Impacts of an increase in irrigated agricultural land on the Beninese economy

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Executive summary

- According to the PAG 2021-2026, it is planned to increase the irrigated agricultural area in Benin by 50,000 ha until 2026.
- We analyze the economy-wide implications of this expansion of irrigated cropland including the investments required.
- We find that the expansion of irrigated cropland has positive multiplier effects throughout the Beninese economy, results in economic growth and can achieve a pro-poor distribution of welfare effects.
- Thereby the distribution of the land property and use -rights under the newly developed irrigation schemes is crucial from a welfare perspective.

Impacts d'une augmentation des terres agricoles irriguées sur l'économie béninoise

Résumé

- Selon le PAG 2021-2026, il est prévu d'augmenter la superficie agricole irriguée au Bénin de 50 000 ha à l'horizon 2026.
- Nous avons analysé les implications économiques de cette expansion des terres agricoles irriguées, y compris les investissements nécessaires.
- Nous avons constaté que l'expansion des terres agricoles irriguées a des effets multiplicateurs positifs sur l'ensemble de l'économie béninoise, qu'elle entraîne une croissance économique et qu'elle peut entraîner une répartition favorable aux pauvres des effets sur le bien-être.
- Ainsi, la répartition des droits de propriété et d'utilisation des terres dans le cadre des nouveaux programmes d'irrigation est cruciale du point de vue du bien-être.

1. Background

- Agriculture in Benin is to a large extent extensive and comprises substantial subsistence production (DRG-MAEP 2016).
- Crop production is largely rainfed, which means that yields are highly dependent on precipitation and thus are uncertain. With climate change rainfed crop yields are even expected to decline.
- One solution under discussion is the expansion of irrigation schemes, as irrigated land has a higher productivity compared to rainfed land due to a) higher and more stable yields and b) potentially multiple harvests (depending on crop type).
- By 2019, only about 25,000 ha (FAO, 2023) (0.6% of the total crop land in Benin) was equipped for irrigation.
- The Beninese government plans to increase the irrigated agricultural area in Benin by 50,000 ha until 2026 (PAG 2021-2026, 2021) which would be tripling the irrigated agricultural area, raising the share of irrigated land to 1.7%.
- The total irrigation potential for Benin has been estimated at 375,000 ha (DRG-MAEP, 2016).
- The total investment costs for increasing the agricultural area to 50,000 ha have been estimated at 805 Billion FCFA, as detailed in Table 1 below.
- It is planned that after the construction of irrigation schemes, the government will leave their management to cooperatives. Farmers will only pay a low contribution per ha, which is supposed to be the water cost and this money will be used for maintenance. Therefore, the irrigation systems are supposed to be self-sufficient in the long run.

Table 1: Estimated costs for developing 50,000 ha of irrigated cropland [Billion FCFA]

Cost items	Mapping to sectors in database (SAM)	Total	Annualized
Research/study	Education, Health and non-Commercial Services	10	2
Control	Other Services	45	9
Construction	Construction	750	150
TOTAL		**805**	**161**

Source: Author's compilation based on Dossouhoui (2023) and expert estimates.

2. Methods

2.1 Database

We use an updated 2019 Social Accounting Matrix (SAM) based on Kinkpe et al. (2022) and national accounts published by INStaD (2022) and additional data from DSA-MAEP (2022a, 2022c, 2022d). The two labour categories (skilled and unskilled) are disaggregated according to gender. Capital is disaggregated into agricultural and non-agricultural and land is

disaggregated into irrigated and non-irrigated. Households are disaggregated into rural poor and non-poor as well as urban poor and non-poor.

With respect to irrigation, according to the SAM, four crop types are grown on irrigated land and irrigated land has a higher productivity compared to rainfed land as it a) produces higher yields and b) allows for multiple harvests for most crops as detailed in Table 2. Irrigated land is owned to 60% by enterprises, the remainder is split among household groups, with rural non-poor households owning the second largest share (17%; compare reference situation in Table 5).

Table 2: Per hectare land productivity ratio between rainfed and irrigated land

	Maize	Rice	Veg.& spices	Other food crops (potato, beans, groundnuts)
Productivity ratio due to multiple harvests	2.00	2.00	3.00	1.00
Productivity ratio due to yield increase	1.11	1.24	1.77	1.63
Total productivity factor of irrigated land	2.23	2.48	5.32	1.63

Source: Author's calculation based on DSA-MAEP (2022b).

2.2 Model and closure rules

We use the computable general equilibrium (CGE) model STAGE (McDonald and Thierfelder 2015). A CGE model combines economic theory and numerical models to establish the impact of shocks in an economy. Real economic data is used to fit a set of equations that replicate the structure of the economy. From this framework, it is possible to simulate the effect of exogenous shocks, such as policy changes, including economy-wide interactions. The following presents a summary of the CGE model used:

- Production is structured by a three-level nest of Constant Elasticity of Substitution (CES) and Leontief production functions. At the top level, aggregate value-added, and intermediate inputs are combined using a CES function. Production factors are aggregated using CES functions at different levels, whereas the intermediate input component is aggregated using a Leontief production function (the second level). Aggregate primary factors (i.e., labour and land) are combined using CES functions (the third level).
- Producers sell their products either in the local or foreign markets, based on relative prices, as determined by a Constant Elasticity of Transformation (CET) function.
- Households supply production factors to productive activities through factor markets in exchange for wages that constitute a significant portion of their incomes. After paying taxes and making savings, households spend their income on purchasing products. Households maximise their utility subject to Stone-Geary utility functions, selecting the optimal mix of commodities and services while considering purchase prices, preferences, and income constraints.

We assume a very high substitutability between rainfed and irrigated land for those crops which are grown on both land types. Due to the higher yields and potentially multiple harvests, the productivity of irrigated land is assumed to be much higher compared to rainfed land as detailed in Section 3.2.

As Benin uses a currency pegged to the Euro with a fixed parity, we apply a fixed exchange rate regime and flexible trade balance (deficit) closure. The model is savings-driven. Government savings are fixed and the household tax rate is flexible. Therefore, any policy change implemented in the model is financed through equiproportional changes in household income tax rates.

2.3 Scenarios

We run three scenarios differentiated according to the time-horizon considered. Simulation results are compared to the reference situation, representing the Beninese economy of 2019 as depicted in the SAM (see section 3.2).

- **Short-run scenario (Invest):** This scenario represents the phase of developing the additional irrigation schemes. In accordance with the PAG 2021-2026 (2021), it is assumed that the investment period is 5 years and that the costs are distributed equally over the years (Table 1). The benefits from the additional irrigated area are assumed to only materialize after this period.
  In this simulation, the full costs are borne by the government, which finances the additional expenditure through a uniform, multiplicative increase of the household income tax rates. This way, this scenario allows to capture and single out the economic effects of the investments required for expanding the irrigation capacity as indicated in the PAG 2021-2026 (2021).

- **Medium-run scenario (IrrigMed):** This scenario shows the effects from expanding the irrigated cropland on the Beninese economy under the following assumptions.
  - The additional land is sourced to 80% from unexploited areas (e.g. rangelands) and 20% from rainfed land.
  - The ownership of the newly irrigated land is distributed only among private households and according to their shares of irrigated landownership in the base situation (Table 3).
  - The expenditure for the additional water required when expanding irrigated crop production is captured by adjusting the intermediate input consumption of the respective cropping activities, increasing the share of water expenditure in total intermediate consumption at the same rate as the increase in irrigated land. This reflects the assumption that the farmers benefitting from the irrigated land will be in charge of maintaining the irrigation scheme once it is established.

Table 3: Ownership distribution of the newly irrigated areas

Household group	%-share
Rural & poor households	29.9
Rural & non-poor households	43.2
Urban & poor households	4.0
Urban & non-poor households	22.9

Source: Author's calculations based on the 2019 SAM for Benin.

- **Long-run scenario (IrrigLong):** As a potential assessment, we additionally run a long run scenario going beyond the current planning horizon in which an additional 305,600 ha (a total 81.5% of the total irrigation potential) are exploited.

2.3.1 Land availability and ownership

While the irrigated land supply in the medium and long run scenarios strongly increases, assuming that 80% of the newly irrigated land is taken from unused land reserves/rangelands and only 20% have been previously rainfed cropland, both scenarios would only result in a very minor relative decline of rainfed cropland (Table 4).

Table 4: Percent-change of land availability

	Invest	IrrigMed	IrrigLong
Irrigated land	0.0	203.1	1241.5
Rainfed land	0.0	-0.2	-1.1

Source: Author's calculations.

Under the assumption that all the newly developed land will be owned by households according to their original land-ownership shares, this would mean that all households in the medium run would own about 6 times as much irrigated land as in the reference situation and even 14.6 times as much in the long-run (compare Table 5).

Table 5: Distribution of irrigated land ownership [ha]

		Reference	IrrigMed	IrrigLong
Irrigated land	Rural & poor households	2,950	17,910	94,390
	Rural & non-poor households	4,250	25,840	136,180
	Urban & poor households	390	2,400	12,630
	Urban & non-poor households	2,260	13,710	72,250
	Enterprises	14,770	14,770	14,770
	TOTAL	24,620	74,620	330,220
Rainfed land	Rural & poor households	943,910	940,920	925,620
	Rural & non-poor households	1,361,810	1,357,490	1,335,420
	Urban & poor households	126,300	125,900	123,860
	Urban & non-poor households	722,520	720,230	708,520
	Enterprises	2,310,590	2,310,590	2,310,590
	TOTAL	5,465,130	5,455,130	5,404,010

Source: Author's calculations.

3. Results

3.1 Factor prices

Throughout the construction period (Invest-scenario), especially wages of skilled labour drop by close to 2%, while the price of non-agricultural capital increases slightly (Figure 1). The latter is caused by the expansion of the construction sector (compare section 4.2), which is capital intensive. The former results from a reduced consumption expenditure especially of urban non-poor households, who suffer from a loss in disposable income due to the required tax increase to finance the construction of the irrigation schemes (section 4.3).

In the medium run, all wages slightly increase due to the expansion of labour-intensive crop production. With the expansion of highly productive cropland, land rents decrease especially for irrigated land but also for rainfed land, due to the assumed high substitutability between land types.

In the long-run, the effects of the medium term are similar in direction but amplified, due to the much larger increase in irrigated land.

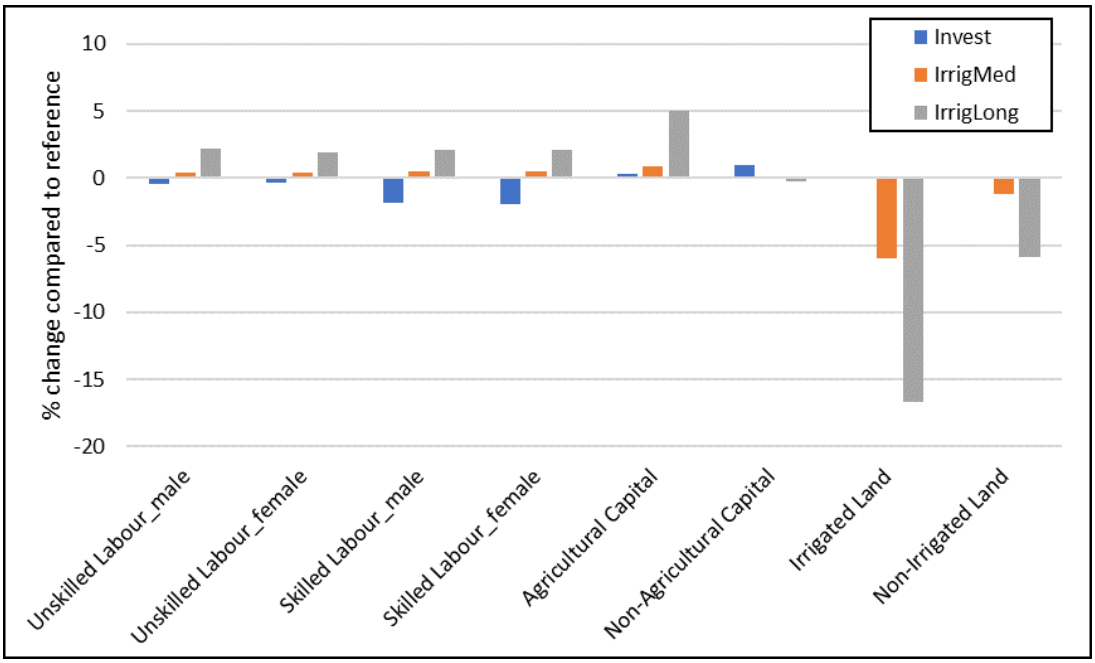

Figure 1: Effects on factor prices, % change compared to the reference scenario

Source: Author's calculations based on simulation results.

3.2 Domestic production

In the investment period, due to the increased demand for construction by the government, especially this sector expands (Figure 2). As construction consumes 44% of mining and 12% of "Water and other industries" outputs, these sectors grow as well. Due to the declining demand from non-poor households (see section 4.4) especially the service sectors are contracting.

With the establishment of the irrigation schemes (IrrigMed), especially the production of land intensive crops expands (rice, cashew cotton). Thereby also crops with a high export share which are not necessarily grown on irrigated land profit (e.g. cashew and cotton), due to the drop in the price of rainfed land (see section 4.1) and the stable producer prices being not much affected by declining domestic prices with expansion of supply. The expansion of crop production also results in positive multiplier effects in the processing industry.

Interestingly, the overall provision of "Water, Other Artisanal and Modern Industries" is falling despite the increasing demand for water from irrigated agriculture. This is because of the low share of water in this aggregate, being dominated by the high share of this aggregate demanded as investment goods. Investments in turn are slightly falling due to lower income of enterprises and a reduced capital inflow from the rest of the world (see Section 4.4). This is also the reason for the slight decline of the construction sector, while this in turn provokes a contraction of the mining sector.

Long-run impacts are similar in terms of direction as the medium run effects (IrrigMed), yet at a much higher magnitude. For representational reasons, they are not depicted in Figure 2.

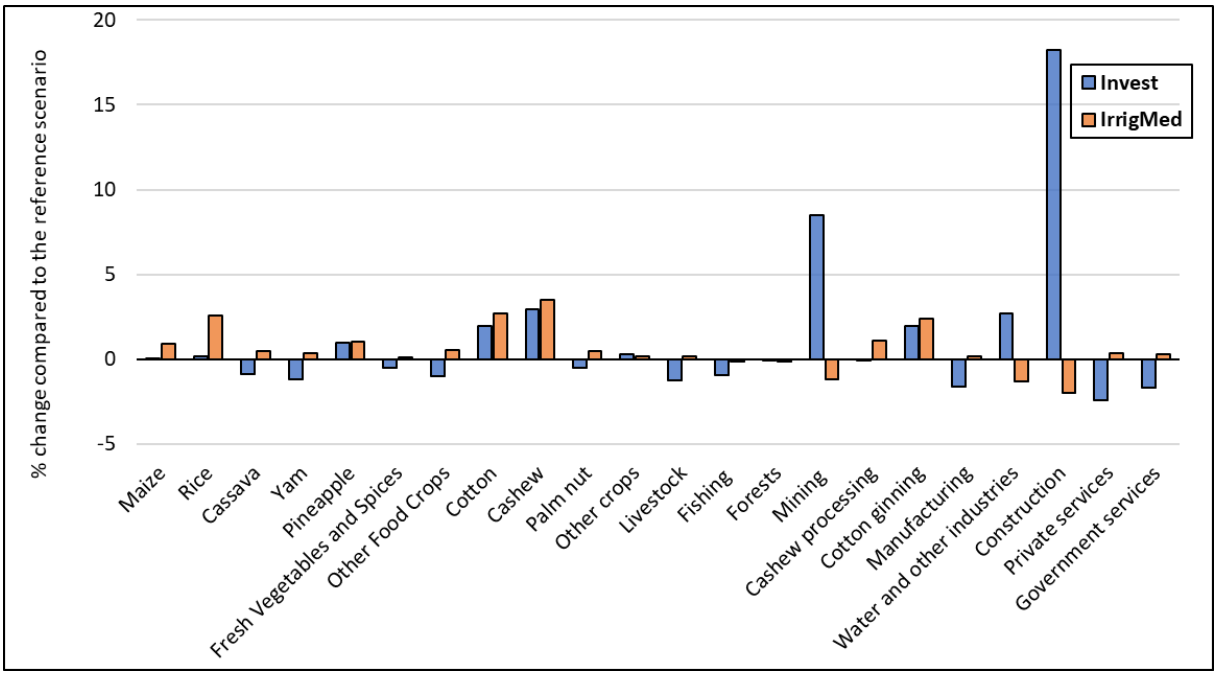

Figure 2: Effects on quantities of domestic production, % change compared to the reference scenario, partially aggregated sectors

Source: Author's calculations based on simulation results.

3.3 Household welfare

As the required irrigation investments are financed through an income tax increase, levied equiproportionally on non-poor households, during the investment period income taxes need to be increased (Table 6). After the investment period, they can be reduced (close to) reference rates again. Tax-rates do not fall back to the reference tax rates completely, as because of an increase of prices of services consumed by the government caused by the overall growth of the economy, a higher government income is needed compared to the reference situation.

Table 6: Income tax rates [%]

	Reference	Invest	IrrigMed	IrrigLong
Rural & poor households	0.0%	0.0%	0.0%	0.0%
Rural & non-poor households	0.4%	0.9%	0.4%	0.4%
Urban & poor households	0.0%	0.0%	0.0%	0.0%
Urban & non-poor households	2.6%	6.5%	2.7%	2.8%

Source: Author's calculations based on simulation results.

As can be seen in Figure 3, during the construction period especially urban non-poor households experience welfare losses, as they on the one hand contribute most to the financing of the irrigation investment and on the other hand experience income losses, due to the reduction of skilled labour wages. Poor households are mainly affected by the lower unskilled wages (compare Figure 1).

With the irrigation-expansion established (IrrigMed), all households benefit. Thereby, rural poor households experience the highest welfare gains, followed by urban poor households. This effect is even enhanced with a larger irrigation expansion (IrrigLong). These positive effects are mainly driven by the increased household income, which in turn is caused by higher factor income from the additional irrigated land (which in relative terms contributes most to the household income of rural and urban poor households) and unskilled (male) labour, being more demanded with expanding crop production. Also, a drop in agricultural prices benefits mainly poor households with a high food expenditure share.

3.4 Macroeconomic effects

In the investment period, government consumption is increasing due to the additional outlays for building the irrigation schemes. As these outlays are financed through increasing income taxes on households, private household consumption drops by almost the same amount (Figure 4).

The trade balance turns more negative in the investment period, mainly driven by the increased demand for “Water and other industrial goods”, of which about half is sourced from abroad. This change in the trade balance results in additional funds being available for investment, as the capital balance compensates for the trade balance. Overall, this leads to an increased absorption.

After the establishment of the irrigation schemes, with government demand falling back to the reference situation, household demand is increasing, due to the raised household income and

relatively stable consumer prices. Also, exports expand, mainly driven by the increased exports of ginned cotton, leading to a more positive trade balance (and hence less capital inflow from the rest of the world).

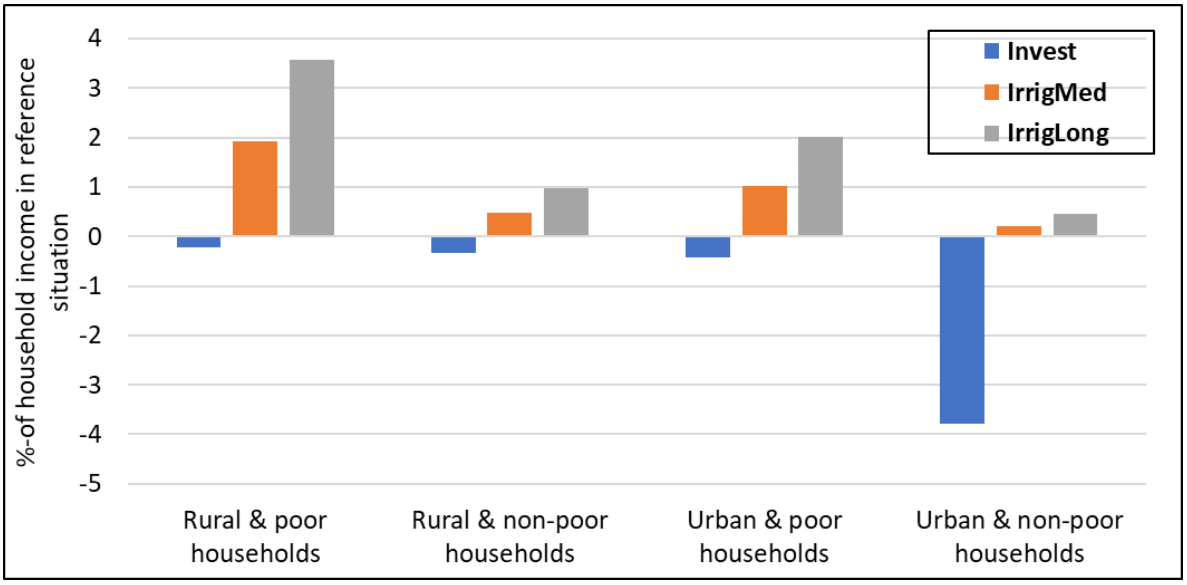

Figure 3: Effects on household welfare, Equivalent Variation (EV) as a share of household expenditure in the reference scenario[1]

Source: Author's calculations based on simulation results.

Altogether, this leads to a positive impact on gross domestic product, increasing by about 0.14% (about 11 Billion FCFA) in the investment period and in the medium term and even more with a further expansion of irrigated cropland in the longer run.

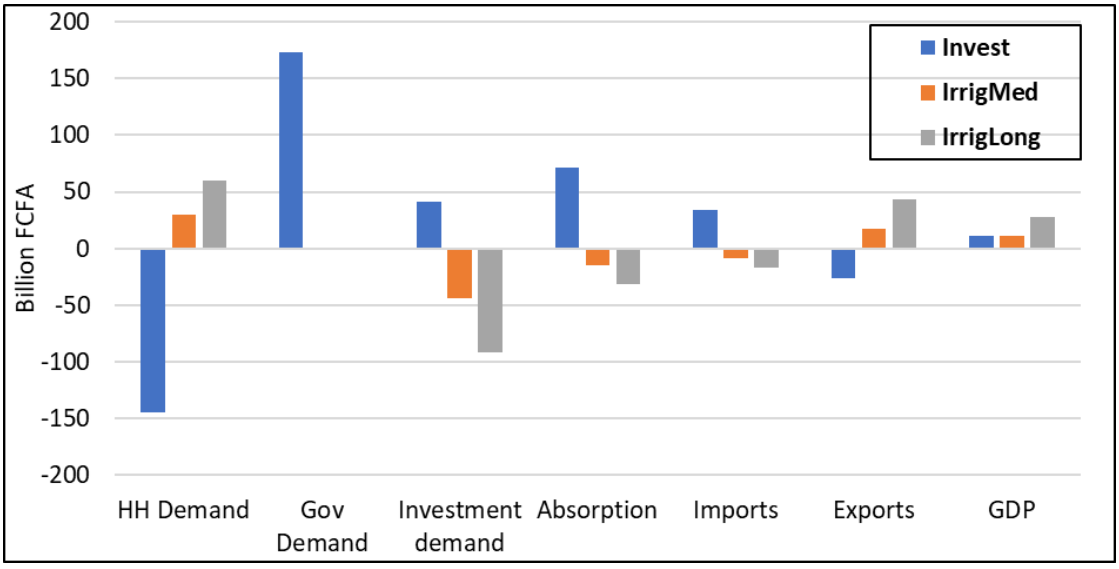

Figure 4: Change in macroeconomic indicators compared to the reference situation in Billion KES

Source: Author's calculations based on simulation results.

[1] Equivalent variation (EV) refers to a change in income that would have an equivalent effect on utility as all price and income changes combined.

4. Conclusions

This analysis shows that the expansion of irrigated agriculture in Benin has positive impacts on the economy and on the welfare of households once the additional irrigation schemes are established.

The financing of the irrigation schemes in this analysis is to 100% sourced from domestic households. As shown, this results in losses of household welfare, especially to those households which contribute most to the funding (in this analysis, with an equiproportional increase in direct tax rates, these are the urban non-poor households).

The analysis shows that the expansion of irrigated agriculture can result in a pro-poor distribution of welfare gains. A crucial factor for the distribution of welfare effects, however, is the allocation of the property and use-rights of the additional irrigated land among institutions. A sensitivity analysis shows, that if the newly irrigated land was distributed according to the distribution in the reference situation (60% belonging to enterprises), the overall welfare gains for households would be much smaller and welfare impacts would be even negative for poor rural households, as 64% of the additional enterprise income is invested and 24% goes to owners abroad, while only 6% to mainly non-poor domestic households, leading to much lower multiplier effects.

The benefits of developing additional irrigation schemes do not only stem from the expansion of irrigated agriculture but also from rainfed agriculture, profiting indirectly from the increased availability of highly productive irrigated land. Also, multiplier effects in downstream and upstream sectors as well as an increased household demand for services and other commodities contribute to the overall positive economic effects. A sectoral analysis would miss these implications.

With respect to gender, men may profit slightly more than women, as more men are employed in crop production, where the demand for labour and hence wages increase. However, more crucial in this respect will be how the ownership of the newly irrigated land is to be distributed among sexes.

Potential adverse environmental implications of increasing the agricultural area, e.g. on water resources, are not considered in this study. Also recall that in this study 80% of the newly irrigated area are converted former rangelands, which may have negative implications in terms of carbon release, biodiversity loss and ecosystem services. In fact, it has been estimated that up to 248 tons of CO2 are emitted from turning one hectare of African savanna-land into crop land (West et al., 2010; Searchinger et al., 2015). Yet, authors also found that turning sparsely vegetated areas into irrigated croplands could also result in more carbon storage (West et al, 2010).

Considering climate change, the benefits of expanding irrigation would even be higher, as rainfed production will be negatively impacted and under irrigation yields are more stable.

5. Policy implications

In order to achieve a balanced economic growth and to especially support women and young people in the agricultural sector as emphasized in the PAG 2021-2026 (2021), the government

needs to put in place mechanisms for those population groups as well as for poor households to have overproportionally access to the newly irrigated land.

Raising some of the funds needed for financing the irrigation schemes from international organizations/donors and the private sector (enterprises) as foreseen in the PAG 2021-2026 (2021), would take away some of the negative impacts on household welfare during the construction period. The invest-scenario thus can be interpreted as an upper limit of the negative effects due to the need for raising funds for the irrigation expansion. In order to build more irrigation schemes as simulated in the IrrigMed-Scenario, the investment period would need to be prolonged.

Converting rangelands to irrigated cropland has the potential to strongly decrease the soil carbon stock. Therefore, the government may consider accompanying measures to compensate for the carbon loss, for example through the establishment of agroforestry systems.

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