using bilinear interpolation, whereas categorical datasets were resampled using nearest-neighbour interpolation to preserve class boundaries. Raster processing, spatial analysis, and map algebra operations were performed using ArcGIS (version 10.x) and QGIS (version 3.x).

Identification of severely eroded agricultural land

The resulting soil-loss map was overlaid with the agricultural land-use layer to isolate cultivated areas. Following Panagos et al. (2018), severely eroded agricultural land (SEA) was defined as agricultural land experiencing annual soil losses exceeding 11 t ha^{-1} yr^{-1}.

The total area classified as severely eroded agricultural land was calculated for each region and subsequently used to estimate the corresponding regional losses in land productivity.

Estimation of land productivity loss

Following Panagos et al. (2018), the land productivity loss coefficient (LPL) was calculated as:

$$\mathrm{LPL_r} = \frac{\mathrm{SEA_r}}{\mathrm{TAA_r}} \times 0.08, \qquad (2)$$

where $\mathrm{LPL_r}$ denotes the proportion of agricultural land productivity loss in region r; $\mathrm{SEA_r}$ is the area classified as severely eroded agricultural land; $\mathrm{TAA_r}$ is total agricultural area. The coefficient 0.08 represents an empirical productivity-loss parameter indicating that land affected by severe soil erosion experiences an average long-term yield reduction of approximately 8%, based on a synthesis of experimental evidence (Pimentel, 2004; Panagos et al., 2018).

The coefficient 0.08 represents the average long-term reduction in land productivity associated with severe soil erosion, as derived from empirical evidence and findings reported by Pimentel et al. (2004) and Panagos et al. (2018).

Regional LPL coefficients were subsequently translated into crop-specific productivity losses according to:

$$\mathrm{CPLir} = \mathrm{LPLr} \times \mathrm{CAir} \times \mathrm{CPir}, \tag{3}$$

where CPLir denotes crop productivity loss; CAir is cultivated area; CPir denotes average crop yield (t ha^{-1}).

Economic losses associated with land degradation were estimated by multiplying the calculated production losses by crop-specific producer prices provided by the Directorate General of Agricultural Statistics, Hydrology and Informatics (DGAHDI) of Burkina Faso for the reference year 2017. All monetary values were expressed in constant 2017 CFA francs, which also served as the base year for the social accounting matrix (SAM) used to calibrate the CGE model.

Computable General Equilibrium (CGE) model

To evaluate the economy-wide consequences of land degradation, this study employs a recursive dynamic Computable General Equilibrium (CGE) model calibrated to the 2016 Social Accounting Matrix (SAM) for Burkina Faso developed by the Partnership for Economic Policy (PEP). The modelling framework is based on the PEP-1-t model developed by Decaluwé et al. (2013), which has been widely applied for policy analysis and environmental-economic assessments in developing countries (Alfsen et al., 1996; Diao & Sarpong, 2011).

The model represents the circular flow of income within the economy and captures interactions among production activities, households, government, investment, and the rest of the world. Production sectors are linked through intermediate input demand, while factor markets connect production activities to household incomes. The framework therefore enables the analysis of both direct and indirect economic effects generated by changes in agricultural land productivity.

The economy is disaggregated into 27 production sectors, 2 household groups, production factors, government accounts, investment accounts, and foreign-sector transactions.

Land degradation is introduced into the model as an exogenous shock affecting the productivity of the land factor used in agricultural production. The magnitude of the shock is derived from the regional land productivity loss coefficients estimated using the RUSLE framework. These productivity reductions modify the effective availability of productive land and are transmitted through production systems, factor markets, commodity markets, and household income channels.

The model consists of four main blocks: (i) production and factor demand, (ii) household income and expenditure, (iii) international trade, and (iv) market equilibrium and macroeconomic closure conditions. The structure of each block is described below.

Production and factor demand

Agricultural production is represented using a nested production structure consistent with the standard PEP-1-t specification (Decaluwé et al., 2013). At the value-added level, producers combine primary factors of production through a Constant Elasticity of Substitution (CES) function. The primary factors include land, labour, and capital, allowing substitution among inputs in response to relative price changes.

Following Panagos et al. (2018), land degradation is incorporated through a land-productivity parameter $\mathrm{T_{i,r}}$ where i denotes the agricultural activity and r the region. The parameter captures the reduction in effective land productivity resulting from soil degradation and is adjusted according to the land productivity loss coefficients estimated from the RUSLE analysis.

The agricultural value-added function is specified as:

$$\mathrm{VA_{i,r}} = (\propto_{\mathrm{i,r}} \mathrm{La_{i,r}}^{\frac{\sigma_j-1}{\sigma_j}} + \beta_{\mathrm{i,r}}\mathrm{K_{i,r}}^{\frac{\sigma_j-1}{\sigma_j}} + \gamma_{\mathrm{i,r}}\mathrm{L_{i,r}}^{\frac{\sigma_j-1}{\sigma_j}})^{\frac{\sigma_j-1}{\sigma_j}}, \sigma_j > 0, \tag{3}$$

where VA is the value added; A is values of land; K is values of land; L is capital and labour respectively.

The elasticity of substitution function is homogeneous of degree 1 in the primary factors. Variables $\alpha, \beta,$ are the associated factors of production. The parameter $\alpha_{\mathrm{i,r}}$ is exogenous. In the simulation, it is adjusted to reflect the impact of the loss of land productivity ($\mathrm{T_{i,r}}$):

$$\alpha_{\mathrm{i,r}}^{\mathrm{New}} = (1 - \mathrm{T_{i,r}})^{\alpha_{\mathrm{i,r}}}. \tag{4}$$

Cost minimization by firms allows them to derive the demand for factors of production. Therefore, the firm seeks to use factors of production up to the point where the marginal productivity of that factor equals its cost, that is, the composite wage rate $\mathrm{WC_J}$ and the composite cost of capital $\mathrm{RC_J}$. This demand for factors can be expressed in relative form and written according to equation 5 below (Decaluwé et al., 2023, Annex C):

$$\mathrm{LDC_J} = \left[\frac{\beta_j^{\mathrm{VA}}}{1-\beta_j^{\mathrm{VA}}} - \frac{\mathrm{RC_j}}{\mathrm{WC_j}}\right]^{\sigma_j^{\mathrm{VA}}}, \tag{5}$$

where $\mathrm{RC_J}$ is the cost of composite capital in the branch j; $\mathrm{WC_J}$ is the composite labour remuneration rate in the industry j; $\mathrm{KDC_J}$ represents the demand for composite capital by the branch j; $\mathrm{LDC_J}$ represents the composite labour demand by the branch j; β_j^{VA} represents the distributive parameter (CES-added value); σ_j^{VA} represents a substitute in the CES.

The production function includes a third level of nesting at both the labour and capital levels. Mathematically, we assume that the composite labour and capital demands are CES functions, described by the following equations:

$$\mathrm{LDC_J} = \mathrm{B_j^{LD}} \left[\textstyle\sum_{l} \mathrm{B_{l,j}^{LD}} \mathrm{LD_{l,j}}^{-\sigma_j{}^{\mathrm{LD}}}\right]^{\sigma_j{}^{-\frac{1}{\mathrm{LD}}}}, \tag{6}$$

where $\mathrm{B_{l,j}^{LD}}$ represents the distributive parameter (CES-composite work); $\mathrm{B_j^{LD}}$ represents the scale parameter (CES-composite work); $\sigma_j{}^{\mathrm{LD}}$ represents the elasticity parameter (CES-composite work).

The capital factor allows for a hierarchy that takes into account different types of capital. Following the formulation of composite labour demand, the general formulation of the capital factor is as follows:

$$\mathrm{KDC_J} = \mathrm{B_j^{KD}} \left[\textstyle\sum_{k} \mathrm{B_{k,j}^{KD}} \mathrm{KD_{k,j}}^{-\sigma_j^{\mathrm{KD}}}\right]^{-\frac{1}{\sigma_j^{\mathrm{KD}}}}, \tag{7}$$

where $\mathrm{KDC_J}$ represents the demand for composite capital by the branch j; $\mathrm{KDC_{k,J}}$ represents the demand for k type capital by the branch j; $\mathrm{B_j^{KD}}$ représente le paramètre d'échelle (CES-capital composite); $\mathrm{B_{k,j}^{KD}}$ represents the distributive parameter (CES-composite capital); σ_j^{KD} represents the elasticity parameter (CES-composite capital).

Formally, we have :

$$\mathrm{DI_{i,J}} = \alpha \mathrm{ij_{i,j}} \mathrm{CI_j}, \tag{8}$$

where $\mathrm{DI}_{i,J}$ represents intermediate consumption of product i by the branch j; CI_j represents the total intermediate consumption of the sector j; $\alpha ij_{i,j}$ represents the input-output coefficient.

Household income, savings, and final demand

Households receive income from the remuneration of production factors and from transfers originating from other institutional agents. Total household income therefore consists of labour income, capital income, and transfer income. The resulting income is allocated among direct taxes, transfers to other agents, savings, and final consumption expenditures.

Household behaviour follows the standard PEP-1-t specification (Decaluwé et al., 2013), in which consumption and savings decisions are determined by disposable income after taxes and transfers. Household savings are modelled through a linear savings function, while consumption expenditures are adjusted according to changes in disposable income and consumer prices.

The household income-generation and expenditure system is represented by Equations (9)–(15), which define the formation of household income, transfers, savings, taxes, and consumption demand. These relationships constitute the principal transmission channel through which land degradation affects household welfare. Reductions in agricultural productivity alter factor returns and production levels, thereby influencing household incomes, consumption opportunities, and savings behaviour.

$$\mathrm{YH}_h = \mathrm{YHL}_h + \mathrm{YHK}_h + \mathrm{YHTR}_h, \tag{9}$$

$$\mathrm{YHL}_h = \gamma_h^{RK} \textstyle\sum_{jl}(\gamma_{h,l}^{WL} w_l \sum_j(\mathrm{LD}_{l,j})), \tag{10}$$

$$\mathrm{YHK}_h = \gamma_h^{RK}(\textstyle\sum_j R_j \mathrm{KD}_j), \tag{11}$$

$$\mathrm{YHTR}_h = \textstyle\sum_{ag} \mathrm{TR}_{h,ag}, \tag{12}$$

$$\mathrm{YDH}_h = \mathrm{YH}_h - \mathrm{TDH}_h - \mathrm{TR}_{gvt',h}, \tag{13}$$

$$\mathrm{CTH}_h = \mathrm{YDH}_h - \mathrm{SH}_h - \textstyle\sum_{agng} \mathrm{TR}_{agng,h}, \tag{14}$$

$$\mathrm{SH}_h = \mathrm{PIXCON}^{\eta} \mathrm{sh0}_h + \mathrm{sh1}_h \mathrm{YDH}_h, \tag{15}$$

where YH_h represents the total household income h; YHL_h represents the household's earned income h; YHK_h represents the household's capital income h; YHTR_h represents the household's transfer income h. $\mathrm{TR}_{gvt',h}$ represents other transfers from the household to the government; $\mathrm{TR}_{agng,h}$ represents transfers from households to non-governmental agents; SH_h is household savings h. TDH_h represents direct taxes on household income h; CTH_h is the household's consumption budget h. PIXCON is the consumer price index; $\mathrm{sh1}_h$ represents the marginal propensity to save (slope); $\mathrm{sh0}_h$ represents the y-intercept of the savings function. η, represents the cost-of-living indexation rate.

International trade

The foreign trade block follows the small-open-economy assumption commonly adopted in CGE modelling frameworks (Decaluwé et al., 2013). Domestic producers allocate output between domestic and export markets according to relative prices and transformation possibilities. This behaviour is represented through a Constant Elasticity of Transformation (CET) function, which determines the optimal distribution of production between domestic sales and exports.

On the demand side, domestic users choose between imported and domestically produced commodities according to the Armington assumption (Armington, 1969). Under this specification, imported and domestic goods are treated as imperfect substitutes, and demand allocation depends on relative prices, initial trade shares, and substitution elasticities.

Equations (16)–(18) describe producer allocation decisions, import demand, and composite commodity demand. Through these mechanisms, productivity shocks originating from land degradation may influence trade flows, import dependence, export competitiveness, and sectoral market adjustments.

Equation (16) determines the allocation of total sectoral output between domestic and export markets as a function of relative prices and the elasticity of transformation:

$$\mathrm{XST}_j = B_j^{XT}\left[\textstyle\sum_i B_{j,i}^{XT} \mathrm{XT}_{j,i}^{\sigma_j^{XT}}\right]^{\sigma_j^{\frac{1}{XT}}}, \tag{16}$$

where $\mathrm{XS}_{j,i}$ is the production of product i by the branch j; XST_j represents the total aggregate production of the sector j; $P_{j,i}$ is the base price of production of branch j in product i; PT is the base price of the total production of the branch j; B_j^{XT} represents the scaling parameter (CET-output); $B_{j,i}^{XT}$ represents the distributive parameter (CET-total output); σ_j^{XT} is the elasticity parameter (CET-total output).

$$Q_{i,t} = B_i^M\left[B_i^M \mathrm{IM}_{i,t}^{-\sigma_j^M} + (1 - B_i^M)\mathrm{DD}_{i,t}^{-\sigma_i^M}\right]^{\sigma_j^{\frac{-1}{M}}}, \tag{17}$$

$$\mathrm{IM}_{i,t} = \left[\frac{B_i^M}{1-B_i^M} - \frac{\mathrm{PD}_{i,t}}{\mathrm{PM}_{i,t}}\right]^{\sigma_i^M} \mathrm{DD}_{i,t}, \tag{18}$$

where Q_i represents the quantity of product requested i; IM_i is the quantity of product i imported; DD_i is the total domestic demand for product i; PD_i is the price of product i sold on the domestic market (including taxes); PM_i represents the price of the imported product i (including taxes and tariffs); B_i^M is the scale parameter (CES-composite product); σ_i^M is the elasticity parameter (CES-composite product).

Equilibrium conditions

Equilibrium conditions ensure the consistency of transactions across all commodity and factor markets. For each commodity, total demand must equal total supply, while factor markets clear through the adjustment of factor prices and allocation across sectors.

Commodity-market equilibrium incorporates household consumption, government demand, intermediate consumption, investment demand, and trade flows. Factor-market equilibrium determines the allocation of labour and capital among production activities according to relative returns.

Equations (19)–(24) define the equilibrium conditions governing commodity markets, factor markets, domestic production, and export markets. Together, these equations ensure that all markets clear simultaneously and that the economy converges to a new equilibrium following the introduction of land-productivity shocks.

$$Q_i = \textstyle\sum_h C_{i,h} + \mathrm{CG}_i + \mathrm{INV}_i + \mathrm{DIT}_i + \mathrm{VSTK}_i + \mathrm{MRGN}_i, \tag{19}$$

$$\textstyle\sum_j \mathrm{LD}_{l,j} = \mathrm{LS}_l, \tag{20}$$

$$\textstyle\sum_j \mathrm{KD}_{k,j} = \mathrm{KS}_k, \tag{21}$$

$$\mathrm{IT} = \textstyle\sum_h \mathrm{SH}_h + \sum_f \mathrm{SF}_f + \mathrm{SG} + \mathrm{SROW}, \tag{22}$$

$$\textstyle\sum_j \mathrm{DS}_{j,i} = \mathrm{DD}_i, \tag{23}$$

$$\textstyle\sum_j \mathrm{EX}_{j,i} = \mathrm{EXD}_i, \tag{24}$$

with, $EX_{j,i}$ represents the quantity of product i exported by branch j and EXD_i expresses the global demand for the exported product i.

Model closure and calibration

The computable general equilibrium (CGE) model was calibrated to reproduce the benchmark equilibrium represented by the 2016 Social Accounting Matrix (SAM) for Burkina Faso developed by the Partnership for Economic Policy (PEP). Calibration followed the standard PEP-1-t methodology (Decaluwé et al., 2013), whereby model parameters were derived so that all endogenous variables exactly replicated the observed base-year equilibrium.

Behavioural parameters, including substitution and transformation elasticities, were obtained from the PEP database. In cases where country-specific estimates were unavailable, parameter values commonly employed in CGE studies of Sub-Saharan African economies were adopted (Diao & Sarpong, 2011; Zhai et al., 2009; Zidouemba & Gérard, 2018).

Model calibration was based on the agricultural Social Accounting Matrix (SAM) of Burkina Faso for 2016, updated to reflect the economic structure of 2018. Prior to policy simulations, benchmark replication tests were conducted to verify that the calibrated model reproduced all SAM accounts within an acceptable numerical tolerance. Model consistency was further confirmed through market-clearing and balance-of-payments validation tests.

Dynamic simulations were performed over the period 2017–2030. Capital accumulation was modelled recursively, with investment in one period contributing to the productive capital stock available in subsequent periods. Population growth, labour-force growth, and exogenous productivity trends were specified following the standard recursive dynamic specification of the PEP-1-t model (Decaluwé et al., 2013), calibrated to the Burkina Faso SAM.

A neoclassical macroeconomic closure was adopted. Aggregate investment was savings-driven, with household, enterprise, government, and foreign savings jointly determining total investment. Direct and indirect tax rates were fixed, while government savings adjusted endogenously to maintain fiscal balance. Government consumption was held constant in real terms throughout the simulation period.

Burkina Faso was modelled as a small open economy facing exogenously determined world prices. Import and export prices expressed in foreign currency were assumed fixed, whereas the real exchange rate adjusted to maintain equilibrium in the balance of payments. The factor-market closure assumed full employment and intersectoral mobility of labour and capital, whereas agricultural land was treated as a sector-specific production factor.

The closure rules were implemented by fixing selected exogenous variables. The nominal exchange rate was fixed at unity and used as the model numeraire. The current account balance, minimum household consumption, and government demand were fixed at their benchmark levels.

Table A1 in the Appendix provides complete definitions of the model sets and variables.

The model assumes perfect competition in commodity and factor markets, producer profit maximization, household utility maximization subject to budget constraints, and market-clearing conditions for all commodity and factor markets. Dynamic adjustment is recursive through capital accumulation and inter-period updating of exogenous variables.

Land degradation was incorporated as an exogenous productivity shock affecting the agricultural land factor. The land productivity parameter was adjusted according to the estimated productivity-loss coefficient derived from the RUSLE model. The estimated productivity-loss coefficients served as exogenous shocks to the land productivity parameter in the CGE model. Alternative simulation scenarios were generated by varying the magnitude of these shocks according to the assumptions described below.

Simulation scenarios

Four policy scenarios were designed to assess the economy-wide impacts of land degradation under alternative assumptions regarding agricultural land productivity. The baseline scenario represents the estimated average national productivity loss (approximately 28%) derived from the RUSLE analysis. The optimistic scenario assumes a moderate productivity decline of approximately 15%, consistent with estimates reported by the IPCC Special Report on Climate Change and Land (2019). The pessimistic scenario represents severe land degradation corresponding to a productivity loss of approximately 40%, reflecting the continued absence of effective land management interventions. Finally, the mitigation scenario simulates the implementation of sustainable land management practices, including soil and water conservation, organic fertilization, agroecological restoration, and soil rehabilitation measures. Productivity improvements under this scenario were parameterized using evidence reported by Sidibé (2005), Zougmoré et al. (2010), and Diop et al. (2022).

For each scenario, the model simulated changes in agricultural productivity, sectoral output, household income, household consumption, and gross domestic product (GDP).

Sensitivity and robustness analysis

To assess the robustness of the CGE simulations, sensitivity analyses were performed for the key behavioural parameters, particularly the substitution elasticities used in the production functions. Following common practice in CGE modelling, elasticity values were varied by ±20% relative to their benchmark values. The resulting changes in sectoral output, household income, consumption, and macroeconomic indicators were compared across simulation scenarios. Model robustness was further evaluated through benchmark replication, verification of market-clearing conditions, and consistency checks between the calibrated equilibrium and the underlying SAM.

Data sources

The analysis integrates economic, agricultural, and environmental datasets obtained from national and international sources. The 2016 Social Accounting Matrix (SAM) used for CGE calibration was obtained from the Partnership for Economic Policy (PEP). Agricultural land-use data were provided by the Directorate-General for Water Resources Management and Irrigation Development (DGAHDI), while crop yield and producer price data were obtained from the National Security Stock Management Company (SONAGESS).

Environmental and spatial datasets required for the RUSLE analysis were derived from Landsat-8 multispectral imagery processed using Google Earth Engine and from spatial datasets provided by the Directorate General for Hydro-Agricultural Development and Irrigation (DGAHDI, 2017).

Unless otherwise stated, all monetary values are reported in constant 2017 CFA francs, which corresponds to the reference year used for the Social Accounting Matrix (SAM) underlying the CGE model.

RESULTS AND DISCUSSION

Estimated annual productivity losses in staple crops

The impact of land degradation on agricultural productivity was assessed across different crop categories and administrative regions. As presented in Table 1, of the approximately 5.2 million ha of cultivated agricultural land in Burkina Faso in 2017, more than 1.45 million ha were classified as degraded, accounting for nearly 28% of the country's total cultivated area. This substantial share of degraded agricultural land highlights the widespread and persistent nature of land degradation and underscores its role as a major structural constraint on agricultural productivity, food production, and the sustainability of rural livelihoods throughout the country.

The largest productivity losses were observed for white sorghum, groundnut, maize, and millet, which are among the most extensively cultivated crops in Burkina Faso. In contrast, fonio (0.28%) and soybean (0.30%) recorded the lowest productivity losses among cereals and cash crops, respectively. The relatively limited impact on these crops may reflect their smaller cultivated area and more localized production systems. Similar patterns were reported by Sartori et al. (2019), who found that land degradation substantially reduces agricultural production in Burkina Faso.

Overall, the estimated annual economic loss associated with declining agricultural productivity due to land degradation amounts to approximately CFAF 321 billion (2017 constant prices), equivalent to nearly 31% of agricultural GDP. This finding demonstrates that land degradation constitutes not only an environmental concern but also a major economic challenge. Comparable results have been reported for other developing countries, where soil erosion and declining soil fertility generate substantial reductions in agricultural value added (Zhai et al., 2009; Panagos et al., 2018).

The estimated productivity losses further illustrate the severity of land degradation. Millet experienced an estimated productivity loss of 25.41%, indicating that approximately one-quarter of its potential production is lost because of soil degradation. Comparable losses were estimated for white sorghum (33.14%), groundnut (28.31%), and yam (31.22%). These findings indicate that land degradation disproportionately affects staple food crops that are essential for household food security and rural incomes, thereby increasing the vulnerability of agricultural production systems and rural communities. Consequently, continued land degradation is likely to reduce farm incomes, increase household vulnerability, and weaken agricultural resilience to climate variability, underscoring the importance of sustainable land management practices.

Table 1. Estimated annual productivity losses by crop

Crop	Total area, ha	Actual production, t	Degraded area, ha	Loss in degraded areas, t	Productivity loss, %	Price, CFAF/t	Economic loss, CFAF billion
Millet	1,187,397	905,071	332,471	229,999.98	25.41	203,000	46.689
Maize	911,728	1,602,525	255,284	399,474.06	24.92	144,000	57.524
Rice	170,158	384,690	47,644	74,438.76	19.35	300,000	22.331
Fonio	14,133	10,936	3,957	1,383.70	12.65	653,000	0.903
White sorghum	1,320,442	1,177,442	369,724	390,250.70	33.14	160,000	62.440
Red sorghum	413,728	486,402	115,844	145,180.21	29.84	152,000	22.067
Peanut	585,302	515,498	163,885	145,945.53	28.31	361,000	52.686
Sesame	282,623	163,819	79,134	44,691.35	27.28	634,000	28.334
Soya	23,164	25,765	6,486	5,388.78	20.91	181,000	0.975
Yam	7,979	48,425	2,234	15,122.81	31.22	314,000	4.748
Potatoes	6,584	65,947	1,844	13,301.34	20.16	76,000	1.010
Nébié	229,548	558,925	64,273	51,903.51	9.28	336,000	17.439
Voandzou	52,991	50,897	14,837	13,230.89	25.99	317,000	4.194
Total	5,205,777		1,457,617.56				321.346

Source: author's own calculations

Furthermore, the analysis reveals substantial regional disparities in the effects of land degradation (Table 2). The North, Hauts-Bassins, Centre-West, Centre-East, Plateau Central, and East regions experience the highest economic losses, accounting collectively for approximately CFAF 52 billion annually out of the CFAF 321 billion total agricultural productivity losses.

These regional differences can largely be explained by biophysical and anthropogenic factors. In the East, Plateau Central, North, and Centre-West regions, sparse vegetation cover combined with intense human activities accelerates water and wind erosion processes. Wind dynamics may further contribute to the transport of sand particles and organic matter, thereby intensifying soil degradation and reducing agricultural productivity. In contrast, in Hauts-Bassins and Centre-East, high-intensity rainfall events appear to exacerbate water erosion processes. These findings are consistent with earlier studies conducted in Burkina Faso (SP/CONEDD, 2006; MAAH, 2018).

More broadly, these regions are characterised by strong demographic pressure and intensive agricultural systems that contribute to ecosystem degradation. Nkonya et al. (2016) similarly estimated that land degradation generates annual economic losses of approximately US$18.9 billion across West Africa. The regions most affected in this study also correspond to those with the largest agricultural land areas, underlining the close relationship between agricultural intensity and land degradation dynamics. Conversely, the Sahel, Boucle du Mouhoun, Cascades, and Centre-Sud regions recorded comparatively lower economic losses.

Table 2. Estimate of annual productivity loss by region

Region	Degraded agricultural land, ha	Total agricultural area, ha	Share of degraded land, %	Loss of land productivity, %	Losses in crop productivity, CFAF billion
Cascades	47,663.72	183,322	0.26	26	16.656
Sahel	73,588.20	490,588	0.15	15	8.813
Centre-Sud	73,146.50	292,586	0.25	25	19.780
Sud-Ouest	82,866.35	236,761	0.35	35	20.401
Hauts-Bassins	85,632.90	570,886	0.15	15	26.771
Boucle du Mouhoun	82,005.12	911,168	0.09	9	17.392
Centre-Nord	168,982.49	286,411	0.59	59	22.279
Centre	81,376.32	84,767	0.96	96	21.405
Nord	146,556.96	444,112	0.33	33	22.864
Centre-Est	106,577.75	426,311	0.25	25	31.545
Centre-Ouest	114,760.80	546,480	0.21	21	25.841
Plateau-Central	172,973.03	205,035	0.84	83	36.487
Est	221,487.00	527,350	0.42	42	51.105
Burkina Faso	1,457,617.14	5,205,777.00			321.346

Source: author's own calculations based on the RUSLE model

Figure 1 illustrates the spatial distribution of land productivity losses across regions. The results indicate that the Centre region records the highest land productivity loss (96%), followed by Plateau-Central (83%), Centre-Nord (59%), and Est (42%). These high rates of productivity loss highlight the severity of land degradation across several agroecological zones of Burkina Faso.

The results suggest that land degradation hotspots are concentrated in regions characterized by intense pressure on land resources, limited vegetation cover, and the widespread use of unsustainable agricultural practices. This spatial pattern indicates that environmental constraints, combined with increasing agricultural pressure, contribute significantly to the severity of land degradation across these regions. To provide a more comprehensive assessment of the economic implications of these productivity losses, the following section applies a Computable General Equilibrium (CGE) model to evaluate not only the direct consequences of declining land productivity but also the indirect and economy-wide effects transmitted through production, factor markets, household incomes, and the broader economic system.

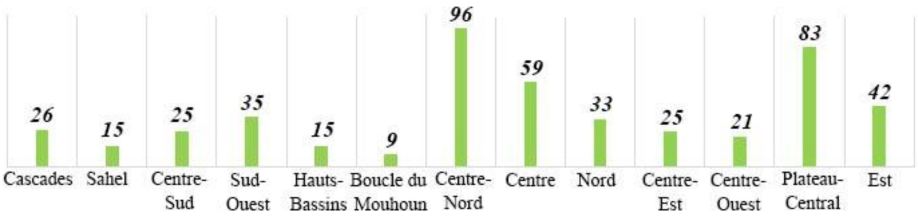

Figure 1. Productivity loss of land, expressed as a percentage (source: author's own calculations)

Macroeconomic Impact of Land Degradation

The CGE (EGC) simulation results highlight the significant economic consequences of land degradation on agricultural production and overall economic performance in Burkina Faso. This section examines the effects of declining land productivity on agricultural output and gross domestic product (GDP), as well as the potential mitigating role of sustainable land management investments.

Results presented in Table 3 indicate that land degradation systematically reduces agricultural productivity across all crop categories, although the magnitude of impacts varies by crop type and scenario. Vegetables, tubers, and maize are the most affected categories. In the baseline scenario, productivity losses reach 21.58% for vegetables, 16.13% for tubers, and 16.42% for maize, while under the pessimistic scenario these losses increase to 31.11%, 23.34%, and 24.59%, respectively.

These results reflect the high sensitivity of nutrient-demanding crops to soil degradation processes, including declining soil fertility, erosion, and deterioration of soil physical structure. Similar findings have been reported in previous studies highlighting the vulnerability of agricultural systems to land degradation (Berry et al., 2003; ELD, 2015; Panagos et al., 2018; Sartori et al., 2019; Mirzabaev & von Braun, 2022). Combary (2016) further argues that declining agricultural productivity in Burkina Faso is partly driven by insufficient investment in the restoration of degraded land.

Rice, millet, and sorghum also experience notable productivity declines, ranging from approximately 11% to 16% in the baseline scenario. These estimates are consistent with empirical evidence from Burkina Faso. For example, Zougmoré et al. (2010) show that uncontrolled land degradation can reduce cereal yields by 30–60% in Sahelian production systems.

Under the optimistic scenario, characterised by a lower intensity of land degradation, productivity losses are substantially reduced across all crops. This improvement can be associated with the adoption of sustainable land management practices, including soil and water conservation techniques, organic and organo-mineral fertilisation, and compost application. These findings support earlier evidence indicating that agroecological interventions in the Sahel can generate productivity gains ranging from 30% to 70% (Sidibé, 2005; Diop et al., 2022).

In contrast, the pessimistic scenario illustrates the potential severity of inaction. Beyond agricultural production losses, continued land degradation may undermine food security, reduce household incomes, and increase the vulnerability of smallholder farmers. These results underscore the importance of strengthening public policies aimed at combating land degradation through integrated land-use planning, incentives for sustainable agricultural investment, and the promotion of local agroecological knowledge.

Table 3. Effect of land productivity loss on agricultural productivity

Products	Baseline (level / simulation)	Variation, %	Optimistic (level / simulation)	Variation, %	Pessimistic (level / simulation)	Variation, %
Maize	37,556.60 / 31,389.04	–16.42	122,943 / 113,388.20	–7.77	37,556.61 / 28,322.87	–24.59
Rice	13,877.45 / 11,724.28	–15.52	65,597 / 60,435.13	–7.87	13,877.45 / 10,661.36	–23.17
Millet	44,840.3345 / 38,804.03	–13.46	116,222 / 108,550.45	–6.60	44,840.33 / 35,460.67	–20.92
Sorghum	63,821.9245 / 56,621.71	–11.28	173,057 / 163,764.88	–5.36	63,821.93 / 52,292.49	–18.06
Fonio	397.4545 / 357.48	–10.05	2,470 / 2,381.05	–3.60	397.45 / 331.61	–16.56
Tubers	26,225.8345 / 21,994.57	–16.13	151,687 / 139,081.46	–8.31	26,225.83 / 20,105.52	–23.34
Vegetables	30,414.9145 / 23,848.39	–21.58	127,005 / 115,070.36	–9.39	30,414.91 / 20,953.36	–31.11
Livestock farming	72,873.1645 / 70,971.89	–2.61	696,436 / 688,678.03	–1.11	72,873.16 / 69,509.63	–4.62

Source: author's own calculations based on CGE model simulation results

Figure 2 below illustrates the effects of declining soil productivity on agricultural productivity. These results show that declining soil productivity has a negative impact on all types of crops.

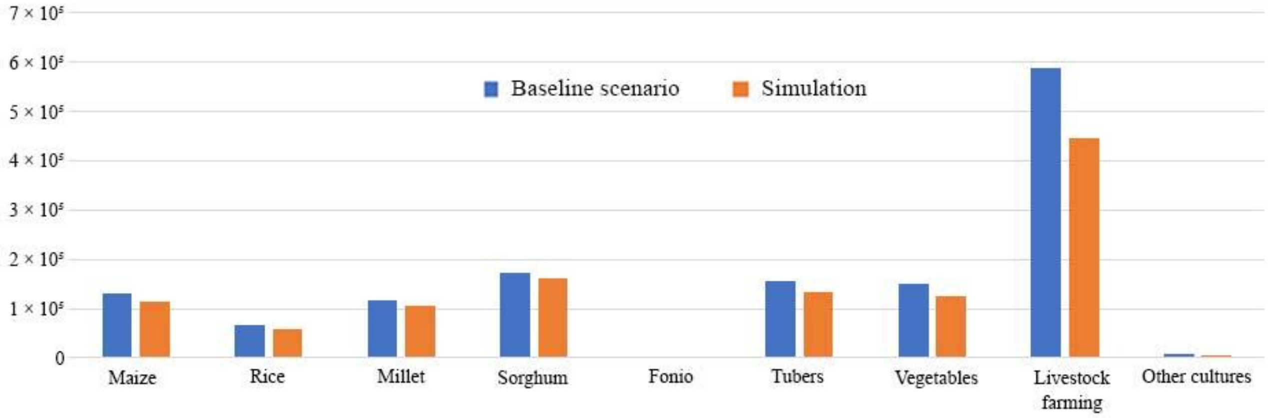

Figure 1. Effect of land productivity loss on agricultural productivity (source: author's own calculations)

Table 4 presents the impact of land degradation on gross domestic product (GDP) through changes in agricultural productivity. Under the baseline scenario, GDP declines by approximately 27.5%, falling from 6.83 million to 4.95 million monetary units. This result highlights the structurally significant role of land productivity in overall economic performance in Burkina Faso, where agriculture remains a key sector.

In the optimistic scenario, the GDP decline is limited to 16.42%, suggesting that improvements in land management and agroecological conditions can preserve a substantial share of national output. In contrast, the pessimistic scenario shows a much more severe contraction of around 39%, despite a higher initial GDP level. This result underscores the strong sensitivity of the economy to land degradation dynamics.

Overall, these findings indicate that, in the absence of restoration and resilience strategies, the cumulative effects of land degradation may lead to persistent and potentially irreversible economic losses. This highlights the importance of integrating sustainable land management and soil conservation into national development strategies. Similar conclusions have been reported by Nkonya et al. (2016) and Gorain et al. (2024), who find that land degradation significantly constrains economic growth in developing countries and in India in particular.

Table 4. Effect of land degradation on agricultural gross domestic product (GDP)

Products	Baseline (level / simulation)	Variation, %	Optimistic (level / simulation)	Variation, %	Pessimistic (level / simulation)	Variation, %
GDP	6,830,998 / 4,951,540.37	–27.51	7,121,348 / 5,951,540.87	–16.42	8,126,486 / 4,951,540.89	–39.06

Source: author's own calculations based on CGE model simulation results

Table 5 presents the effects of investments in water and soil conservation (WSC) techniques on agricultural productivity under different land degradation scenarios. The results indicate substantial productivity gains across all agricultural systems, with improvements ranging from approximately 7% to 127%, depending on crop type and scenario.

Maize shows the strongest response to WSC interventions, with productivity increases of 114.70%, 127.57%, and 103.05% under the baseline, optimistic, and pessimistic scenarios, respectively. Significant gains are also observed for rice, millet, sorghum, fonio, tubers, and vegetables. Even livestock production, which is less directly affected by land degradation, records moderate improvements ranging from 7% to 9%.

These findings are consistent with previous studies in Sub-Saharan Africa. Zougmoré et al. (2010) show that soil and water conservation techniques such as stone bunds and zaï practices can significantly increase cereal yields in Sahelian agroecosystems. Barbier & Hochard (2018) highlight that sustainable land management contributes not only to higher agricultural productivity but also to poverty reduction and long-term economic growth. In Burkina Faso, Sawadogo (2012) reports yield increases of 60–100% associated with zaï and composting practices in rain-fed agriculture.

Overall, the results suggest that sustainable land management is a key strategy for strengthening resilience and supporting agricultural transformation in the Sahel under increasing climate and land-use pressures.

Table 5. Effect of investments in water and soil conservation techniques on agricultural productivity

Products	Baseline (level / simulation)	Variation, %	Optimistic (level / simulation)	Variation, %	Pessimistic (level / pessimistic)	Variation, %
Maize	37,556.6092 / 80,637.3603	114.7088	37,556.6092 / 85,468.7299	127.5731	37,556.6092 / 76,261.2451	103.0568
Rice	13,877.4536 / 21,197.6108	52.7485	13,877.4536 / 21,719.9896	56.5127	13,877.4536 / 20,702.2206	49.1788
Millet	44,840.3281 / 64,214.8244	43.2077	44,840.3281 / 65,609.1319	46.3172	44,840.3281 / 62,890.5200	40.2543
Sorghum	63,821.9256 / 86,007.2155	34.7612	63,821.9256 / 87,677.2018	37.3778	63,821.9256 / 84,437.4230	32.3016
Fonio	397.454659 / 505.091245	27.0815	397.454659 / 512.240570	28.8802	397.454659 / 498.256009	25.3617
Tubers	26,225.8356 / 43,451.6546	65.6826	26,225.8356 / 44,751.9484	70.6406	26,225.8356 / 42,218.1749	60.9793
Vegetables	30,414.9114 / 57,186.9301	88.0227	30,414.9114 / 59,167.5665	94.5347	30,414.9114 / 55,302.9421	81.8283
Livestock farming	72,873.1568 / 78,728.9951	8.0356	72,873.1568 / 79,216.2274	8.7042	72,873.1568 / 78,274.6540	7.4122

Source: author's own calculations based on CGE model simulation results

Sensitivity analysis

The behavioural parameters used in the CGE model were drawn from multiple sources. To assess the robustness of the model results, sensitivity analyses were conducted on the elasticities of the production functions.

In the sensitivity tests, the elasticities of production factors were first reduced by 20% to simulate low-elasticity conditions and then increased by 20% to represent high-elasticity conditions. The results of these simulations are presented in Table 6.

A comparison of the sensitivity results with the baseline simulations (Table 4) indicates that the overall effects remain relatively stable across alternative elasticity assumptions. In particular, changes in elasticity values do not significantly alter the direction or magnitude of the simulated impacts.

These findings confirm the robustness and internal consistency of the model parameters used in the study. The relative stability of the results strengthens confidence in the estimated economic impacts of land degradation and in the projected effects of sustainable land management interventions.

Table 6. Model sensitivity test results

Products	Baseline (level / simulation)	Variation, %	Optimistic (level / simulation)	Variation, %	Pessimistic (level / simulation)	Variation, %
Maize	37,556.6092 / 101,376.8450	169.9307	37,556.6092 / 109,157.2070	190.6471	37,556.6092 / 94,354.6184	151.2331
Rice	13,877.4536 / 20,594.7458	48.4044	13,877.4536 / 21,043.1732	51.6357	13,877.4536 / 20,164.8813	45.3068
Millet	44,840.3281 / 62,509.1768	39.4039	44,840.3281 / 63,681.0798	42.0174	44,840.3281 / 61,383.7110	36.8939
Sorghum	63,821.9256 / 85,101.0346	33.3414	63,821.9256 / 86,653.5344	35.7739	63,821.9256 / 83,640.4248	31.0528
Fonio	397.454659 / 500.143537	25.8366	397.454659 / 506.533011	27.4442	397.454659 / 494.013113	24.2942
Tubers	26,225.8356 / 41,614.0144	58.6756	26,225.8356 / 42,662.0047	62.6716	26,225.8356 / 40,599.4222	54.8069
Vegetables	30,414.9114 / 54,722.5654	79.9202	30,414.9114 / 56,325.1777	85.1893	30,414.9114 / 53,161.9414	74.7890
Livestock farming	72,873.1568 / 79,548.4246	9.1601	72,873.1568 / 80,076.9583	9.8854	72,873.1568 / 79,051.9368	8.4788

Source: author's own calculations based on simulation results from the CGE model

CONCLUSION

This study confirms that land degradation represents a structural constraint on both agricultural performance and macroeconomic outcomes in Burkina Faso. The empirical results support the central hypothesis that declining land quality significantly reduces agricultural productivity and generates economy-wide losses extending beyond the agricultural sector. The estimated degradation of nearly 28% of agricultural land translates into annual productivity losses of approximately CFAF 321 billion, corresponding to about 31% of agricultural GDP. These losses are concentrated in staple crops that are essential for national food security, particularly maize, millet, sorghum, and groundnuts, indicating that land degradation directly threatens agricultural output and rural livelihoods.

The CGE simulations further show that these effects propagate throughout the economy via strong intersectoral linkages. Under the baseline scenario, reduced agricultural productivity leads to a GDP decline of more than 27%, while the pessimistic scenario suggests potential contractions approaching 40%. These results indicate that land degradation in Burkina Faso is not only an environmental challenge but also a systemic macroeconomic risk, affecting economic growth, household income, and rural vulnerability.

The analysis also demonstrates that investments in sustainable land management can substantially mitigate these losses. Water and soil conservation practices generate significant productivity gains across all production systems, with increases exceeding 100% for maize and remaining consistently positive for cereals, tubers, vegetables, and livestock under all simulated scenarios. These findings indicate that restoration investments are not merely compensatory measures but economically productive interventions that enhance both agricultural resilience and overall economic performance.

A key contribution of this study lies in the integration of a biophysical land degradation assessment based on the RUSLE framework with a computable general equilibrium model that captures economy-wide transmission effects. While previous studies on Burkina Faso and the Sahel have typically analysed either biophysical degradation processes or localized agricultural impacts in isolation, this study links spatially explicit productivity losses with macroeconomic dynamics. It therefore provides a comprehensive quantification of how land degradation simultaneously affects agricultural systems, household welfare, and national economic performance, filling an important gap in the literature on West African economies.

The results also reveal strong regional heterogeneity in both degradation intensity and economic exposure. Regions characterized by high agricultural pressure, limited vegetation cover, and severe erosion risks experience disproportionately large productivity and income losses. This spatial variation highlights that the economic consequences of land degradation are unevenly distributed and should not be assumed to be uniform across agroecological zones.

Several avenues for future research can be identified. First, the integration of spatially disaggregated CGE frameworks with household- or regional-level econometric models would allow for a more precise assessment of local vulnerability and adaptive capacity. Second, future studies could incorporate climate variability, demographic dynamics, and migration pressures into dynamic modelling frameworks to better capture long-term interactions between land degradation and structural transformation in Sahelian economies. Third, further research is needed to assess the cost-effectiveness of specific land restoration technologies under different agroecological conditions.

Finally, it should be noted that the CGE framework used in this study relies on sectoral aggregation, which limits the explicit representation of spatial heterogeneity in soil characteristics, farming systems, and agroecological zones. This limitation suggests the need to complement macroeconomic modelling with more disaggregated spatial and econometric approaches to better inform locally targeted policy interventions aimed at combating land degradation.

Author's statements

Contributions

All contributions were made by the sole author.

Declaration of conflicting interest

The author declares no competing interests.

Financial interests

The author declares no competing financial interests.

Funding

Not applicable.

Data availability statement

All data are included in this manuscript.

AI Disclosure

Generative AI tools were used solely for language editing and proofreading. The author assumes full responsibility for the content of the manuscript, including its arguments, analysis, interpretation, and conclusions.

Ethical approval declarations

Not applicable.

Additional information

Publisher's note

Publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Appendix

Table A1. Definitions of model sets and variables

Category	Symbol	Definition
Sets	*i*	Commodities
	j	Industries
	h	Household types
	k	Capital types
	l	Labor types
	f	Business types
	ag	Agents
	agj	Agents (source of transfers)
Quantity variables	C(i,h)	Consumption of commodity *i* by household type *h*
	CG(i)	Government final consumption of commodity *i*
	CI(j)	Total intermediate consumption of industry *j*
	CMIN(i,h)	Minimum consumption of commodity *i* by household type *h*
	CTH_REAL(h)	Real consumption budget of household type *h*
	DD(i)	Domestic demand for locally produced commodity *i*
	DI(i,j)	Intermediate consumption of commodity *i* by industry *j*
	DIT(i)	Total intermediate demand for commodity *i*
	DS(j,i)	Supply of commodity *i* by industry *j* to the domestic market
	EX(j,i)	Exports of commodity *i* by industry *j*
	EXD(i)	World demand for exports of commodity *i*
	G_REAL	Real government expenditure on goods and services
	GDP_BP_REAL	Real GDP at basic prices
	GDP_MP_REAL	Real GDP at market prices
	GFCF_REAL	Real gross fixed capital formation
	IM(i)	Imports of commodity *i*
	INV(i)	Investment demand (gross fixed capital formation) for commodity *i*
	KD(k,j)	Demand for capital type *k* by industry *j*
	KDC(j)	Demand for composite capital by industry *j*
	KDNA(j)	Demand for composite capital by industry *j* (non-agricultural)
	KLD(j)	Demand for composite capital–labor input by industry *j*
	KTD(j)	Demand for land capital by industry *j*
	KS(k)	Supply of capital type *k*
	LD(l,j)	Demand for labor type *l* by industry *j*
	LDC(j)	Demand for composite labor by industry *j*
	LDA(j)	Demand for composite labor by industry *j*

	LDNA(j)	Demand for composite labor by industry *j* (non-agricultural)
	LS(l)	Supply of labor type *l*
	MRGN(i)	Demand for commodity *i* as trade and transport margins
	Q(i)	Demand for composite commodity *i*
	VA(j)	Value added of industry *j*
	VSTK(i)	Inventory changes of commodity *i*
	XS(j,i)	Production of commodity *i* by industry *j*
	XST(j)	Total output of industry *j*
Price variables	e	Nominal exchange rate (price of foreign currency in local currency)
	P(j,i)	Basic price of commodity *i* produced by industry *j*
	PC(i)	Purchaser price of composite commodity *i* (including taxes and margins)
	PCI(j)	Intermediate consumption price index of industry *j*
	PD(i)	Domestic market price of commodity *i* (including taxes and margins)
	PE(i)	Producer price of exported commodity *i* (excluding export taxes)
	PE_FOB(i)	FOB export price of commodity *i* in local currency
	PIXCON	Consumer price index
	PIXGDP	GDP deflator
	PIXGVT	Government expenditure price index
	PIXINV	Investment price index
	PL(i)	Producer price of domestically produced commodity *i* (excluding product taxes)
	PM(i)	Price of imported commodity *i* (including import duties and taxes)
	PP(j)	Unit production cost of industry *j*
	PT(j)	Basic output price of industry *j*
	PVA(j)	Value-added price of industry *j*
	PWM(i)	World price of imported commodity *i* (foreign currency)
	PWX(i)	World price of exported commodity *i* (foreign currency)
	R(k,j)	Rental rate of capital type *k* in industry *j*
	RC(j)	Rental rate of composite capital in industry *j*
	RLC(j)	Rental rate of composite capital in industry *j*
	RTK(j)	Rental rate of land capital in industry *j*
	RNA(j)	Rental rate of composite capital in industry *j*
	RA(j)	Rental rate of composite capital in industry *j*
	RK(k)	Economy-wide rental rate of capital type *k*
	RTI(k,j)	Rental rate paid by industry *j* for capital type *k*, including capital taxes
	W(l)	Wage rate of labor type *l*
	WC(j)	Wage rate of composite labor in industry *j*
	WA(j)	Wage rate of composite labor in industry *j*
	WNA(j)	Wage rate of composite labor in industry *j*
	WTI(l,j)	Wage rate paid by industry *j* for labor type *l*, including payroll taxes
Nominal (value) variables	CAB	Current account balance
	CTH(h)	Consumption budget of household type *h*
	G	Government expenditure on goods and services
	GDP_BP	GDP at basic prices
	GDP_FD	GDP at purchasers' prices (final demand approach)
	GDP_IB	GDP at market prices (income approach)
	GDP_MP	GDP at market prices

GFCF	Gross fixed capital formation
IT	Total investment expenditure
SF(f)	Savings of business type *f*
SG	Government savings
SH(h)	Savings of household type *h*
SROW	Rest-of-the-world savings
TDF(f)	Income tax paid by business type *f*
TDFT	Total revenue from business income taxes
TDH(h)	Income tax paid by household type *h*
TDHT	Total revenue from household income taxes
TIC(i)	Indirect tax revenue from commodity *i*
TICT	Total indirect tax revenue on commodities
SUB(i)	Government subsidy on commodity *i*
SUBT	Total government subsidies
TIK(k,j)	Capital tax revenue from capital type *k* used by industry *j*
TIKT	Total capital tax revenue
TIM(i)	Import duty revenue from commodity *i*
TIMT	Total import duty revenue
TIP(j)	Production tax revenue from industry *j*
TIPT	Total production tax revenue
TIW(l,j)	Payroll tax revenue from labor type *l* employed in industry *j*
TIWT	Total payroll tax revenue
TIX(i)	Export tax revenue from commodity *i*
TIXT	Total export tax revenue
TPRCTS	Total revenue from taxes on products and imports
TPRODN	Total revenue from other production taxes
TR(ag,agj)	Transfers from agent *agj* to agent *ag*
YDF(f)	Disposable income of business type *f*
YDH(h)	Disposable income of household type *h*
YF(f)	Total income of business type *f*
YFK(f)	Capital income of business type *f*
YFTR(f)	Transfer income of business type *f*
YG	Total government income
YGK	Government capital income
YGTR	Government transfer income
YH(h)	Total income of household type *h*
YHK(h)	Capital income of household type *h*
YHL(h)	Labor income of household type *h*
YHTR(h)	Transfer income of household type *h*
YROW	Income of the rest of the world

REFERENCES

Adam, M., MacCarthy, D. S., Traoré, P. C. S., Nenkam, A., Freduah, B. S., Ly, M., & Adiku, S. G. (2020). Which is more important to sorghum production systems in the Sudano-Sahelian zone of West Africa: Climate change or improved management practices?. *Agricultural Systems*, 185, 102920. https://doi.org/10.1016/j.agsy.2020.102920.

Alfsen, K. H., De Franco, M. A., Glomsrød, S., & Johnsen, T. (1996). The cost of soil erosion in Nicaragua. *Ecological Economics*, 16(2), 129–145. https://doi.org/10.1016/0921-8009(95)00083-6.

Arumugam, P., Chemura, A., Aschenbrenner, P., Schauberger, B., & Gornott, C. (2023). Climate change impacts and adaptation strategies: an assessment on sorghum for Burkina Faso. *European Journal of Agronomy*, 142, 126655. https://doi.org/10.1016/j.eja.2022.126655.

Barbier, E. B., & Hochard, J. P. (2018). Land degradation and poverty. *Nature Sustainability*, 1(11), 623–631. https://doi.org/10.1038/s41893-018-0155-4.

Berry, L., Olson, J., & Campbell, D. (2003). *Assessing the extent, cost and impact of land degradation at the national level: findings and lessons learned from seven pilots*. World Bank.

Combary, O. S. (2017). Analysing the efficiency of farms in Burkina Faso. http://www.afjare.org/resources/issues/vol_12_no3/5.%20Combary.pdf.

Decaluwé, B., Lemelin, A., Robichaud, V., & Maisonnave, H. (2013). *PEP-1-t. Standard PEP Model: Single-Country, Recursive Dynamic Version. Nairobi, Kenya: Partnership for Economic Policy Network*. https://agrodep.org/sites/default/files/PEP%201-t.pdf.

Diao, X., & Sarpong, D. B. (2011). Poverty implications of agricultural land degradation in Ghana: an economy-wide, multimarket model assessment. *African Development Review*, 23(3), 263–275. https://doi.org/10.1111/j.1467-8268.2011.00285.x.

Diop, M., Chirinda, N., Beniaich, A., El Gharous, M., & El Mejahed, K. (2022). Soil and water conservation in Africa: State of play and potential role in tackling soil degradation and building soil health in agricultural lands. *Sustainability*, 14(20), 13425. https://doi.org/10.3390/su142013425.

Direction générale des aménagements hydro-agricoles et du développement de l'irrigation (DGAHDI). (2017). *Situation de référence des terres dégradées et de la CES au Burkina Faso [Rapport définitif]*. Ministère de l'Agriculture et des Aménagements Hydro-agricoles.

Dugué, P., Andrieu, N., & Bakker, T. (2024). Pour une gestion durable des sols en Afrique subsaharienne. *Cahiers Agricultures*, 33, Article 6. https://doi.org/10.1051/cagri/2024003.

ELD Initiative. (2015). *The economics of land degradation*. https://www.eld-initiative.org.

Food and Agriculture Organization (FAO). (2021). *Soil degradation and restoration*. https://www.fao.org/soils-portal/soil-degradation-restoration/.

Gambella, F., Quaranta, G., Morrow, N., Vcelakova, R., Salvati, L., Gimenez Morera, A., & Rodrigo-Comino, J. (2021). Soil degradation and socioeconomic systems' complexity: Uncovering the latent nexus. *Land*, 10(1), 30. https://doi.org/10.3390/land10010030.

Gorain, S., Kuriachen, P., Kumar, C. V., & Suresh, A. (2024). Land degradation and its impact on agricultural productivity: The case of India. *Land Degradation & Development*, 35(1), 196–212.

Hu, Y., Liu, C., & Peng, J. (2021). Financial inclusion and agricultural total factor productivity growth in China. *Economic Modelling*, 96, 68–82. https://doi.org/10.1016/j.econmod.2020.12.021.

Institut national de la statistique et de la démographie (INSD). (2022). *Enquête harmonisée sur les conditions de vie des ménages de 2018 (EHCVM-2018): Diagnostic de la pauvreté*. Ministère de l'Économie, des Finances et du Développement.

IPCC. (2022). Climate change 2022: *Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Li, H., Yang, X., & Zhang, K. (2021). Understanding global land degradation processes interacted with complex biophysics and socioeconomics from the perspective of the Normalized Difference Vegetation Index (1982–2015). *Global and Planetary Change*, 198, 103431. https://doi.org/10.1016/j.gloplacha.2021.103431.

Marx, K. (1894). *Capital: A critique of political economy.* Volume III: The process of capitalist production as a whole. Progress Publishers.

Millennium Ecosystem Assessment (MEA). (2005). *Ecosystems and human well-being: Synthesis*. Island Press.

Ministère de l'Agriculture et des Aménagements Hydro-agricoles (MAAH). (2018). *Rapport bilan annuel des activités agricoles*. http://www.agriculture.bf.

Ministère de l'Environnement, de l'Économie Verte et du Changement Climatique. (2016). *Quatrième rapport sur l'état de l'environnement au Burkina Faso*. MEEVCC.

Mirzabaev, A., & von Braun, J. (2022). True cost of food and land degradation. *Russian Journal of Economics*, 8(1), 7–15. https://doi.org/10.32609/j.ruje.8.78376.

Nedd, R., & Anandhi, A. (2024). A synthesis on land degradation in the context of sustainable development goals. *Land Degradation & Development*, 35(13), 3937–3964. https://doi.org/10.1002/ldr.5168.

Nkonya, E., Johnson, T., Kwon, H. Y., & Kato, E. (2015). *Economics of land degradation in sub-Saharan Africa. In Economics of land degradation and improvement–a global assessment for sustainable development (pp. 215–259).* Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-19168-3_9.

Panagos, P., Ballabio, C., Himics, M., Scarpa, S., Matthews, F., Bogonos, M., ... & Borrelli, P. (2021). Projections of soil loss by water erosion in Europe by 2050. *Environmental Science & Policy*, 124, 380–392. https://doi.org/10.1016/j.envsci.2021.07.012.

Panagos, P., Standardi, G., Borrelli, P., Lugato, E., Montanarella, L., & Bosello, F. (2018). Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models. *Land Degradation & Development*, 29(3), 471–484. https://doi.org/10.1002/ldr.2879.

Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., ... & Nandagopal, S. (2004). Water resources: agricultural and environmental issues. *BioScience*, 54(10), 909–918. https://doi.org/10.1641/0006-3568(2004)054[0909:WRAAEI]2.0.CO;2.

Renard, K. G. (1997). *Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE)*. US Department of Agriculture, Agricultural Research Service.

Ricardo, D. (1817). *On rent. The Economics of Structural Change*, 1. https://readingmarx.wordpress.com/wp-content/uploads/2022/07/ricardo_principles_2-1.pdf.

Ritchie, H. (2022, April 4). *Increasing agricultural productivity across Sub-Saharan Africa is one of the most important problems this century*. Our World in Data. https://ourworldindata.org/africa-yields-problem.

Sartori, M., Philippidis, G., Ferrari, E., Borrelli, P., Lugato, E., Montanarella, L., & Panagos, P. (2019). A linkage between the biophysical and the economic: Assessing the global market impacts of soil erosion. *Land Use Policy*, 86, 299–312. https://doi.org/10.1016/j.landusepol.2019.05.014.

Sawadogo, H., Bock, L., Lacroix, D., & Zombré, N. P. (2008). Restauration des potentialités de sols dégradés à l'aide du zaï et du compost dans le Yatenga (Burkina Faso). *Biotechnologie, Agronomie, Société et Environnement*, 12(3). https://orbi.uliege.be/bitstream/2268/33221/1/279.pdf.

sba-Ecosys-CEDRES. (2011). *Évaluation économique de l'environnement et des ressources naturelles au Burkina Faso*. Consortium sba-Ecosys-CEDRES.

Sidibé, A. (2005). Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. *Agricultural Water Management*, 71(3), 211–224. https://doi.org/10.1016/j.agwat.2004.09.002.

SP/CONEDD. (2006). *Étude réalisée dans le cadre du programme de gestion durable des terres. Revue scientifique sur l'état de la dégradation des sols du Burkina Faso* (p. 16). Secrétariat Permanent du Conseil National pour l'Environnement et le Développement Durable.

Szangolies, L., Lohmann, D., Hauptfleisch, M., & Jeltsch, F. (2023). Balanced functional herbivore composition stabilizes tree-grass coexistence and productivity in a simulated savanna rangeland ecosystem. *Rangeland Ecology & Management*, 90, 208–220. https://doi.org/10.1016/j.rama.2023.05.001.

Wang, H., Zhou, S., Li, X., Liu, H., Chi, D., & Xu, K. (2016). The influence of climate change and human activities on ecosystem service value. *Ecological Engineering*, 87, 224–239. https://doi.org/10.1016/j.ecoleng.2015.11.027.

Zhai, F., Lin, T., & Byambadorj, E. (2009). A general equilibrium analysis of the impact of climate change on agriculture in the People's Republic of China. *Asian Development Review*, 26(01), 206–225. https://doi.org/10.1142/S0116110509500073.

Zhang, W., Ricketts, T. H., Kremen, C., Carney, K., & Swinton, S. M. (2007). Ecosystem services and dis-services to agriculture. *Ecological economics*, 64(2), 253–260. https://doi.org/10.1016/j.ecolecon.2007.02.024.

Zidouemba, P. R., & Gerard, F. (2018). Does agricultural productivity actually matter for food security in a landlocked Sub-Saharan African country? The case of Burkina Faso. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 66(1), 103–142. https://doi.org/10.1111/cjag.12140.

Zougmoré, R., Mando, A., & Stroosnijder, L. (2004). Effect of soil and water conservation and nutrient management on the soil–plant water balance in semi-arid Burkina Faso. *Agricultural Water Management*, 65(2), 103–120. https://doi.org/10.1016/j.agwat.2003.07.001.