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A CGE Analysis

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ECONOMIC RESEARCH FORUM

منتدى البحوث الاقتصادية

Assessing Economic and Distributional Impacts of Restoring Degraded Rangelands in Jordan: A CGE analysis

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Abstract

Jordan's rangelands play a critical role in the country's ecosystem, economy, and cultural heritage, supporting biodiversity, rural livelihoods, and agricultural production. However, overgrazing, climate change, and socio-political challenges have led to severe rangeland degradation, undermining the sustainability of small ruminant production—a key component of rural livelihoods and Jordan's agricultural sector. This study evaluates the economic implications of rangeland restoration through a micro-water harvesting approach, focusing on productivity gains and associated costs. Utilizing a Computable General Equilibrium (CGE) model, we simulate scenarios to capture the interconnected effects on Jordan's economy, including the impacts on small ruminant production, factor markets, and household welfare. Results highlight that rangeland restoration provides positive overall welfare gains, particularly for rural households, by reducing production costs, increasing small ruminant output, and stimulating labour demand in agricultural sectors. However, while the investment is relatively modest, it generates positive GDP impacts and facilitates export growth. Overall, the study suggests that rangeland restoration offers significant economic, social, and environmental returns, with implications that extend beyond Jordan to similar contexts in the MENA region.

Keywords: Rangeland restoration, Jordan, micro-water harvesting, small ruminant production, Computable General Equilibrium (CGE) modeling, household welfare, agricultural productivity, climate change, ecosystem services.

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1. Introduction

Jordan's rangelands are a critical component of the country's ecosystem, economy, and cultural heritage. These rangelands provide essential ecosystem services, support biodiversity, and sustain rural livelihoods. However, their sustainability is increasingly threatened by overgrazing, climate change, and socio-political challenges(Westerberg et al., 2015). Among the practices rooted in Jordan's rangelands, pastoralism, particularly small ruminant herding—holds a significant role in shaping the cultural identity and economic foundations of rural communities. This sector is not only integral to household income and capital accumulation but also This sector plays an important role in rural household household's income and capital accumulation while also making a considerable contribution to Jordan's agricultural GDP through meat and dairy production (IFAD, 2020).

Historically, rangelands were a vital source of forage for small ruminants, such as sheep and goats, under extensive grazing systems. However, rangeland degradation, driven by unsustainable practices and policies, has significantly reduced their productivity (Al-Karablieh & Jabarin, 2010).Consequently, pastoralists increasingly depend on imported barley and concentrated feed, creating a substantial financial burden for the government due to subsidies and posing a threat to the economic viability of small ruminant production. Compounding these challenges are recurring droughts linked to climate change, which further reduce forage availability and inflate feed costs, pushing many farmers to the brink of unsustainability (Awad et al., 2023).

The degradation of Jordan's rangelands has spill-over effects on the economy, the environment, and the livelihoods of pastoralist communities. Restoring these fragile ecosystems is crucial to sustaining small ruminant production, supporting rural livelihoods, and ensuring the long-term viability of the agricultural sector. Various initiatives have aimed to rehabilitate Jordanian rangelands through ecological restoration, socio-economic strategies, and institutional reforms. Notably, studies utilizing cost-benefit analyses have demonstrated that the benefits of large-scale restoration projects often outweigh their costs (Westerberg et al., 2015). However, existing studies rarely account for the broader social, economic, and environmental interactions associated with rangeland rehabilitation.

This paper employs an economy-wide approach to evaluate the implications of rangeland restoration using micro-water harvesting in Jordan. By exploring the interconnected social, economic, and environmental dimensions, this analysis provides valuable insights for policy and decision-making. Our modelling strategy includes accounting for non-market natural forage and augmenting the production structure of small ruminants accordingly. Moreover, our approach allows us to capture the backwards and forwards multiplier effects of rangeland restauration, such as on the import of feed grains, and food processing sectors. Finally, also the financing of implementing restauration measures is depicted. The findings contribute to advancing research and fostering development in fragile rangelands and pastoralist communities in Jordan, offering lessons applicable across the similar contexts in the Middle East and North Africa region and beyond.

This remainder of the paper is organized as follows: Section 2 outlines the methods and data as well as the scenarios analyzed , section 3 present the results and discussions and section 5 derives conclusions and research outlook.

2. Methodes and data

a. Model

In this paper, we employ the STAGE2 model (McDonald & Thierfielder, 2015) a single-country, comparative static Computable General Equilibrium (CGE) model, to evaluate the economy-wide impacts of rangeland restoration in Jordan. Using real economic data, the model reconstructs the structure of Jordan's economy and simulates the effects of exogenous shocks by comparing the economy's equilibrium state before and after the restoration intervention.

STAGE2 operates on standard microeconomic principles, where productive activities maximize profits, and consumers seek to maximize utility. Production is represented as a three-level system of nested functions, combining Constant Elasticity of Substitution (CES) and Leontief production functions. At the top level, productive activities integrate aggregate primary production factors (value added) with aggregate intermediate inputs using a CES function. The production factors are further disaggregated within a nested CES structure, while intermediate inputs are combined using a Leontief function. Producers allocate outputs to either local or export markets based on relative prices, employing a Constant Elasticity of Transformation (CET) function. Households contribute production factors (e.g., labor) in exchange for wages, which serve as a primary income source. This income is spent on goods and services, subject to taxes, savings, and the constraints of preferences and income, derived from a Stone-Geary utility function.

As described, over time Jordan's pastoralists have replaced more and more forage from rangelands by (imported) feed grains due to deterioration of the rangeland's productivity. To capture this trend and its reversion, the standard production structure of STAGE2 has been enhanced based on Elnour et al. (2024) to allow for substitution between factors and selected intermediate inputs.

In this study concentrated feed and barley have been moved from the intermediate input arm of the production nest to the value-added nest, allowing for some degree of substitution between these two inputs. Subsequently, the feed composite—formed from concentrated feed and barley—is combined with rangeland resources to create a value-added feed nest. This extension enables the model to account for substitution between different feed types as well as the feed composite and rangelands, with substitution elasticities governing the degree of flexibility between these inputs.

This more flexible setup better reflects the dynamics of pastoralist production systems, while a standard production structure would underestimate the impact of increased forage availability on the demand for concentrated feed, given the assumption of intermediate inputs being consumed in fixed shares, independently from factor as shown in figure 1.

For the closure rules, we assume a fixed exchange rate regime, as the Jordanian Dinar is pegged to the U.S. dollar. The model is saving-driven, meaning investment adjusts to available savings. All production factors are fully employed. The Producer Price Index (PPI) serves as the model's numeraire.

Government savings are fixed, which implies that any changes in policies or expenditure will need an adjustment of government revenue. We model that through an endogenous equiproportional adjustment of direct taxes on households.

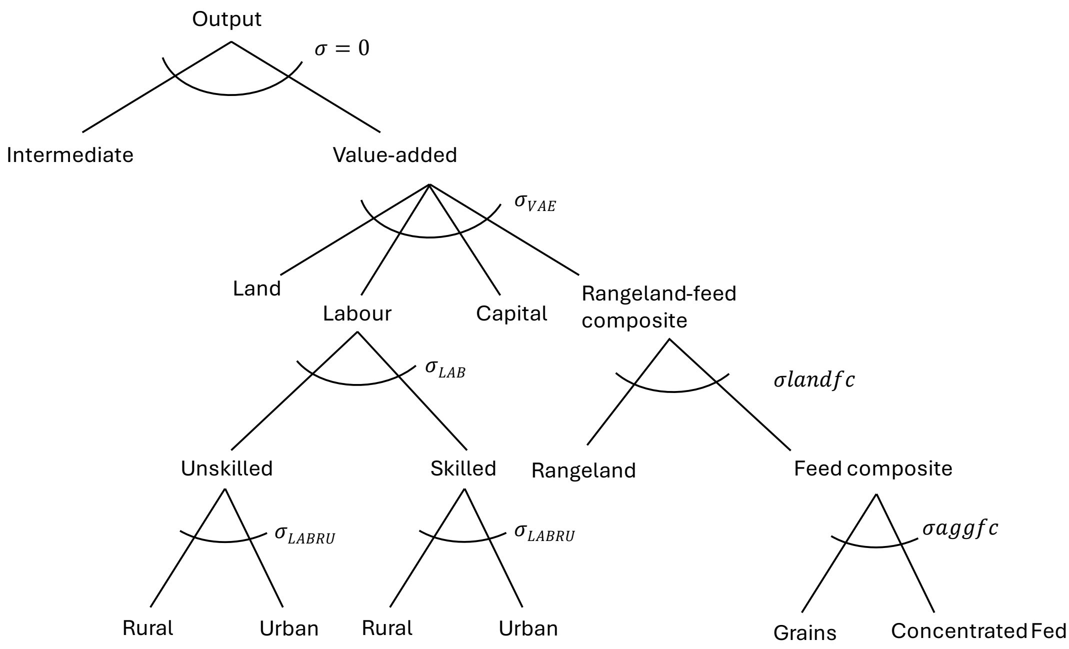

Figure 1: Production nest with rangelands and feed as substitutes

b. Data

i. Jordan IFPRI SAM 2015

The model is calibrated using an extended version of a Social Accounting Matrix (SAM) developed for Jordan by IFPRI (Raouf et al., 2021). This IFPRI SAM, which depicts the Jordanian economy of the year 2015 includes 56 sectors and 62 products. Factors of production are classified into three broad categories: labor, land, and capital. Labor is further disaggregated into eight subcategories based on rural or urban residence and four education levels. Capital is similarly disaggregated into four subcategories: crops, livestock, mining, and others. Our primary focus is to evaluate the impact of rangeland restoration on the Jordanian economy by analyzing changes in the relative prices of production factors and, consequently, the cost of production. However, the IFPRI SAM does not include information specific to small ruminant production or rangelands. To address this gap, we extend the SAM by incorporating relevant data on small ruminants and rangeland activities.

ii. Updating the livestock sector to small ruminants' production sectors and rangelands

In this paper, we are interested in examining the economic impacts of restoring rangelands. We consider rangelands to be an asset that provides an ecosystem service, here pasture, which is used in livestock production. Pasture, as an ecosystem service and production input, is not exchanged on the market and, therefore, is not part of the standard national accounting and social accounting matrices. We make several extensions to the IFPRI SAM to estimate a value for rangelands and link it to the rest of the economy. We start by depicting the economic sectors that are dependent on rangeland pasture. In the case of Jordan, this is the small ruminant sector. We add small ruminant activity and commodity accounts based on information from the 2015 Input-Output tables, the 2017 Agricultural Survey, and the 2013 Household Survey (DoS, 2018).

Secondly, we provide a monetary valuation of the rangelands based on the guidelines of SEEA (System of Environmental-Economic Accounting). SEEA provides a useful framework for incorporating environmental accounting into national accounting. The framework proposes several methods to value grazed biomass as an ecosystem service. We choose the residual value approach, as it is the preferred method and fits the data and context of Jordan. In this approach, we impute the value of grazed biomass from the gross operating surplus, which is the gross output minus payments to labor, capital, and intermediates. The remaining amount provides an estimate of the rangelands' value. In the context of this paper, we apply this approach and deduce the value of rangelands from the gross operating surplus. The value of the rangelands is based on the cost structure of small ruminant production detailed in (Al-Sharafat & Majdalawi, 2005). Since most of the rangelands in Jordan are open access or common resources, we assign ownership of the rangelands to the beneficiaries, in this case, the livestock producers.

c. Scenario design

In this paper, we simulate the impact of restoring rangelands using micro-water harvesting as a specific example. This approach involves capturing runoff water to enhance soil moisture and support vegetation growth, combined with planting seedlings of shrubs. This technique, developed to support rangeland rehabilitation, involves ploughing contour ridges to retain water and improve soil moisture, coupled with planting grazing shrubs. This method can halt the degradation of rangelands and enhance grazing biomass (Strohmeier et al., 2021).

i. Costs

The costs of this technology are detailed in (Haddad, 2021) and include labour, equipment, and plant material. The total cost for establishing this technology have been estimated at $345 /ha. These are solely establishment costs, with no maintenance costs. The success of the experiment is conditioned on sustainable grazing practices and the site being closed off from grazing for two years, such that the shrubs can get established.

ii. Benefits

The experiments conducted by the International Center for Agricultural Research in the Dry Areas (ICARDA) were carried out at a research site in Wadi Mujib, Jordan. These experiments, initiated in 2016, spanned three growing seasons and investigated the effectiveness of a micro-water harvesting technique. This method involves creating soil contours and planting shrub seedlings alongside them. The research team measured several benefits of the micro-water harvesting technique, which collectively contribute to halting land degradation and promoting sustainable agro-pastoral development in arid regions such as Jordan's rangelands.

This paper focuses on the observed increase in grazing forage resulting from this technique. We draw on data from a similar experiment by Abu-Zanat et al. (2020) which reported a significant increase in rangeland dry matter productivity—from 154 to 695 kg/ha—representing a 351% improvement.

Cost and productivity data were calculated for an experiment covering a 10-hectare area. To upscale the costs and benefits, we utilize findings from the ICARDA team's study on the upscalability of this technique across Jordan. Based on a comprehensive multi-criteria analysis, Haddad et al. (2024) concluded that 21% of Jordan's land area is highly suitable for implementing the micro-water harvesting restoration technique with a high success rate. For the purposes of this paper, we apply an implementation level of 30% to project costs and expected forage productivity at scale.

iii. Calculations of the scenarios

According to the experiment design, there is a time lag between the costs and benefits of the experiments. To reflect this difference in the time horizon, we implement our simulation in two scenarios:

1- Short-run Scenario (Invest):

This scenario represents the costs of restoring 30% of the area identified as suitable for restoration. The intervention involves only the establishment costs, as the restoration site will be closed to grazing for two years to allow for regeneration. The long-term success of these interventions depends on the sustainable management of the restored site in subsequent periods.

Using the data provided by Haddad et al. (2024) we calculate the costs associated with restoring 30% of the suitable area. These costs are modelled as an increase in government spending on services required for the establishment phase, including construction, transportation, and seed procurement. The total estimated cost of the intervention is 17 million JD, equivalent to 19 million USD.

2- Med-run scenario (Rangprod):

This scenario illustrates the increase in forage productivity two years after the implementation of the restoration interventions. According to Abu-Zanat et al. (2020), the micro-water harvesting experiment demonstrated a 351% increase in rangeland productivity. For this analysis, we consider 30% of this increase, corresponding to a simulated 105% increase in rangeland productivity.

3. Results and discussion

We conducted analyses of two scenarios: the "Invest" and "Rangprod" scenarios. However, due to the relatively modest scale of the required investments—19 million JD, equivalent to 0.3% of total government expenditure in 2015—the economy-wide impacts of the "Invest" scenario are limited. Therefore, we focus on reporting the results of the "Rangprod" scenario, as it has a more pronounced effect on the economy.

a. Domestic production

The changes in the small ruminant's sector are driven mainly by the cost structure, small ruminant's production benefits from the increase in forage availability as the production costs decrease especially as increased grazing can reduce the use of concentrated feed. The expansion of the small ruminant sector (Figure 2) creates positive upstream multiplier effects in the dairy and meat sectors. Cattle production becomes more expensive as livestock capital becomes more costly, subsequently decreasing the production of milk which is mainly cow-milk in Jordan. The impact on the rest of the productive sectors is relatively marginal in relative terms given the comparatively small share of the small ruminant sector in the economy as a whole. Yet, non-agricultural sectors slightly contract as labor moves into small ruminant production and processing.

The relative small increase of small ruminant production is due to the relatively inelastic domestic demand for food products, resulting in a drop in consumer prices by 1.8%. As Jordan can be considered a small country in terms of small ruminant production, exports do not face a falling demand curve and hence expand overproportionate by 7%,

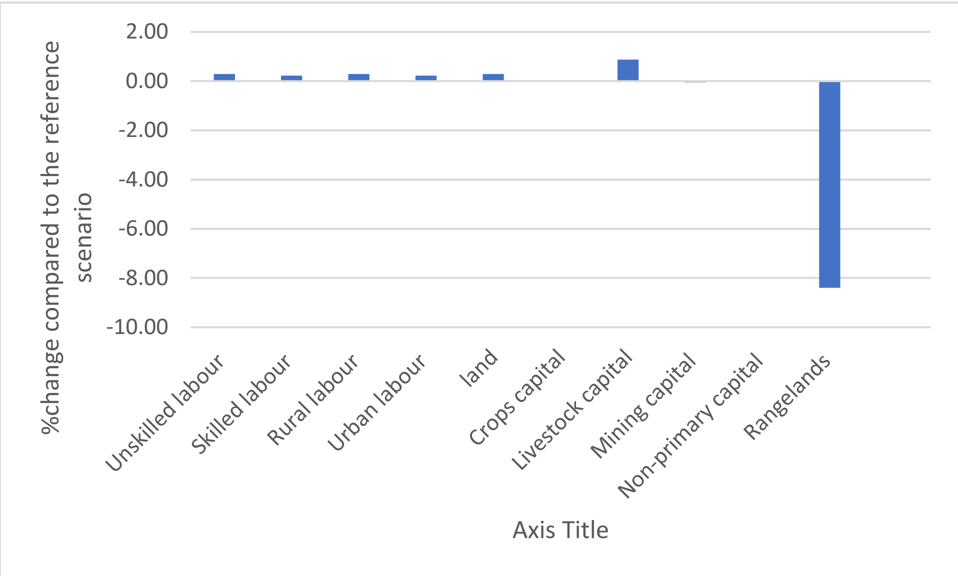

Figure 2.. Changes in output – Rangprod scenario

b. Factor prices

After the restoration period, rangeland prices exhibit a noticeable decline once the restored rangelands can be used for grazing again (Figure 3). This decline can be attributed to the increased productivity of rangelands, which enhances forage output per unit area. The resulting increase in rangeland supply exerts a downward pressure on its price, thereby reducing the implicit rent/ income associated with the right to use these lands.

Conversely, the expansion of the livestock production (Figure 2) leads to a rise in the rent of complementary production factors such as livestock capital employed within this sector. With production expanding demand for livestock-related equipment (breeding stock, barns, other equipment) increases. Furthermore, labor wages, as well as rents of non-livestock capital and agricultural land, experience marginal increases. These changes are largely the result of both immediate and multiplier effects stemming from the growth of the livestock sector. As these production factors are used in a wider range of activities, the positive income effect is more diluted. Non-agricultural capital prices marginally decline because the expansion of small ruminant production triggers a movement of labor out of non-agricultural sectors, which hence contract slightly (Figure 3).

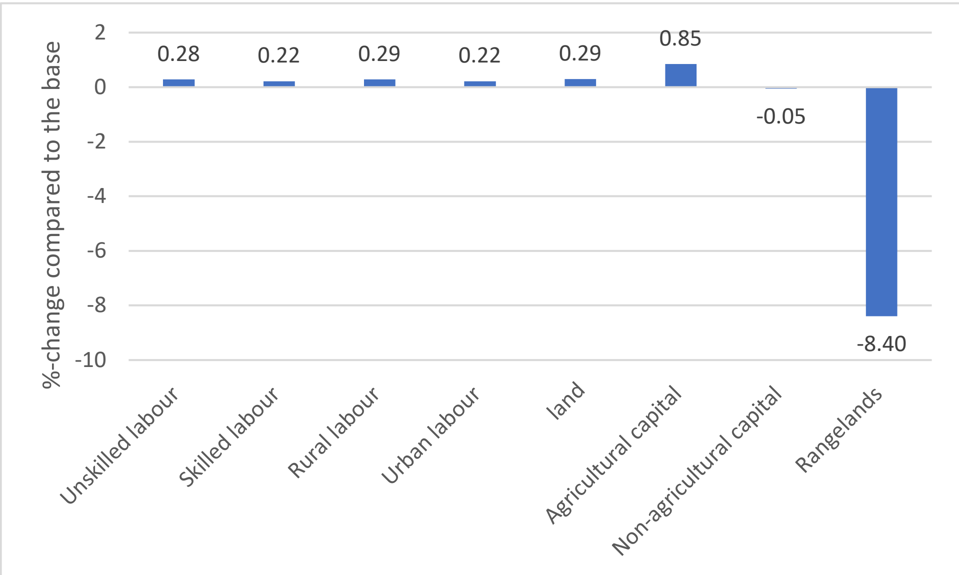

Figure 3. Changes in factor prices – Rangprod scenario

c. Household welfare

Changes in factor markets significantly influence household welfare by altering income distribution. Overall, rural households, which rely more heavily on labor, experience greater welfare gains from rangeland restoration. This improvement is driven by increased demand for rural labor resulting from the expansion of small ruminants, meat, dairy, and poultry production.

In contrast, urban households see less pronounced welfare changes, with some even experiencing welfare losses. For instance, households in Urban Quintile 5 suffer a decline in welfare due to reduced income (Figure 4), primarily caused by a decrease in crop capital rents, which account for 7% of their total income.

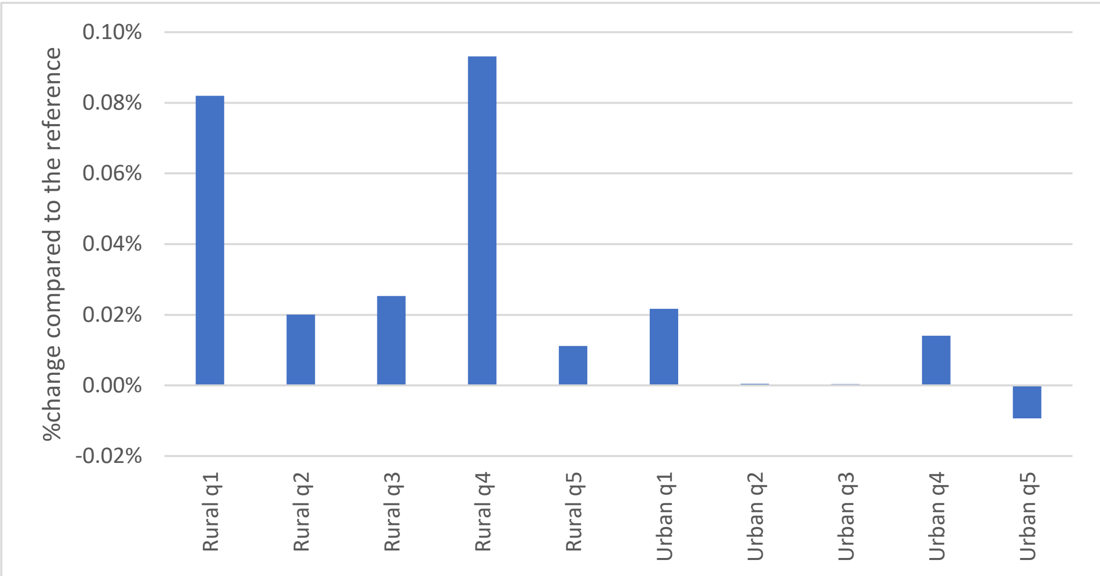

Figure 4: Change in Equivalent variation as % of base household expenditure

d. Macroeconomic effects

Overall, the restoration process contributes to an increase in household consumption, primarily driven by higher household incomes. Exports also rise, led by the expansion of small ruminants, dairy, and milk exports. However, the growth of the small ruminant's sector necessitates greater imports of barley and concentrated feed, which results in an overall increase in imports. The restoration has a positive impact on the economy, with GDP increasing slightly by $1.3 million USD (figure 5).

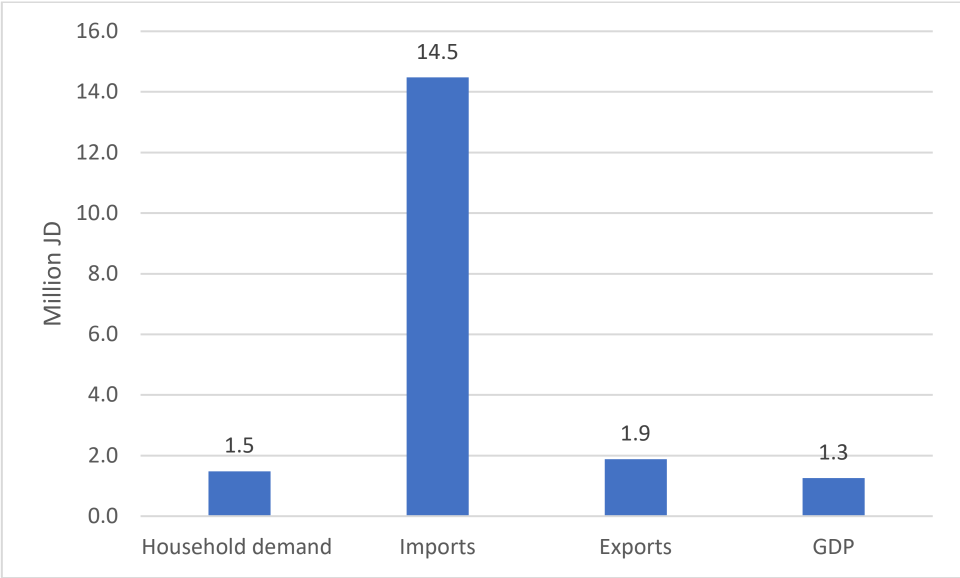

Figure 5: Changes in macroeconomic indicators compared to the base

1. Discussion and Conclusions

This study highlights the economic implications of rangeland restoration by weighing the associated costs and benefits. While the findings emphasize the gans to rural households and the labor market, particularly for the rural poor, it is critical to contextualize these results within a broader policy and economic framework.

The results indicate that rural households, especially those relying on labor income, are among the primary beneficiaries of rangeland restoration. Increased demand for rural labor, driven by the expansion of livestock production, contributes to improved welfare for these communities. This suggests that rangeland restoration policies could play a pivotal role in reducing rural poverty and fostering inclusive economic growth.

From a cost-benefit perspective, the restoration investments, while modest relative to total government expenditures, yield substantial benefits in terms of increased household welfare and GDP growth. However, the associated costs to the government, including subsidies and potential short-term trade deficits, must be weighed against these benefits. Furthermore, the analysis likely underestimates the total value of restoration, as long-term benefits and gains from improved ecosystem services are not fully accounted for.

In conclusion, rangeland restoration represents a promising environmental investment with the potential for substantial economic and social returns.

2. Limitations and further research needs

This analysis provides valuable insights into the economic impacts of rangeland restoration as an example of environmental investment. However, there are several limitations that must be acknowledged, and opportunities for further research that could enhance the robustness of the findings.

The analysis could benefit from more granular data on households and labor employed within the rangelands and small ruminant's sector. Disaggregated household data would enable a deeper understanding of the welfare impacts on different socio-economic groups, especially those most closely involved in or reliant upon small ruminant production. Additionally, more detailed labor data would allow for a better assessment of employment dynamics and income distribution effects within the sector.

The current analysis does not account for improvements in other ecosystem services that may result from rangeland restoration, such as enhanced biodiversity, carbon sequestration, and recreational opportunities. These omitted benefits mean that the overall economic and social value of restoration is likely underestimated. Future research should aim to incorporate these broader ecosystem service benefits into the evaluation framework to provide a more comprehensive understanding of the impacts.

The analysis focuses on short- to medium-term economic impacts and does not fully capture the potential long-term benefits of rangeland restoration, such as sustained increases in productivity, resilience to environmental changes, and reduced degradation costs.

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