The Macroeconomic Impacts of Climate Change and Adaptation Measures in Georgia

Application of the e3.ge Model to Investments in Natural Windbreaks for Adapting to the Impact of Extreme Winds

Summary

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Between 2020 and 2021, the Economic Analysis and Reforms Department of the Georgian Ministry of Economy and Sustainable Development (MoESD) developed in collaboration with GIZ and GWS a macroeconomic model, the e3.ge model, to provide scenarios of macroeconomic impacts of climate change and adaptation measures.

This briefing note presents an example of application of the e3.ge model with a focus on investments in natural windbreaks to adapt to the impacts of extreme winds on crop yields in the context of climate change in Georgia.

It describes the five key steps that are required for applying the model: from (1) clarifying the objectives for running the model, to (2) establishing a reference scenario, (3) establishing scenario(s) with climate change impacts, (4) establishing scenario(s) with investments in investments in adaptation measure(s), and (5) comparing the scenarios for results. In sharing this example, we aim to clarify the data and information required for running the model, the assumptions made, and some possible results.

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GWS SPECIALISTS IN EMPIRICAL ECONOMIC RESEARCH

Step 1: Clarifying the objectives for running the e3.ge model

In its present form, the e3.ge model is set up to provide scenarios of macroeconomic impacts of single climate change hazards and of single adaptation measures in Georgia.[1]

In this example, the model is used to answer the following two questions:

- What are the macroeconomic impacts of wind erosion on Georgia's crop yields in the context of climate change?
- What are the macroeconomic impacts of investing in natural windbreaks to adapt to the negative impacts of extreme winds on crop yields in the context of climate change?[2]

Based on a reference scenario (step 2), the e3.ge model calculates two different types of scenarios to evaluate the economy-wide effects of climate change hazards and adaptation measures: a scenario with climate change impacts (step 3) and a scenario with climate change impacts and investments in climate adaptation (step 4).

Step 2: Establishing a reference scenario

The **reference (baseline) scenario** explores the question 'What could the macroeconomic development of Georgia look like in the future without climate change and climate change adaptation?'. This scenario extrapolates the economic relationships observed in the past into the future and does not explicitly include consideration of climate change and climate adaptation for the future. However, the economic database contains past climate change impacts as they are implicit in the statistics. This reference scenario serves as a basis for other scenario analyses.

Ideally, the reference scenario should be updated (recalculated) on **an annual basis** to reflect the most recent economic development and forecasts of the country.

In 2021, a reference scenario was calculated (Flaute et al., 2022[3]) for the period 2022-2050 based on the data and information sources listed in Table 1.

[1] "Single" refers to the effects of individual climate hazards/adaptation measures instead of looking at the effects of a combination of climate hazards/adaptation measures. The latter could be calculated by the model depending on the data and information available. Data and information on the combined effects of climate hazards and/or adaptation measures must be available (e.g., effects of the joint implementation of windbreaks and irrigation systems on crop yields). In addition, including multiple effects (e.g., combining different climate hazards and/or adaptation measures) makes it difficult to identify where the economy-wide effects originally come from.

[2] Additional information on the example of windbreaks for adapting to climate change in Georgia can be found in: Flaute, Banning, Lutz (2020): Economy-wide Effects of Adaptation in Agriculture. Sectoral policy brief. On behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Bonn and Eschborn, Germany.

[3] Flaute, Reuschel, Lutz, Banning, Hohmann (2022): Supporting climate resilient economic development in Georgia – Application of the e3.ge model to analyze the economy-wide impacts of climate change and adaptation. On behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Bonn and Eschborn, Germany.

Table 1: Data and information used for building the 2021 reference scenario

Data and information	Data sources	Assumptions/remarks
■ Macroeconomic data: ○ GDP ○ Imports/Exports ○ Price information of goods and services ○ Consumption of goods and services (of households, of government) ○ Gross fixed capital formation ○ Employment	■ Geostat. (2021). National Accounts of Georgia 2020. Tbilisi: National Accounts Department of National Statistics Office of Georgia. ■ Geostat. (2021). Statistical Yearbook of Georgia 2021. Tbilisi: National Statistics Office of Georgia	■ The model calculates on an annual basis and extrapolates historical time series data into the future. ■ The model only captures the Georgian economy in detail.
■ Annual national input-output tables [IOT] (sectoral data) provide information on the economic relationships between suppliers and producers in the national economy. ○ IOT data help to answer the following questions: what inputs does sector X need from other sectors to produce its outputs? (incl. what is imported by sector X to produce its products); where do all the products from sector X end up? (households, government, export, import)	■ IOT calculated based on MoESD's supply and use tables (2017, 2018, 2019)	■ Constant relationship between inputs and output assumed (e.g., inputs would have to double if output doubled). ■ No constraints on productive capacity (the supply of factor inputs is perfectly elastic).
■ Economic growth forecast: expected growth rates for important economic variables ○ Expected growth rates (in %) of GDP, volume of exports of goods and services, volume of imports of goods and services for the years 2019 – 2025 ○ Population forecasts by 2050	■ International Monetary Fund (IMF) website. 2021. World Economic Outlook Database. ■ MoESD's internal near-term up to 2025 forecast data. ■ United Nations website. World population prospects 2019.	■ The IMF's near-term (up to 2025) forecast data was used as a time series to compare the model with.

The 2021 reference scenario was based on the following assumptions:

- According to the 2019 UN population forecast for Georgia, the population and the number of employed persons continue to decline until 2050. Thus, a significant improvement in productivity by 2050 is assumed so that more can be produced with the same or even reduced labour input to meet the high targets of the economic growth forecasts.
- The increasing demand for energy will be met. The assumptions regarding energy supply and demand are a strict continuation of past developments and the status quo of today.

Step 3: Establishing scenario(s) with climate change impacts

The **scenario with climate change impacts** aims to explore the question 'What could the macroeconomic development of Georgia look like in the future with the impact of a specific climate change hazard?'.

This scenario is based on the reference scenario and contains additional assumptions on the economic damages and losses caused by climate hazards (e. g., the destruction caused by heavy precipitation, effects of extreme heat on labour productivity). Data and information of past climate hazards and their economic impacts serve as a benchmark.

In its present form, the model can calculate scenarios with climate change impacts looking at a single macroeconomic effect of a single climate hazard (e.g., the effects of extreme winds on crop yields) or looking at various macroeconomic effects of a single climate hazard (e.g., the effects of extreme wind on crop yields, infrastructure, electricity production). The model has not calculated a scenario that contains all impacts of multiple climate hazards at once (e.g., impacts of drought, extreme winds, and extreme precipitation). This calculation would require additional assumptions on the interlinkages between the impacts, since the simultaneous occurrence of extreme winds and precipitation has compounding and cascading impacts on, for example, crop yields. In other words, the impact of simultaneous climate hazards is different than just the sum of the impact of each climate hazard. Climate scientists first need to understand these interlinkages.

In this example, a scenario is developed on the effects of extreme winds on crop yields in the context of climate change in Georgia for the period 2022-2050. Table 2 summarises the types and sources of data and information that can be used to develop such a scenario.

Table 2: Example of data and information used for building the scenario with the impacts of extreme winds on crop yields in the context of climate change in Georgia

Data and information	Data sources	Assumptions/remarks
Past extreme wind events and economic impacts		
▪ Occurrence of past storms/strong winds and recorded monetary damages from storms/strong winds: ○ Reported overall monetary damages in million GEL for extreme wind events for the years 1995 to 2020: GEL 119 million in total during that time; average damages per year is GEL 5 million	▪ TBSC Consulting. (2020). Data Collection Support in Georgia on Climate Change Effect Damages. Damage Data Summary Report. GIZ.	▪ TBSC's analysis is based on data collected based on desk research and stakeholder consultations (mostly insurance companies and government agencies, and in particular the National Environmental Agency) ○ Based on TBSC consulting's analysis, it is understood that the categories of damages from strong wind are very similar to those of heavy rain (this is not assuming the same damages in monetary terms).

▪ A Frequency and intensity of past extreme wind events o Figure of the average extreme wind speed values in the historical period (m/s) o Map of the spatial variability of the evolution of extreme wind for the period 1976-2005, and time series of extreme winds yearly evolution at specific locations o The average annual growth rate for the number of extreme wind events under the RCP8.5 scenario is 0.1% in total for Georgia between 1980 and 2005, and 0.2% between 2006 and 2020.	▪ Navarro, J. S. & Jorda Sanchez, G. (2021). Report on the climate hazards analysis for Georgia. GIZ.	▪ No data and information were found on past crop loss due to extreme winds in Georgia.
Future occurrence of extreme winds and impacts		
▪ Extreme wind speed evolution (occurrence and frequency) in the 21st century under RCP 8.5 emission scenario and RCP 2.6 emission scenario ▪ Maps showing the average increase/decrease (in %) of the number of extreme wind events per year with respect to the historical period (1976 – 2005)	▪ Navarro, J. S. & Jorda, G. (2021): Report on the climate hazards analysis for Georgia. GIZ.	
▪ The average annual growth rate of the number of extreme wind events is 0.2% in total for Georgia for the each of the following three 30 – year time horizons (2021-30; 2031-40; 2041-2050) ▪ Economy-wide impacts of extreme wind using RCP 8.5 (high emission scenario) for the period 2022-2050 > calculation of a timeseries for future damages	▪ GWS calculations based on data from Navarro, J. S. & Jorda, G. (2021). Report on the climate hazards analysis for Georgia. GIZ.	▪ An increased number of extreme events leads to increased economic damages on a 1:1 basis

To establish the scenario with the impacts of extreme winds on crop yields in the context of climate change in Georgia, the share of crops in the gross output of the agriculture sector in monetary terms was estimated to be approx. 44% (calculations based on the 2017 IOT tables).

The timeseries of future damages of extreme winds on crop yields was calculated based on the following assumptions:

- Annual loss in crop yields of 1.5% due to wind erosion.
- Beginning in 2025, heavy wind is assumed to occur every 5 years, destroying 5% of the crop yield every 5 years.

Step 4: Establishing scenario(s) with investment in adaptation measure(s)

The **scenario with investments in adaptation** explores the question ‘What could the macroeconomic development of Georgia look like in the future (up to 2050) with investments in a selected climate adaptation measure?’.

This scenario contains assumptions on the economic damages and losses caused by climate change hazards and assumptions on one adaptation measure (in this example the focus is on natural windbreaks). This scenario is based on the scenario with climate change impacts.

A scenario with investments in adaptation should be calculated for each adaptation measure separately. If the model is run for different adaptation measures, the results can be used to compare each adaptation measure in terms of their macroeconomic impacts. Potential criteria for determining when to use the model could include: (a) high-cost adaptation measures, such as large infrastructures, and (b) low-cost adaptation measures expected to have high, long-term benefits (e.g., national information campaign). It should be noted that when the cost or benefits of the adaptation measure is low, the macroeconomic impact may not be visible.

As already mentioned about the effects of multiple climate change hazards, additional cost-benefit data from the implementation of combined adaptation measures (e.g., the simultaneous implementation of windbreaks and irrigation systems) would need to be available and accessible and additional assumptions would need to be made to evaluate the macroeconomic impacts of more than one adaptation measures taken together.

In this example, a scenario is developed with investments in natural windbreaks for climate resilient agriculture for the period 2022-2050. Table 3 summarizes the types and sources of data and information used to develop such scenario.

Table 3. Data and information needed for establishing the scenario with investment in climate adaptation (here: natural windbreaks for climate resilient agriculture)

Data and information	Data sources	Assumptions/remarks
■ Estimated costs of adopting windbreaks (in monetary terms): investments in plants, agricultural services, machinery ■ Estimated benefits (in monetary terms): increased crop yield in all years: windbreaks lead to increased crop yields in years without heavy wind (in total, +18%) and reduced damages in years with heavy wind	■ Expert information from the Macrofinancial Modeling and Analysis Division, Financial Stability Department of the National Bank of Georgia ■ Geostat. 2020. Agriculture of Georgia 2019. Preliminary data on plant growing. National Statistics Office of Georgia. ■ Moore, L. (no date.) Economics of Windbreaks. PowerPoint presentation. United States Department of Agriculture. Natural Resources Conservation Service (USDA-NRCS).	■ Data on the costs and benefits of the adaptation measure must be available for setting up the scenario with investments in adaptation. ■ If no country and sector specific data is available, best-practice adaptation options of comparable situations in other countries may serve as an initial indication.

The scenario with investments in natural windbreaks is based on the following assumptions:

- The additional costs associated with the investment in windbreaks is borne 50% by the government and 50% by households.
- The installation of windbreaks requires: (1) growing domestic seedlings, which are produced and planted by local workers, (2) delivering additional agricultural services for planting the new trees, (3) purchasing plastic tubes for tree protection, and (4) installing imported irrigation systems.
- The plastic covers required for planting the windbreaks increase production in the rubber and plastic sector, which is also largely produced domestically.
- Windbreaks lead to increased crop yields in years without extreme wind (in total, +18%) and reduced damages in years with heavy wind

Step 5. Results – Comparing the scenarios

This final step aims to answer the overarching questions 'What are the macroeconomic impacts of wind erosion on Georgia's crop yields in the context of climate change?' and 'What are the macroeconomic impacts of investing in natural windbreaks to adapt to the negative impacts of extreme winds on crop yields in the context of climate change?'.

For each scenario, the model creates a large data set that contains all values for all model variables up to the year 2050. The macroeconomic variables of special interest are:

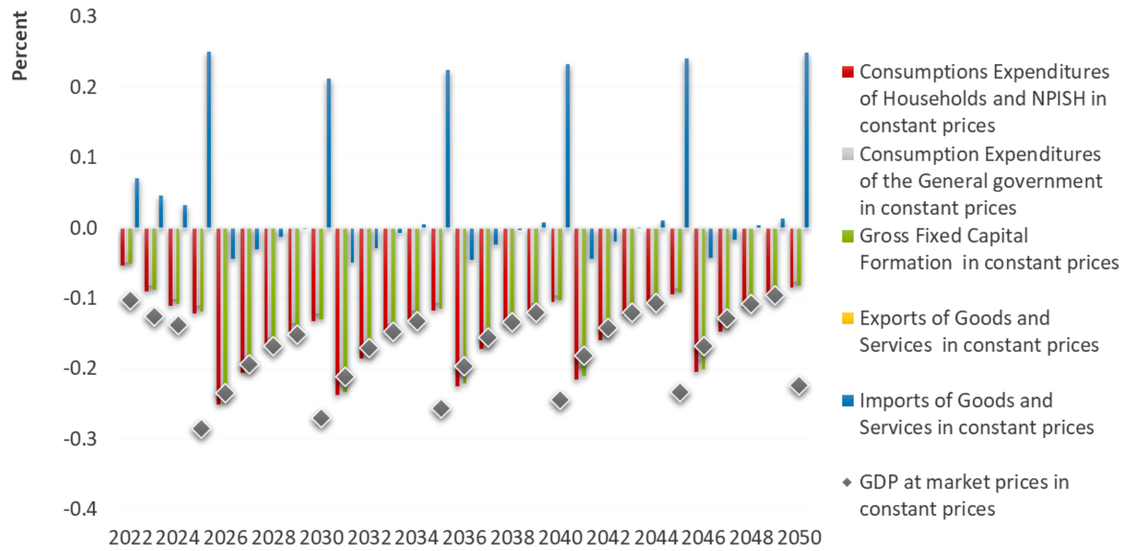
- GDP
- Production activity on sectoral level
- Components of GDP (consumption expenditures of households and government and gross fixed capital formation)
- Employment in total and on sectoral level

The macroeconomic effects of extreme winds on crop yields in the context of climate change can be determined from the absolute or relative difference between the scenario with the effects of extreme winds on crop yields in the context of climate change (step 3) and the reference scenario (step 2).

The key findings #1: Without adaptation, the macroeconomic impact of extreme winds on Georgia's crop yields in the context of climate change for the period 2022-2050 mean:

- **GDP** will decrease by up to 0.3% (see Figure 1).
- **Production** will decline in the agriculture sector and those sectors dependent on agriculture inputs (e.g., food industry, transportation).
- **Consumption expenditures of households and government and gross fixed capital formation** will be negatively impacted. The negative GDP effects in years with heavy wind (e.g., 2045) have a negative impact on consumption and investment decisions in the following years (e.g., 2046-2049).
- **Employment** will decline by over 0.2% in one year due to the reduced production activity in the different economic sectors.

*Figure 1: Macroeconomic effects of the "wind damages on crop yields" scenario (deviations from the reference scenario in percent)**



Source: Flaute et al. (2022)

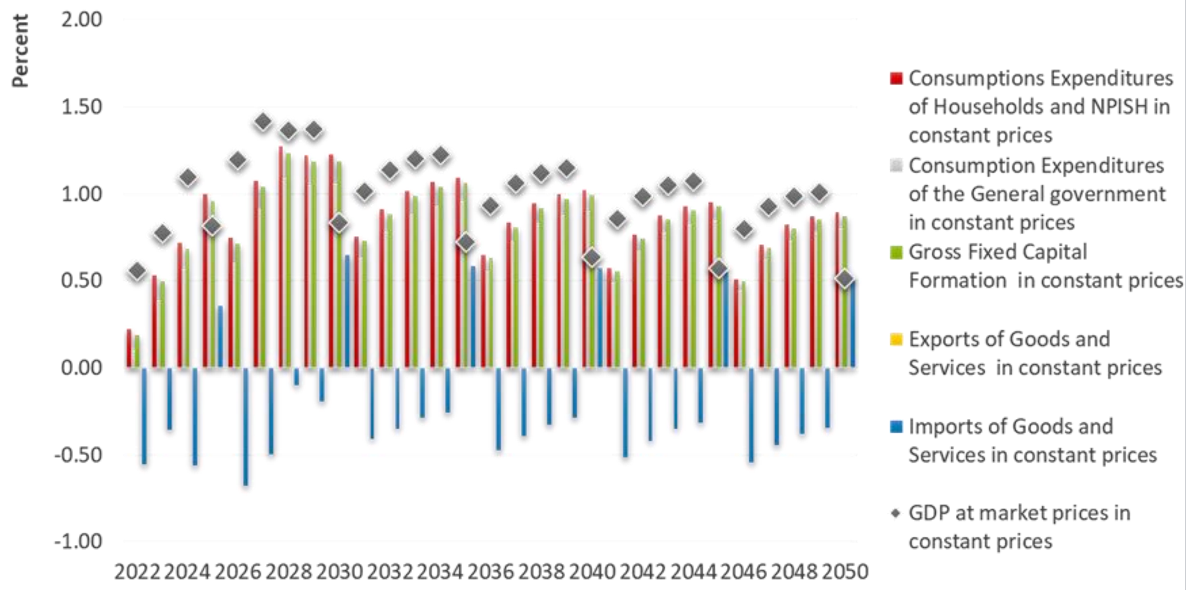
* Note that when comparing the reference scenario with the climate change scenario, negative values do not mean that the macroeconomic indicators (e.g., GDP, imports) are declining, but that they grow less strongly under the climate change scenario.

The macroeconomic effects of investing in natural windbreaks for climate resilient agriculture can be determined from the absolute or relative differences between the scenario with investments in natural windbreaks (step 4) and the scenario with climate change impacts (step 3).

The key findings #2: The macroeconomic impact of investing in natural windbreaks for climate resilient agriculture and for the period 2022-2050 mean

- GDP will increase by up to 1.4% (GEL 1,400 million) in one year (see Figure 2). The increased demand for seedlings calls for a higher production in the agricultural sector, the additional agricultural services increase the production in the respective sector. The greatest economic effects are to be expected from the increased crop yields in agriculture due to the windbreaks.
- Production will increase in the agricultural sector as well as in sectors delivering inputs for the agricultural sector and using agricultural products as an input.
- Consumption expenditures of households and government and gross fixed capital formation will increase. The positive impact on GDP and the economy stimulates additional consumption and investments.
- Employment will increase. The higher production leads to additional employment. In the year 2040, employment is higher in total by 0.35% (6,000 people).

Figure 2: Macroeconomic effects of the "investment in natural windbreaks" scenario from 2022 to 2050 (deviations from the "wind damages on crop yields" scenario in percent).



Source: Flaute et al. (2022)

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