# Integrated Economic-Environmental Modeling (IEEM) for Evidence-Based Public Policy and Investment Design.

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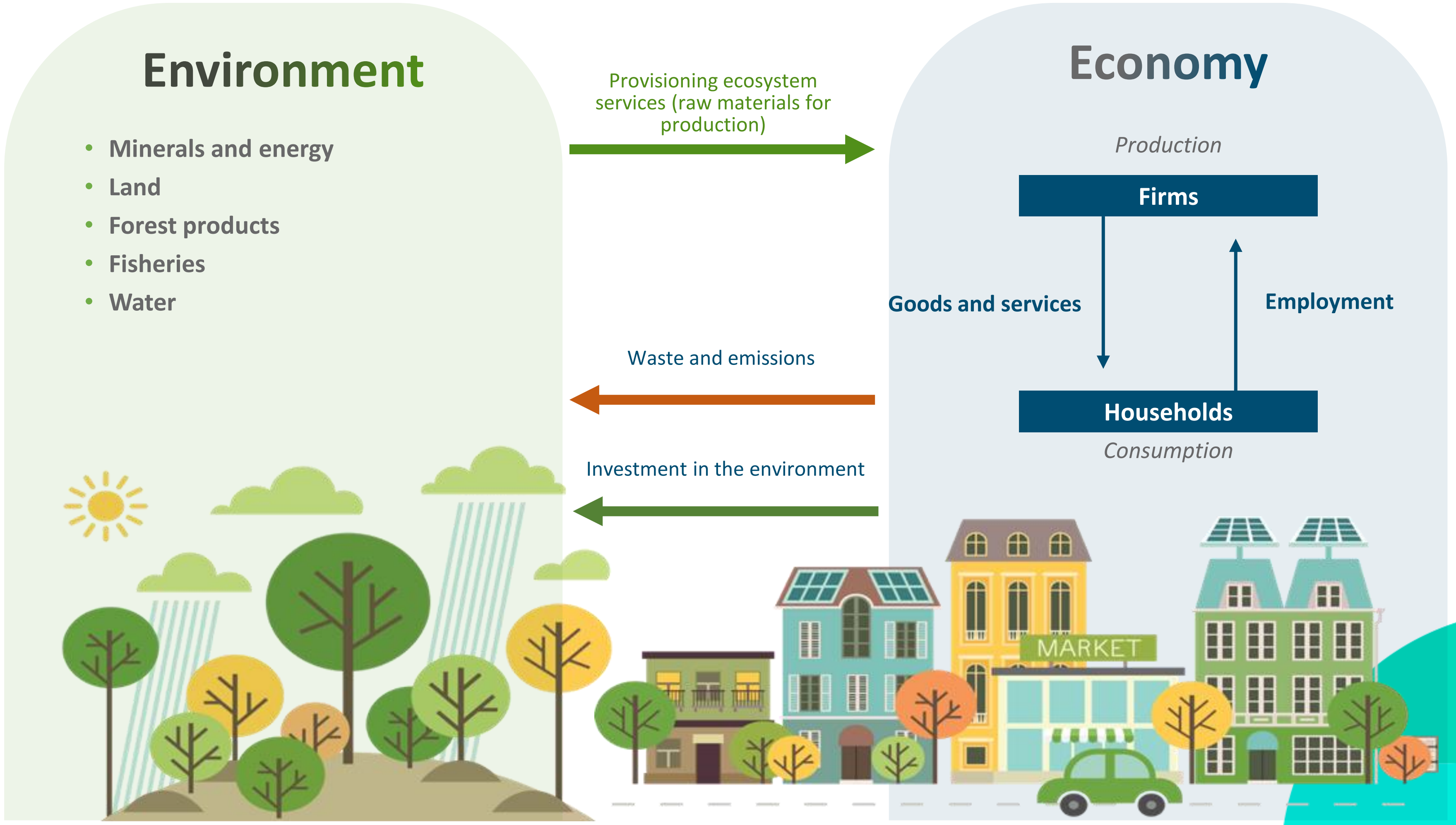
RMGEO Consultants Inc.

# IEEM APPLICATION TO THE SDGs IN GUATEMALA

**Guatemala was the first IEEM application. At the time, Guatemala had the most complete SEEA data and enabled us to pilot its integration in a CGE Model.**

# ECONOMIC-ENVIRONMENT INTERACTIONS IN IEEM



# INVESTING IN THE SDGs IN GUATEMALA

1. **SDG 2: ending hunger, achieving food security, promoting sustainable agriculture.**

- Target 2.3: Double agricultural productivity and income of rural producers.
- Strategy- restore irrigation infrastructure (IRRIG1) and increase irrigated area (IRRIG2). Improved nutrition.

2. **SDG 6: access to water and sanitation for all.**

- Target 6.1: Access to drinking water.
- Target 6.2: Access to sanitation and hygiene.
- Strategy- expand infrastructure and access (WTSN); include health benefits.

**3. SDG 2 and SDG 6.** COMBI.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ELSEVIER

Analysis

Evaluating synergies and trade-offs in achieving the SDGs of zero hunger and clean water and sanitation: An application of the IEEM Platform to Guatemala

Onil Banerjee[a,*], Martin Cicowiez[b], Mark Horridge[c], Renato Vargas[d]

# SDG 2: ZERO HUNGER AND SDG 6: WATER AND SANITATION

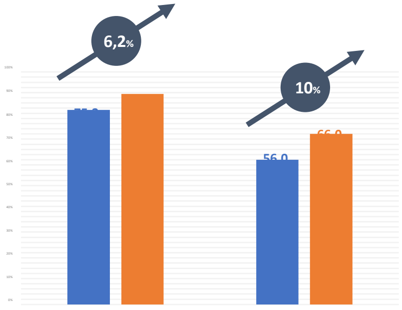
Increase of irrigated area:
**112,798 ha.**

Investment:
**US$7.996 million**

Time horizon:
**5 years**

SDG

**SDG 2, Target 2.3**




Increase water and sanitation coverage by 6.2% and 10% to **81.5% and 66%, respectively**

Investment:
**US$1.607 billion**

Time horizon:
**13 years**

SDG

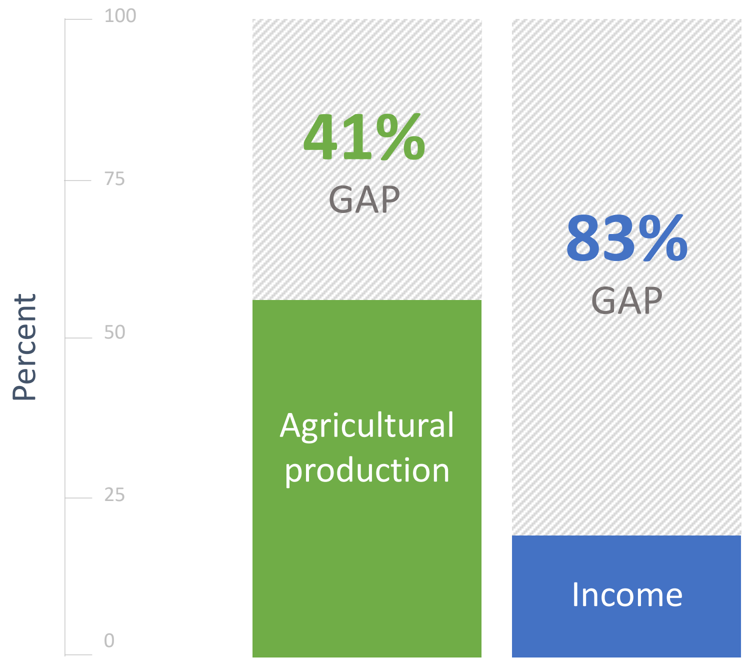
**SDG 6, Target 6.1 and 6.2**

# RESULTS

- 41% and 83% gap remain to double agricultural output and income, respectively. Additional investments in both agriculture and water and sanitation would be required to meet targets.
- Microsimulation: investments increased inequality between urban and poor rural households; greater output of higher value products which used less unskilled labor (which is predominantly rural); 117,000 less poor.
- Net Present Value of US$126.7 million, US$2.1 billion,

-US$718.5 million, and US$1.3 billion for IRRIG1, IRRIG2, WTSN and COMBI, respectively.

- Increase in wealth of over US$595 million (savings vs. negative environmental impacts).



# SYNERGIES AND TRADE-OFFS

## Synergies

Certain lines of action (**2-** Zero Hunger) can contribute to various SDGs: **SDG 1-** Eliminating Poverty, and; **SDG 8-** Promoting Sustainable Economic Development and Employment (increase GDP by US$1.37 billion).

## Trade-offs

Trade-offs: **SDG 2** implies more deforestation, moving away from **SDG 15-** Sustainable Use of Forests. Increased emissions slows progress on **SDG 13-** Action on Climate Change.

Deforestation ↑ 9,820 ha by 2030.

Water consumption ↑ 1,860 ML/capita.

GHG ↑: 642,346 tons $CO_2$.

$CH_4$ and $N_2O$ also reported.

# CONCLUDING REMARKS

- Integration of SEEA enables reporting of indicators in both physical and economic value terms, consistent with SNA (land, water, energy, emissions)
- Integrated approach enables identification of synergies and trade-offs.
- A portfolio approach to investment could be desirable given negative NPV of investment in water and sanitation.

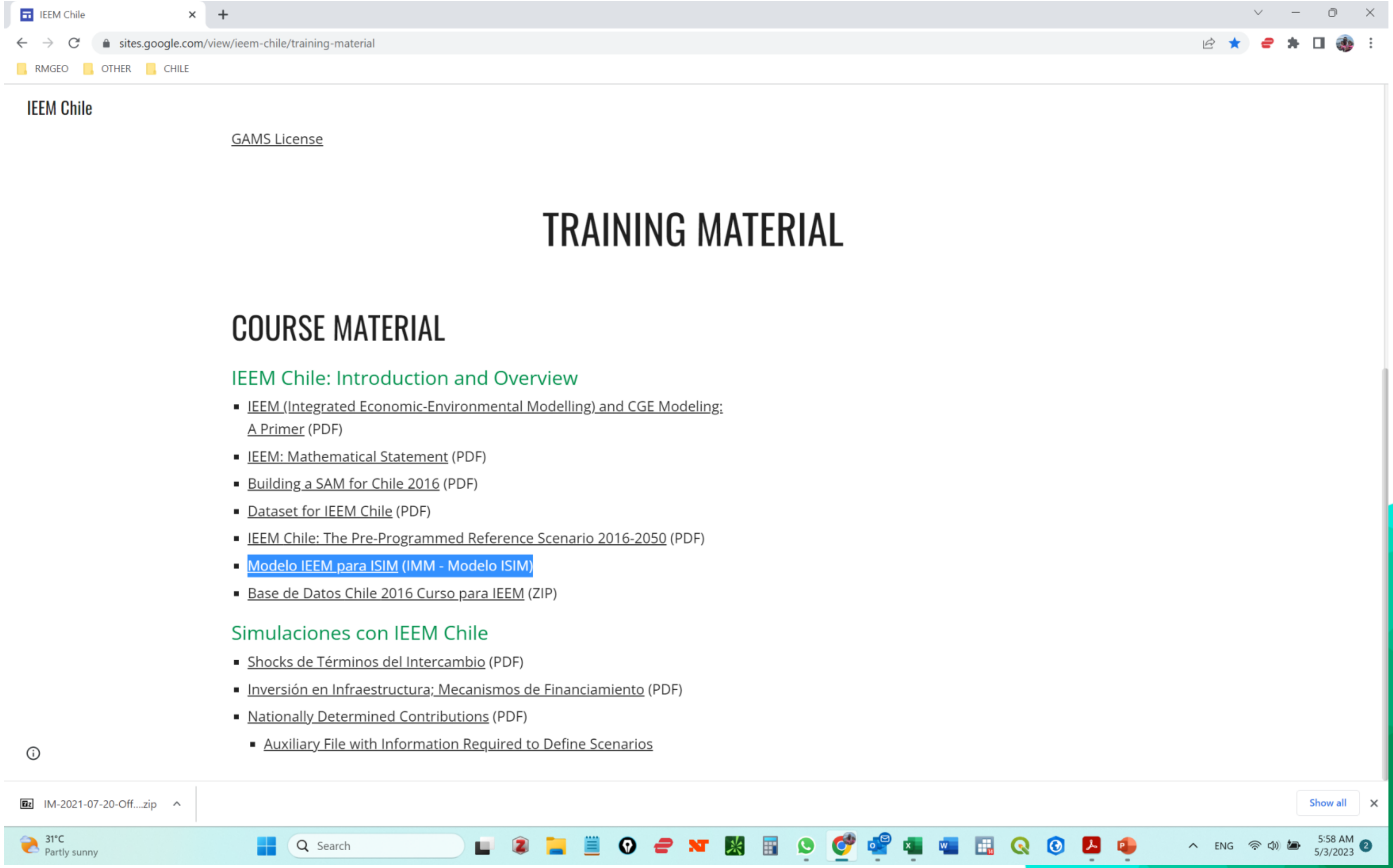

Percent deviation from business as usual.

# OVERVIEW OF APPLYING IEEM

# COURSE MATERIALS

- Access IEEM materials temporarily at:

https://sites.google.com/view/ieem-chile/training-material

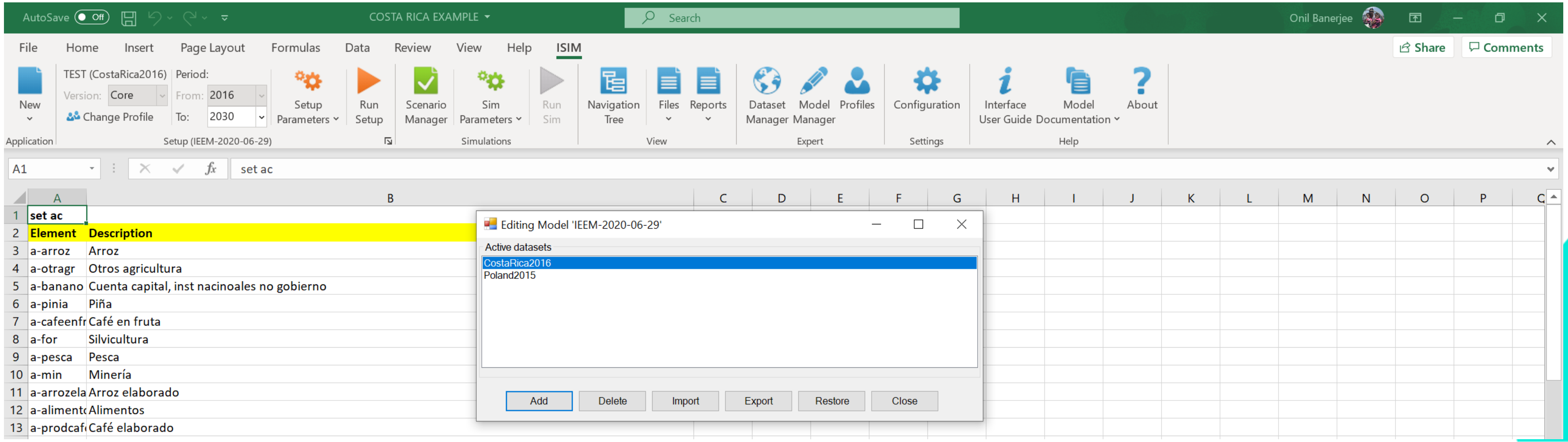


# APPLYING IEEM

- The IEEM model is coded in GAMS as a “standard” model applicable to any country, with a separation between model theory and data used in calibration.
- Excel files contain country data and parameters used to define scenarios.
- Technical Guides; full online training in IEEM at OPEN IEEM. Check it out!

# IEEM-ISIM USER INTERFACE 1

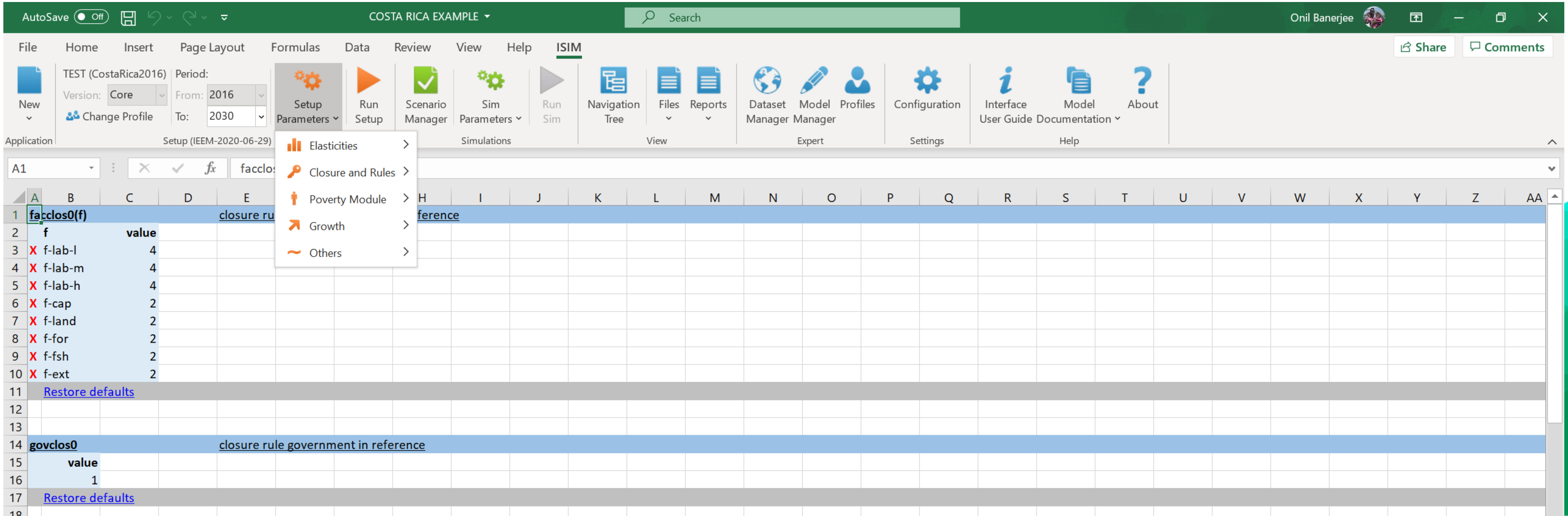
- A user-friendly interface to enable analysts to focus on policy questions and interpretation; no GAMS programming knowledge required.
- Step 1. Install ISIM. Select a model (IEEM) and database; this is a new version of IEEM therefore only Chile2016bc will appear.



IEEM

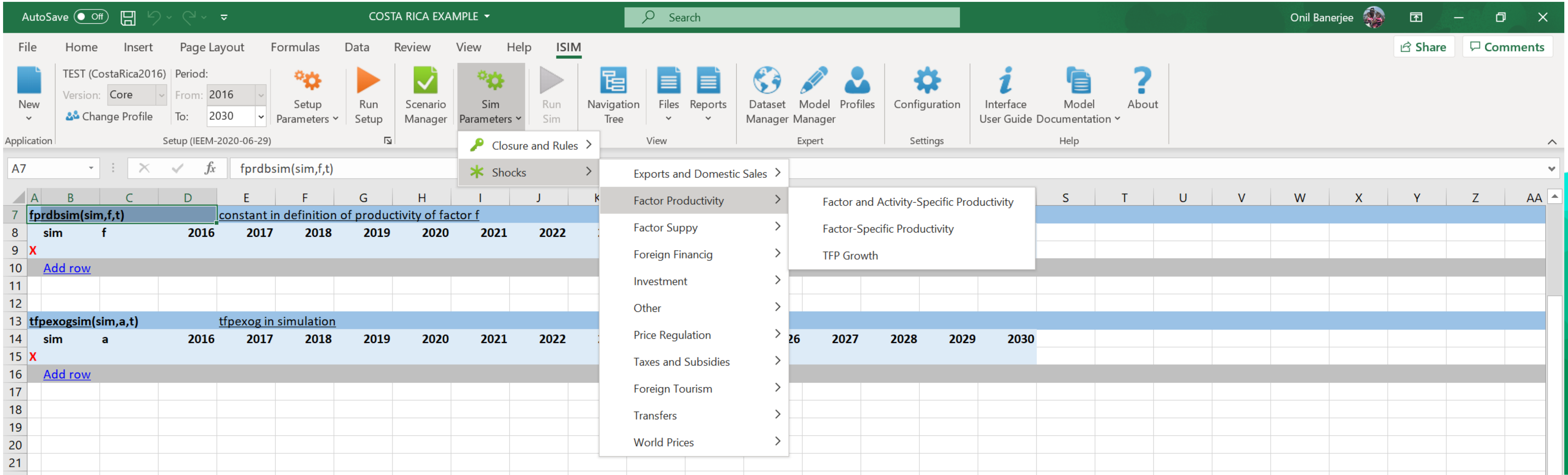
# IEEM-ISIM USER INTERFACE 2

- Step 2. Baseline projection setup. Define period. Set-up parameters: elasticities, closures/rules, growth rates. Run baseline set-up!



# IEEM-ISIM USER INTERFACE 3

- Step 3A. Set-up simulation. Start with a narrative, operationalize in IEEM. For Chile's NDCs, there is some Excel work required to calculate/organize shocks. We will go through this step-by-step.



# IEEM-ISIM USER INTERFACE 4

- Step 3B. Define shocks. Crop Total Factor Productivity.

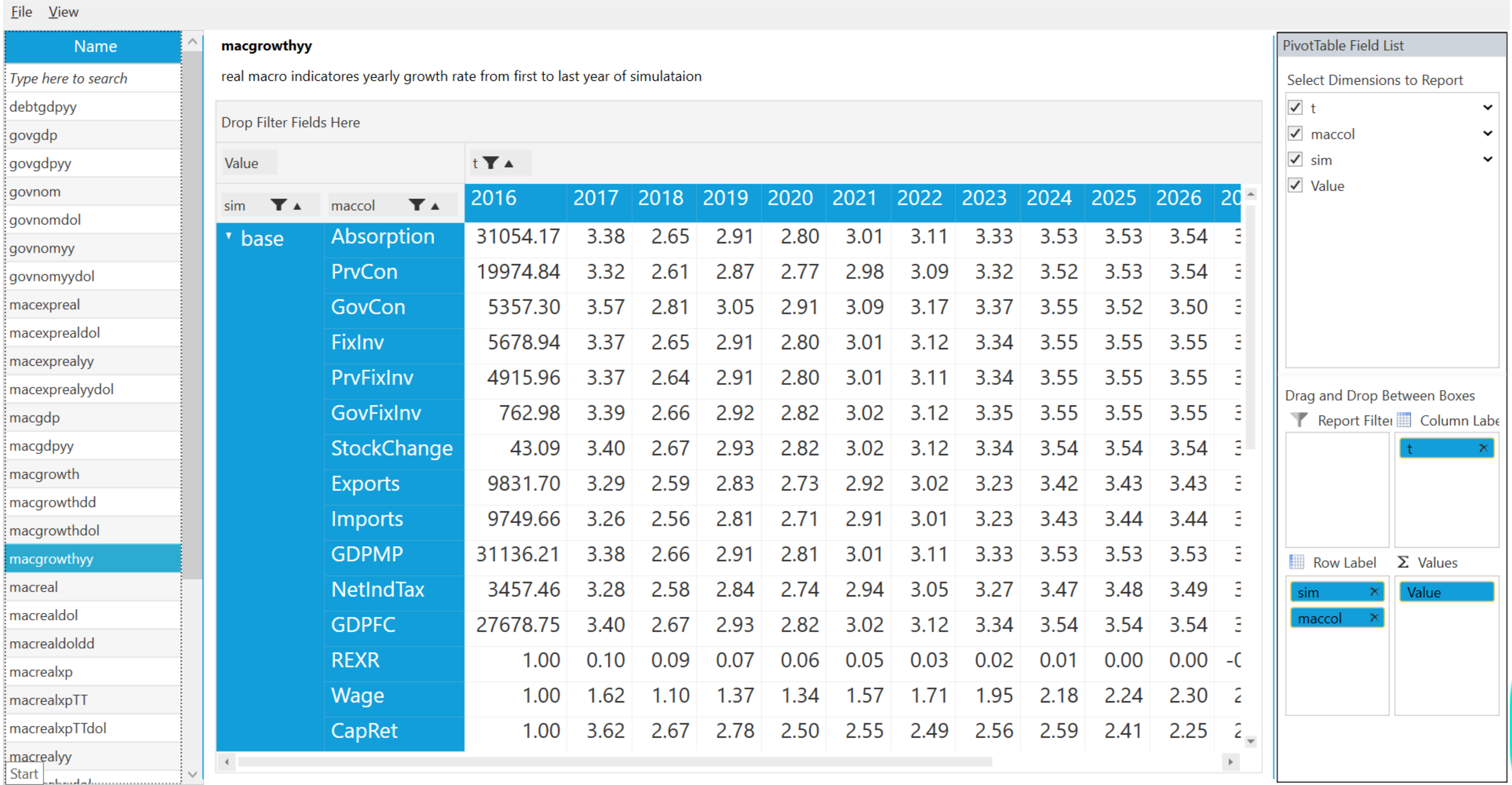
Run simulation!

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | tfpexogsim(sim,a,t) | | | | tfpexog in simulation | | | | | | | | |
| 4 | | sim | a | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2 |
| 5 | X | yield | a-arroz | 1 | 1.0445711 | 1.08702151 | 1.12593439 | 1.16173424 | 1.19478025 | 1.22537841 | 1.25379099 | 1.28024408 | 1.30493 |
| 6 | X | yield | | 1 | 1.00559854 | 1.01085341 | 1.01567038 | 1.02010199 | 1.02419271 | 1.02798041 | 1.03149756 | 1.03477215 | 1.03782 |
| 7 | X | yield | | 1 | 1.03836585 | 1.07363334 | 1.10596188 | 1.13570413 | 1.16315852 | 1.18857924 | 1.21218421 | 1.23416124 | 1.25467 |
| 8 | | Add row | | | | | | | | | | | |

a-arroz
a-otragr
a-banano
a-pinia
a-cafeenfruta
a-for
a-pesca
a-min

# IEEM-ISIM USER INTERFACE 5

- Step 4. Interpret results. Adjust. Rerun. Engage in elevated discourse with government and write beautiful paper.




| sim | maccol | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| base | Absorption | 31054.17 | 3.38 | 2.65 | 2.91 | 2.80 | 3.01 | 3.11 | 3.33 | 3.53 | 3.53 | 3.54 |
| | PrvCon | 19974.84 | 3.32 | 2.61 | 2.87 | 2.77 | 2.98 | 3.09 | 3.32 | 3.52 | 3.53 | 3.54 |
| | GovCon | 5357.30 | 3.57 | 2.81 | 3.05 | 2.91 | 3.09 | 3.17 | 3.37 | 3.55 | 3.52 | 3.50 |
| | FixInv | 5678.94 | 3.37 | 2.65 | 2.91 | 2.80 | 3.01 | 3.12 | 3.34 | 3.55 | 3.55 | 3.55 |
| | PrvFixInv | 4915.96 | 3.37 | 2.64 | 2.91 | 2.80 | 3.01 | 3.11 | 3.34 | 3.55 | 3.55 | 3.55 |
| | GovFixInv | 762.98 | 3.39 | 2.66 | 2.92 | 2.82 | 3.02 | 3.12 | 3.35 | 3.55 | 3.55 | 3.55 |
| | StockChange | 43.09 | 3.40 | 2.67 | 2.93 | 2.82 | 3.02 | 3.12 | 3.34 | 3.54 | 3.54 | 3.54 |
| | Exports | 9831.70 | 3.29 | 2.59 | 2.83 | 2.73 | 2.92 | 3.02 | 3.23 | 3.42 | 3.43 | 3.43 |
| | Imports | 9749.66 | 3.26 | 2.56 | 2.81 | 2.71 | 2.91 | 3.01 | 3.23 | 3.43 | 3.44 | 3.44 |
| | GDPMP | 31136.21 | 3.38 | 2.66 | 2.91 | 2.81 | 3.01 | 3.11 | 3.33 | 3.53 | 3.53 | 3.53 |
| | NetIndTax | 3457.46 | 3.28 | 2.58 | 2.84 | 2.74 | 2.94 | 3.05 | 3.27 | 3.47 | 3.48 | 3.49 |
| | GDPFC | 27678.75 | 3.40 | 2.67 | 2.93 | 2.82 | 3.02 | 3.12 | 3.34 | 3.54 | 3.54 | 3.54 |
| | REXR | 1.00 | 0.10 | 0.09 | 0.07 | 0.06 | 0.05 | 0.03 | 0.02 | 0.01 | 0.00 | 0.00 |
| | Wage | 1.00 | 1.62 | 1.10 | 1.37 | 1.34 | 1.57 | 1.71 | 1.95 | 2.18 | 2.24 | 2.30 |
| | CapRet | 1.00 | 3.62 | 2.67 | 2.78 | 2.50 | 2.55 | 2.49 | 2.56 | 2.59 | 2.41 | 2.25 |

# Developing IEEM Modeling Infrastructure and Capacity Around the World.

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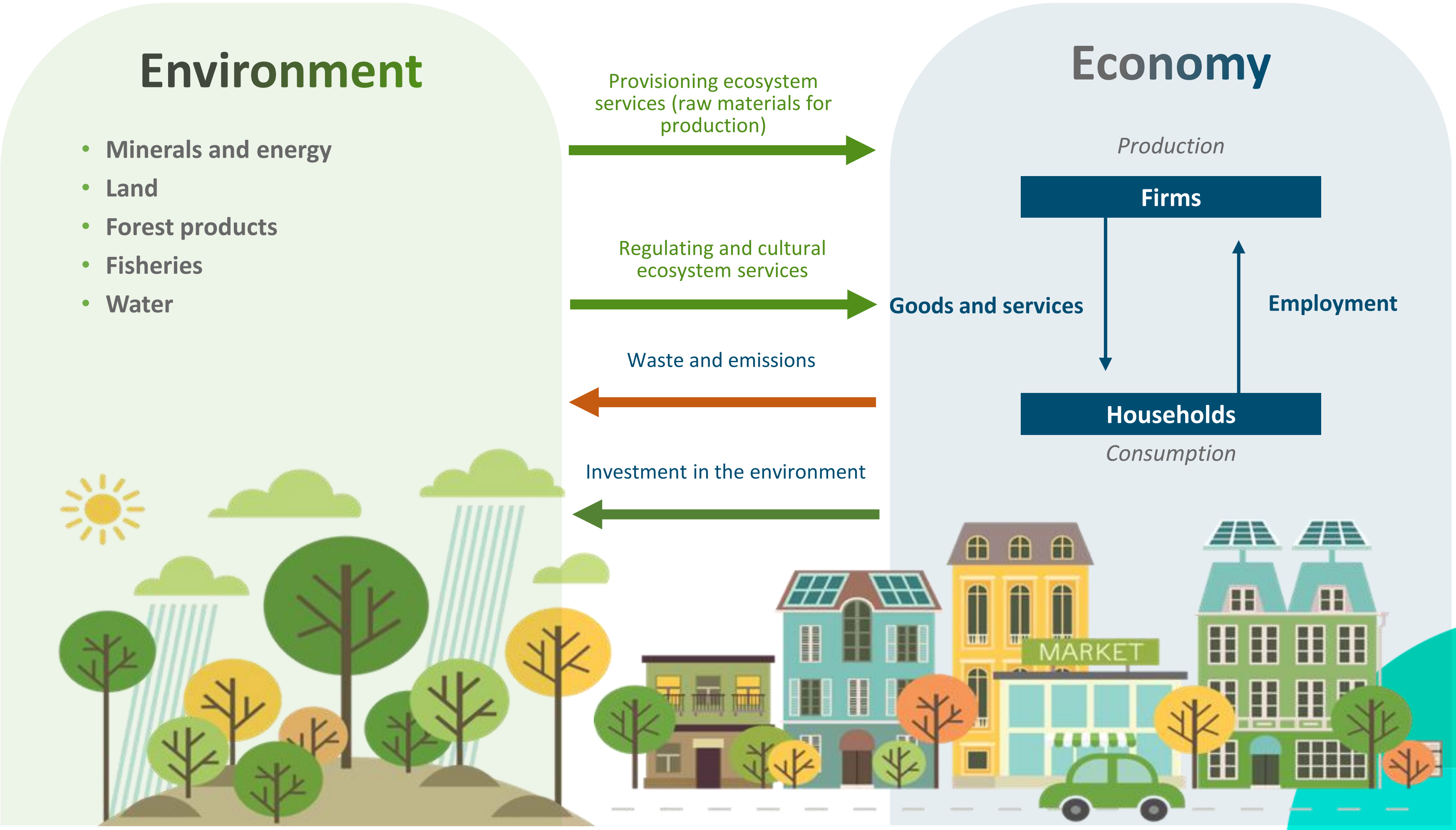
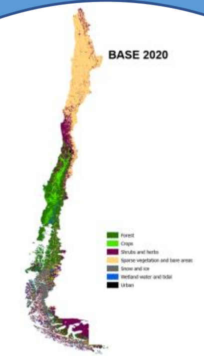
# IEEM+ESM AND CHILE’S NATIONALLY DETERMINED CONTRIBUTIONS

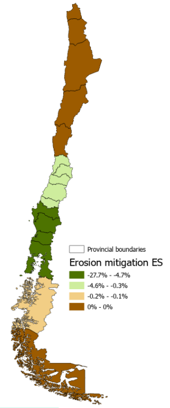
IEEM

# ECONOMIC-ENVIRONMENT INTERACTIONS IN IEEM

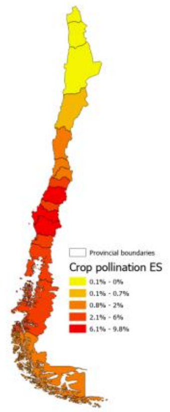


# CHILE'S NDCs AND THE IEEM+ESM WORKFLOW




Policy question: Chile's NDCs → Calibrate IEEM → Run BASE + scenarios in IEEM → Spatially allocate LULC change, **Dyna-CLUE** → Model ES with InVEST and IEEM+ESM data packets


- IEEM, the LULC change model and ES models are iterated to account for agent response to changes in future ES flows.
- An economic value estimate of regulating ES is generated consistent with Chile's System of National Accounts.

# OVERVIEW

- Chile is committed to contributing to limit global temperature rise to 1.5° C.
- Update to its NDCs was developed in parallel to the country's Climate Change Framework Bill to align international commitments with national guidelines and instruments.
- Unconditional goal of reducing emissions to 95Mt$CO_2$ by 2030 (a 30% reduction in the GHG balance as per 2016 figures) and a greenhouse gas emissions budget of 1,100Mt$CO_2$ for the period 2020 to 2030.
- Chile aims to achieve carbon neutrality by 2050 (Government of Chile, 2020).
- We focus on Forestry and Other Land Use component of NDC targets.

# SCENARIO DESIGN

- **BASE**: Business-as-usual scenario (GDP and population projection from Chile Central Bank). Deforestation from Global Forest Watch 2001-2013; assumed 50% of deforested area is converted to agriculture.
- **REDEFOR**: Reduction in deforestation.
- **AFFOR**: Afforestation of 200,000 ha.
- **RESTORE**: Restoring 200,000 ha of land.
- **COMBI**: **REDEFOR** + **AFFOR** + **RESTORE** + increase in total factor productivity due to changes in erosion mitigation and crop pollination ES.
- **COMBI***: Same as combi wihout ES.

# REDEFOR KEY ELEMENTS

- 25% reduction in deforestation by 2030 with respect to the average rate of deforestation registered between 2001 and 2013 (Global Forest Watch data).
- The deforestation rate is reduced linearly beginning in 2023 until reaching a 25% reduction by 2030 which is maintained until 2050.
- The cost of reducing deforestation is distributed equally from 2023 to 2050; cost estimated for Brazil of USD538.70 per hectare/year.
- 90% recurrent government expenditure and 10% government investment.
- 50% financed by non-reimbursable grants and 50% through international development loans with standard repayment terms.

# AFFOR SCENARIO KEY ELEMENTS

- 200,000 ha of forests planted on areas designated as shrub and herbaceous vegetation areas in the LULC map; these areas do not currently generate economic value.
- The afforestation will commence in 2023 with planting of 15% of the total area followed by 25%, 35% and 25% in 2024, 2025 and 2026, respectively.
- Trees mature at 25 years, no additional carbon stored; 50% managed for forest products, generating value after 10 years.
- The cost of afforestation was estimated in 2015 CLP986,251.
- 100% government investment.
- 50% financed by non-reimbursable grants and 50% through international development loans with standard repayment terms.

# RESTORE SCENARIO KEY ELEMENTS

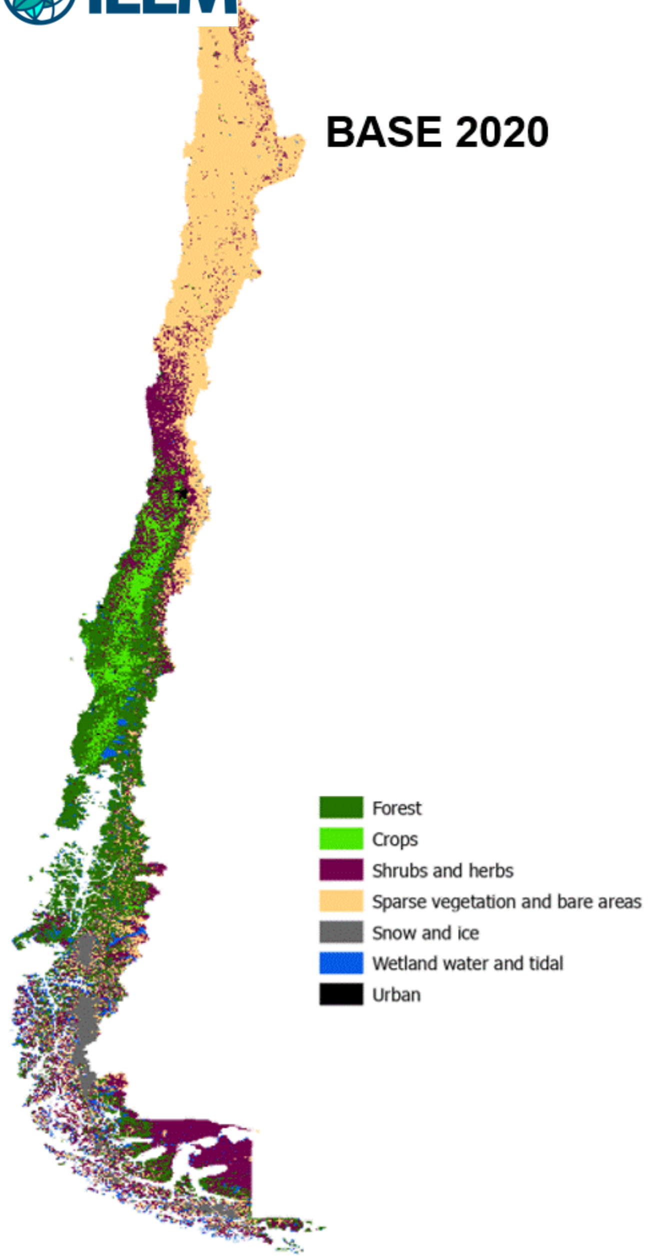
- 200,000 ha restored to native forest conditions by 2030.
- The restoration will also take place in areas designated as shrub and herbaceous vegetation areas in the LULC map and currently do not generate economic value.
- The restoration will start in 2023, restoring 12.5% per year and concluding in 2030.
- Trees mature at 30 years, no additional carbon stored; 100% managed for forest products, generating value after 10 years.
- The cost of restoration was estimated at 50% of the cost of afforestation

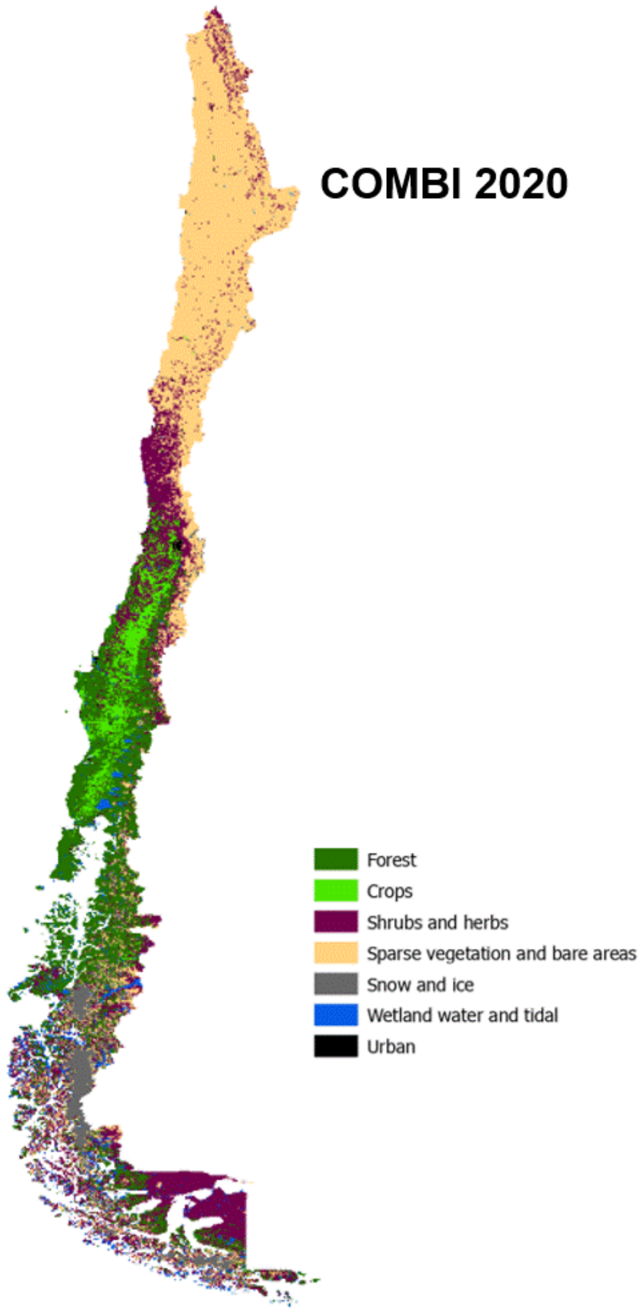
# COMBI AND COMBI* SCENARIOS KEY ELEMENTS

- COMBI: REDEFOR+AFFOR+RESTORE+ES.
- COMBI*: REDEFOR+AFFOR+RESTORE.

# LULC CHANGE AND ES MODELING

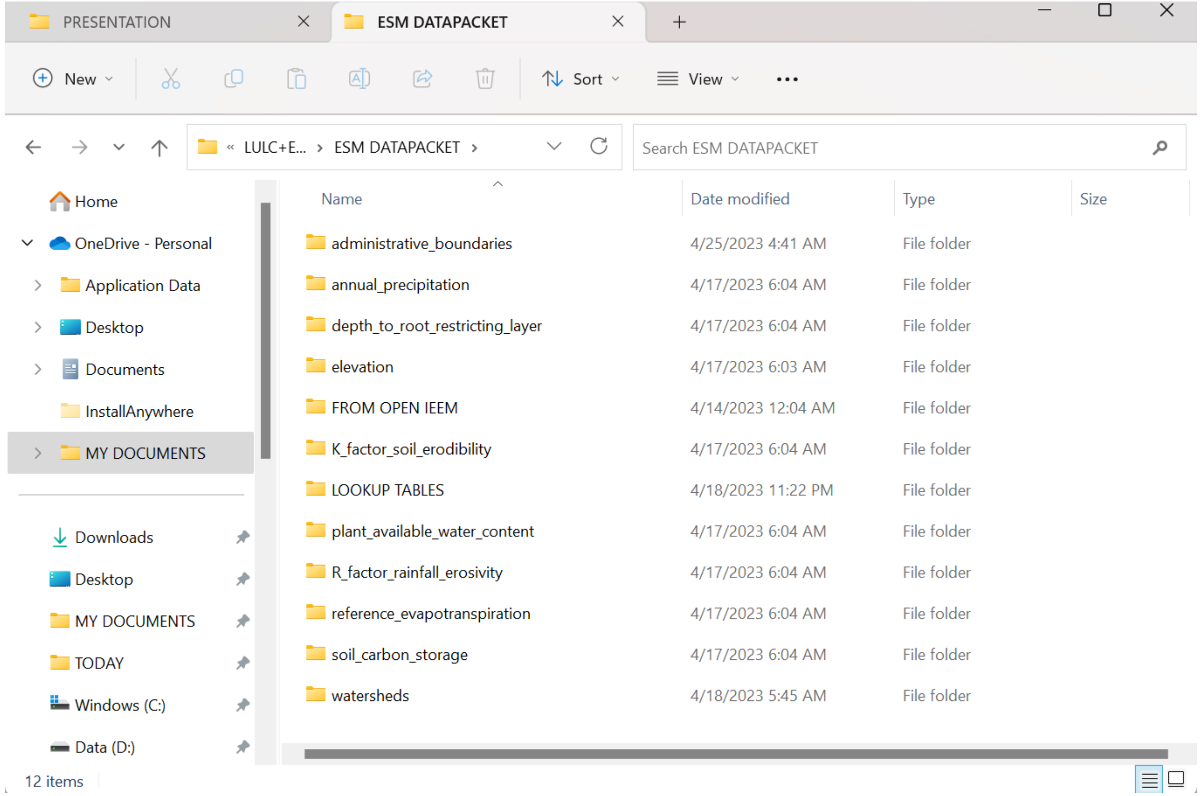
- Demand for land determined exogenously, therefore iterate only LULC and ES models.
- Run LULC change model for BASE and COMBI projection to 2050; 5-year time steps.
- Run Sediment Delivery ratio (erosion) and crop pollination ES models in 5-year time steps.

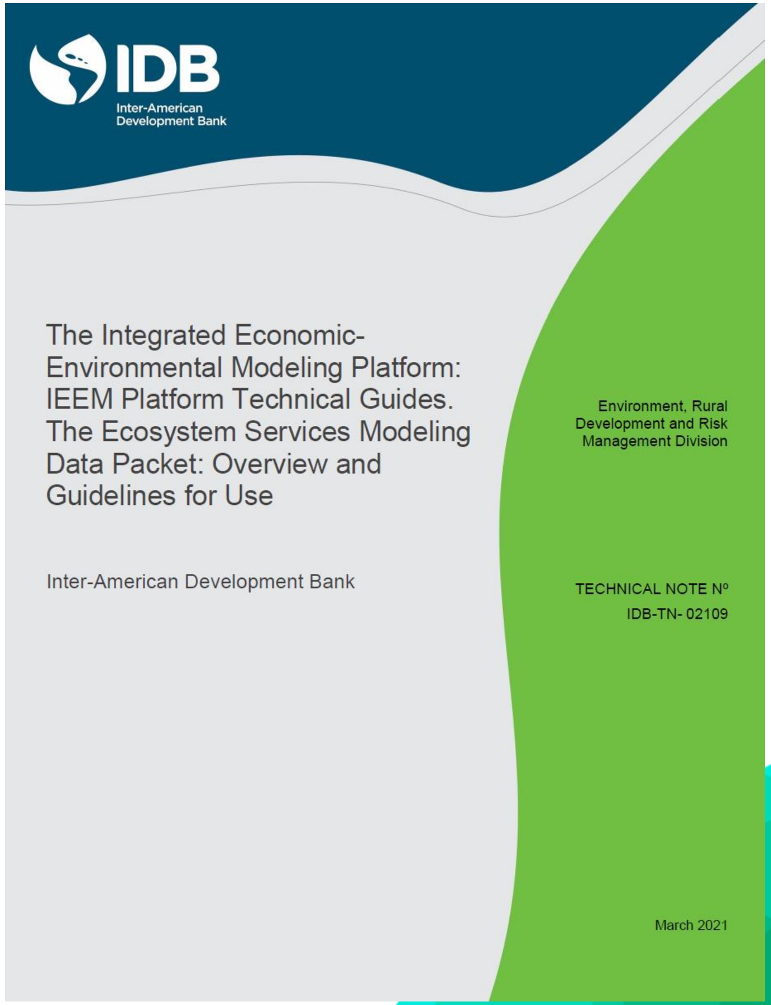


# ES MODELING DATAPACKETS

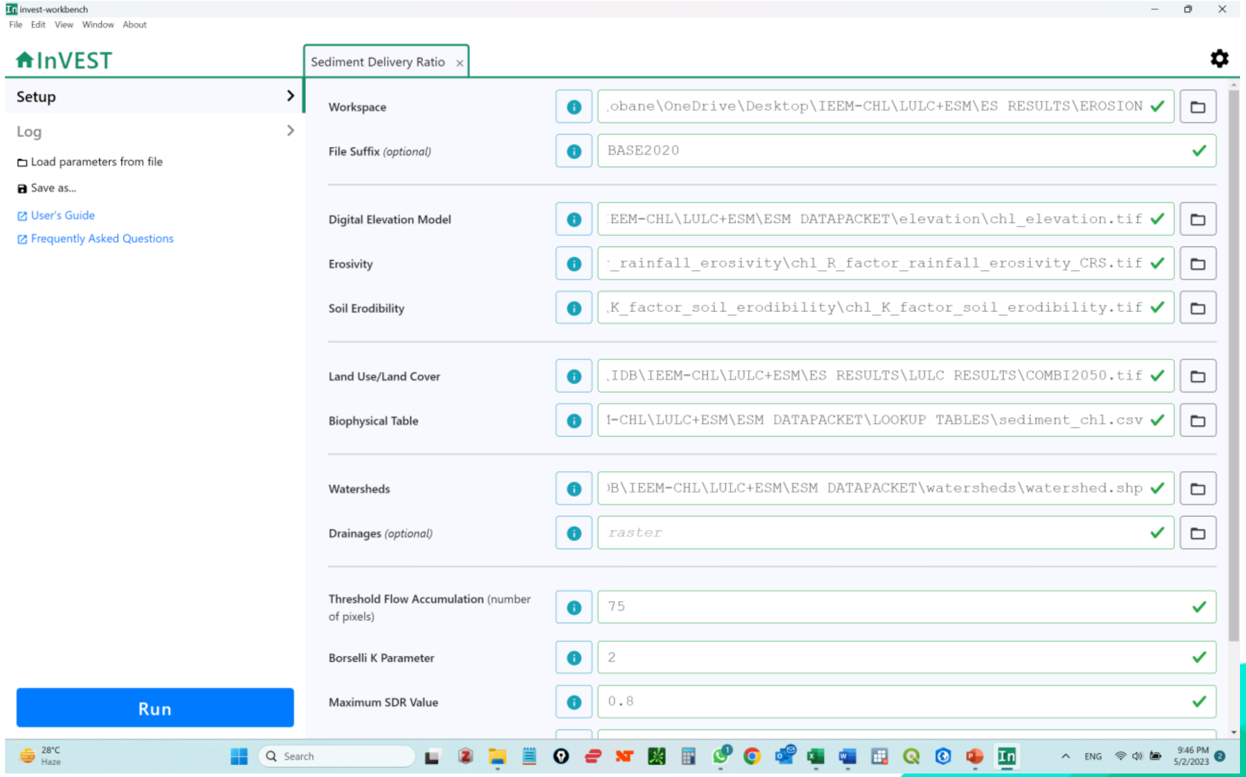
- Available at OPEN IEEM for Carbon, Sediment Delivery Ratio, Nutrient Delivery Ratio and Water Yield models.



# CALCULATING THE EROSION SHOCK

- Erosion affects agricultural productivity (linkage).
- Run BASE and scenarios (COMBI) in LULC change model and erosion model.
- Based on USLE result, calculate difference of number of pixels above/below 11 tons/ha threshold for severe erosion (national or regional). **Increasing or decreasing?**




| BASE20 | | BASE25 | | BASE30 | | BASE35 | | BASE40 | | BASE45 | | BASE50 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <11 | >11 | <11 | >11 | <11 | >11 | <11 | >11 | <11 | >11 | <11 | >11 | <11 | >11 |
| 43,812,657 | 28,212,165 | 43471737 | 28553085 | 43126155 | 28898667 | 42732396 | 29292426 | 42326532 | 29698290 | 41902659 | 30122163 | 41506488 | 30518334 |

| COMBI25 | | COMBI30 | | COMBI35 | | COMBI40 | | COMBI45 | | COMBI50 | | AGRI LAND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <11 | >11 | <11 | >11 | <11 | >11 | <11 | >11 | <11 | >11 | <11 | >11 | CROPS |
| 43566849 | 28457973 | 43322355 | 28702467 | 43027920 | 28996902 | 42702570 | 29322252 | 42380523 | 29644299 | 42079167 | 29945655 | 4213750 |

# CALCULATING THE EROSION SHOCK

- Calculate agricultural productivity shock:

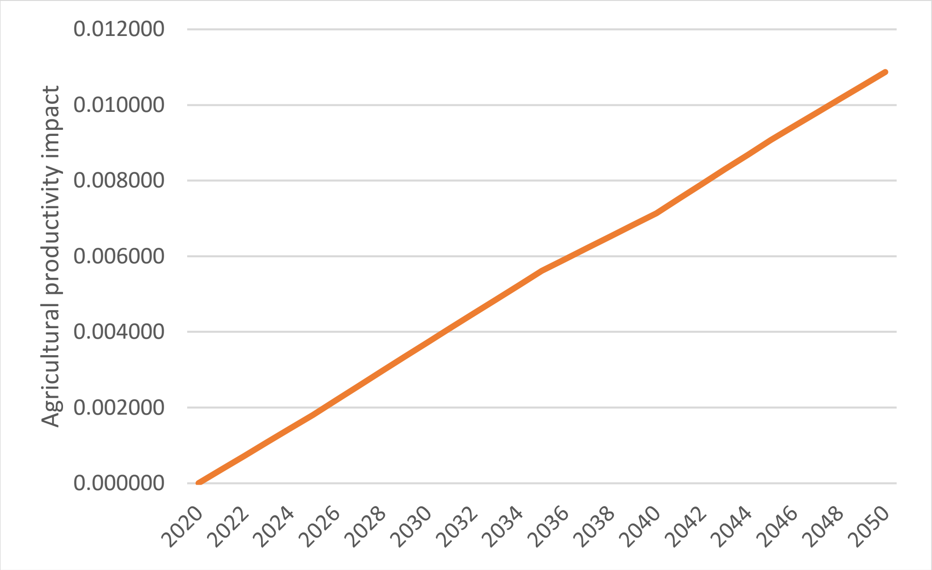
- $LPL_{rg} = \frac{SER_{rg}}{TAA_{rg}} \cdot 0.08$

- Where:
- $LPL_{rg}$ is the land productivity loss by subscript *rg* region of Chile;
- $SER_{rg}$ is the agricultural land area (hectares) subject to erosion >11t/ha/year in each region;
- $TAA_{rg}$ is the total agricultural area, both crop and livestock, by region and;
- $0.08$ is the agricultural productivity shock based on extensive literature review.

# CALCULATING THE EROSION SHOCK

- 5-year time steps.
- Interpolate between years.
- Erosion mitigation ES increasing as a result of COMBI.

| COMBI | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.000000 | 0.000361 | 0.000722 | 0.001083 | 0.001445 | 0.001806 | 0.002190 | 0.002573 | 0.002957 | 0.003341 | 0.003725 |



# CALCULATING THE POLLINATION SHOCK

- Map FAOSTAT crop output data to Klein et al (2007) which associates crops to their dependence.

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3. Results and discussion
4. Management conclusions and future directions
Footnotes
Supplemental Material

## Importance of pollinators in changing landscapes for world crops

Alexandra-Maria Klein, Bernard E Vaissière, James H Cane, Ingolf Steffan-Dewenter, Saul A Cunningham, Claire Kremen and Teja Tscharntke

Published: 27 October 2006 https://doi.org/10.1098/rspb.2006.3721

Abstract

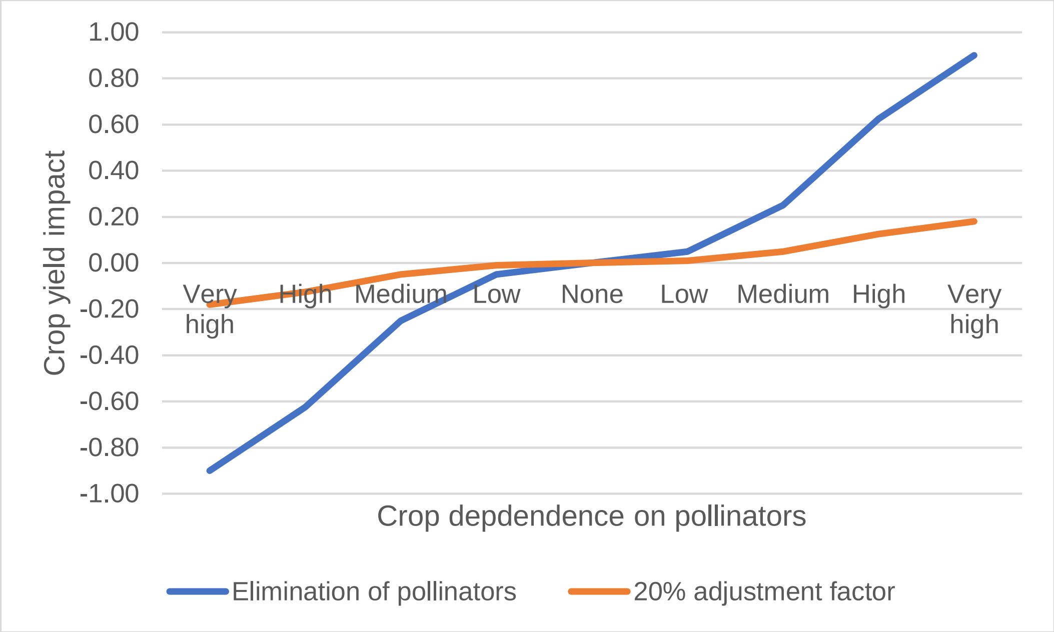
The extent of our reliance on animal pollination for world crop production for human food has not previously been evaluated and the previous estimates for countries or continents have seldom used primary data. In this review, we expand the previous estimates using novel primary data from 200 countries and found that fruit, vegetable or seed production from 87 of the leading global food crops is dependent upon animal pollination, while 28 crops do not rely upon animal pollination. However, global production volumes give a contrasting perspective, since 60% of global production comes from crops that do not depend on animal pollination, 35% from crops that depend on pollinators, and 5% are unevaluated. Using all crops traded on the world market and setting aside crops that are solely passively self-pollinated, wind-pollinated or parthenocarpic, we then evaluated the level of dependence on animal-mediated pollination for crops that are directly consumed by humans. We found that pollinators are essential for 13 crops, production is highly pollinator dependent for 30, moderately for

| | Very high | High | Medium | Low | 000s of USD | FAO CROP NAME |
|---|---|---|---|---|---|---|
| **REDUCTION IN YIELD** | **-0.18** | **-0.125** | **-0.05** | **-0.01** | | |
| **VERY HIGH** | | | | | | |
| Cantaloupe, melon | -0.18 | | | | 22,411 | Cantaloupes and other melons |
| Kiwi | -0.18 | | | | 119,834 | Kiwi fruit |
| Pumpkin, squash, gourd, marrow, | -0.18 | | | | 61,404 | Pumpkins, squash and gourds |
| **TOTAL VERY HIGH** | | | | | **203,649** | |
| **HIGH** | | | | | | |
| Apple | | -0.125 | | | 942,133 | Apples |
| Apricot | | -0.125 | | | 5,813 | Apricots |
| Avocado | | -0.125 | | | 374,257 | Avocados |
| Peach, nectarine | | -0.125 | | | 357,880 | Peaches and nectarines |
| Pear | | -0.125 | | | 156,062 | Pears |
| Plum, greengage, mirabelle, sloe | | -0.125 | | | 263,462 | Plums and sloes |
| Raspberry, blackberry, other berries | | -0.125 | | | 70,414 | Raspberries |
| Sweet cherry | | -0.125 | | | 611,051 | Cherries |
| **TOTAL HIGH** | | | | | **2,781,072** | |
| **MEDIUM** | | | | | | |
| Broad bean, faba bean, field bean, horse bean | | | -0.05 | | 19,629 | Beans, dry |
| Fig | | | -0.05 | | 253 | Figs |
| Rapeseed, oilseed rape | | | -0.05 | | 58,674 | Rape or colza seed |
| Strawberry | | | -0.05 | | 46,759 | Strawberries |
| Sunflower | | | -0.05 | | 1,400 | Sunflower seed |
| **TOTAL MEDIUM** | | | | | **126,715** | |
| **LOW** | | | | | | |
| Chile pepper, red pepper, bell pepper, green pepper | | | | -0.01 | 86,094 | Chillies and peppers, green (Capsicum spp. and Pimenta spp.) |
| Citrus (Bergamot, citron grapefruit, lemon, lime, orange, pomel | | | | -0.01 | 156,661 | Lemons and limes |
| | | | | | 79,104 | Oranges |
| | | | | | 895 | Pomelos and grapefruits |
| | | | | | 169,314 | Tangerines, mandarins, clementines |
| **TOTAL CITRUS** | | | | | **405,974** | |
| Papaya | | | | -0.01 | 3,365 | Papayas |
| Persimmon | | | | -0.01 | 699 | Persimmons |
| Tomato | | | | -0.01 | 540,134 | Tomatoes |
| **TOTAL LOW** | | | | | **1,036,266** | |

# CALCULATING THE POLLINATION SHOCK

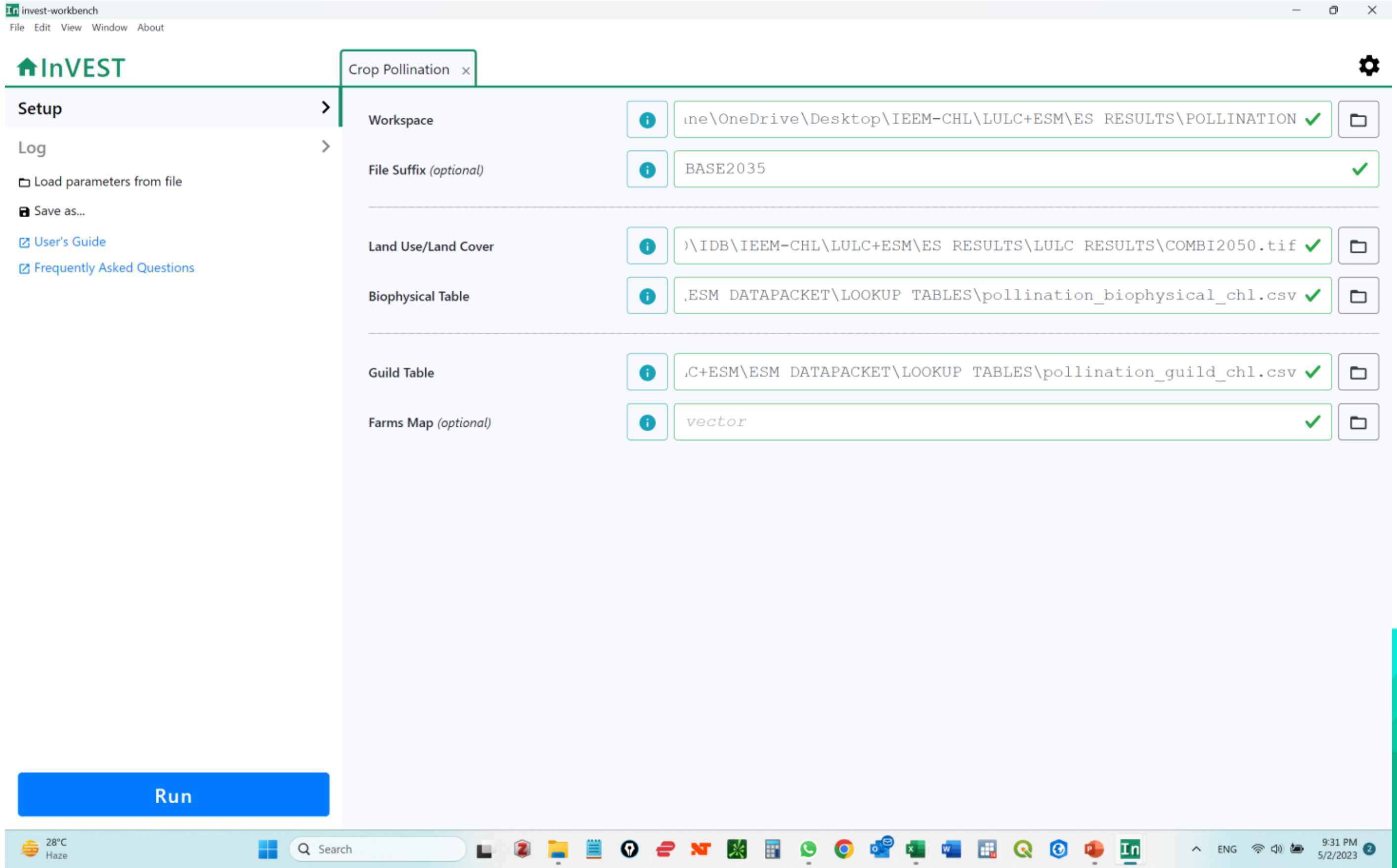
- Calculate crop yield impact by crop type (figure right).
- Adjustment factor accounts for starting point in terms of abundance.
- For Chile, assumed that 20% of productivity potential was possible (India 40% based on literature).
- Pollinator decline due to both habitat loss, reduced sources of food and application of chemicals in the landscape.

| | |
|---|---|
| TOTAL CROPS POLLINATOR DEPENDENT | 4,147,702 |
| TOTAL CROPS NOT DEPENDENT | 5,697,202 |
| TOTAL CROP OUTPUT | 9,844,904 |
| **SHARE OF CROPS POLLINATOR DEPDENDENT** | **0.42** |



# CALCULATING THE POLLINATION SHOCK

- Run pollination model to calculate BASE and scenario-driven changes in pollinator abundance.
- **Pollinators increasing or decreasing (BASE vs. COMBI)?**




| Zonal statistics sum | BASE20 | BASE25 | BASE30 | BASE35 | BASE40 | BASE45 | BASE50 | COMBI25 | COMBI30 | COMBI35 | COMBI40 | COMBI45 | COMBI50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NATIONAL | 53491 | 52704 | 51907 | 51090 | 50324 | 49560 | 48859 | 53332 | 53048 | 52396 | 51743 | 51130 | 50581 |
| Change in abundance wrt BASE | | -0.0147 | -0.0296 | -0.0449 | -0.0592 | -0.0735 | -0.0866 | 0.0119 | 0.0220 | 0.0256 | 0.0282 | 0.0317 | 0.0352 |

# CALCULATING THE POLLINATION SHOCK

- Shock applied to IEEM 'crops' category, thus must be weighted.
- Greater disaggregation is possible if there is a reason for it.

$$CPC_r = D_r \cdot (A_r \cdot Y_{r,vh} \cdot V_{r,vh} \cdot W_{r,vh} + A_r \cdot Y_{r,h} \cdot V_{r,h} \cdot W_{r,h} + A_r \cdot Y_{r,m} \cdot V_{r,m} \cdot W_{r,m} + A_r \cdot Y_{r,l} \cdot V_{rl} \cdot W_{r,l})$$

Where:

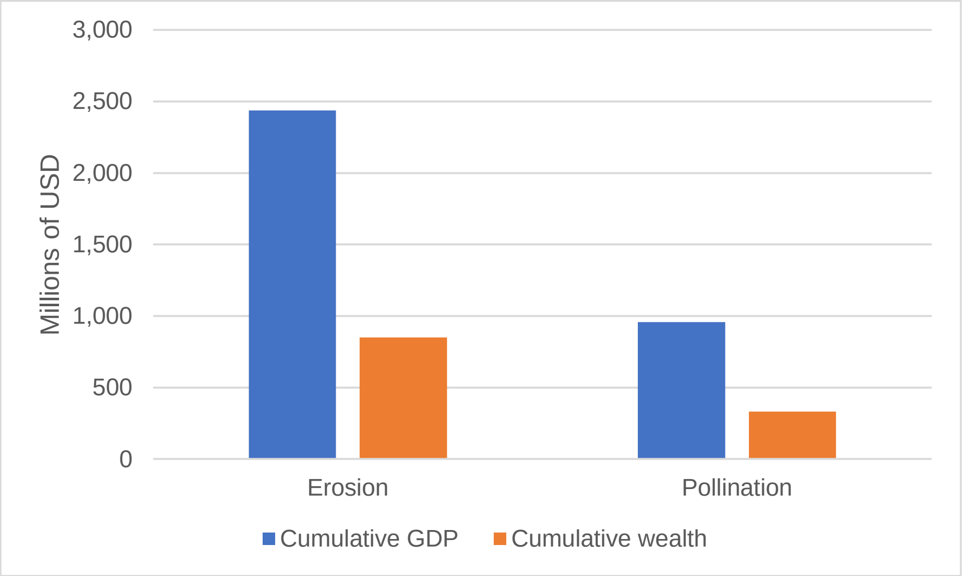
- $CPC_r$ is the crop productivity impact for subscript region *r* of Chile;
- $D_r$ is a pollinator adjustment factor representing current pollinator abundance relative to full potential abundance.
- $A_r$ is pollinator abundance in subscript region *r* of Chile;
- $Y_{r,vh}$ is the yield impact in region *r* for very highly pollinator dependent crops (subscript *vh*);
- $V_{r,vh}$ is the value of crop output in region *r* for very highly pollinator dependent crops (subscript *vh*);
- $W_{r,vh}$ is the weight of the value of very highly pollinator dependent crops (subscript *vh*) in Chile's total crop output value and;
- Subscripts *h*, *m* and *l* refer to high, medium and low dependent pollinator crops.

# ECONOMIC IMPACTS

In millions of USD as difference from BASE in final year (or cumulative as indicated). COMBI* is without ES.

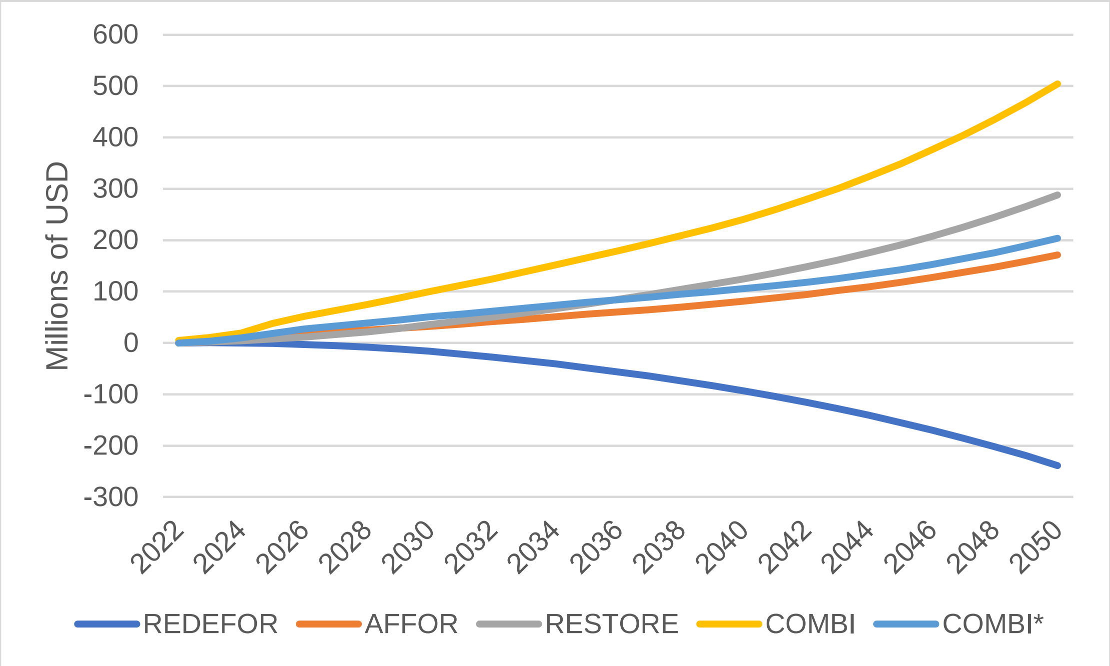
| | REDEFOR | AFFOR | RESTORE | COMBI | COMBI* |
|---|---|---|---|---|---|
| GDP | -239 | 171 | 288 | 504 | 204 |
| Cumulative GDP | -2,250 | 1,980 | 2,982 | 5,878 | 2,552 |
| Wealth | -5 | 174 | 315 | 499 | 385 |
| Cumulative wealth | 202 | 1,922 | 3,221 | 5,502 | 4,324 |
| Private consumption | -270 | 116 | 194 | 240 | 27 |
| Private investment | -141 | 78 | 133 | 178 | 61 |
| Exports | -413 | 80 | 140 | -43 | -202 |
| Imports | -222 | 71 | 123 | 99 | -37 |

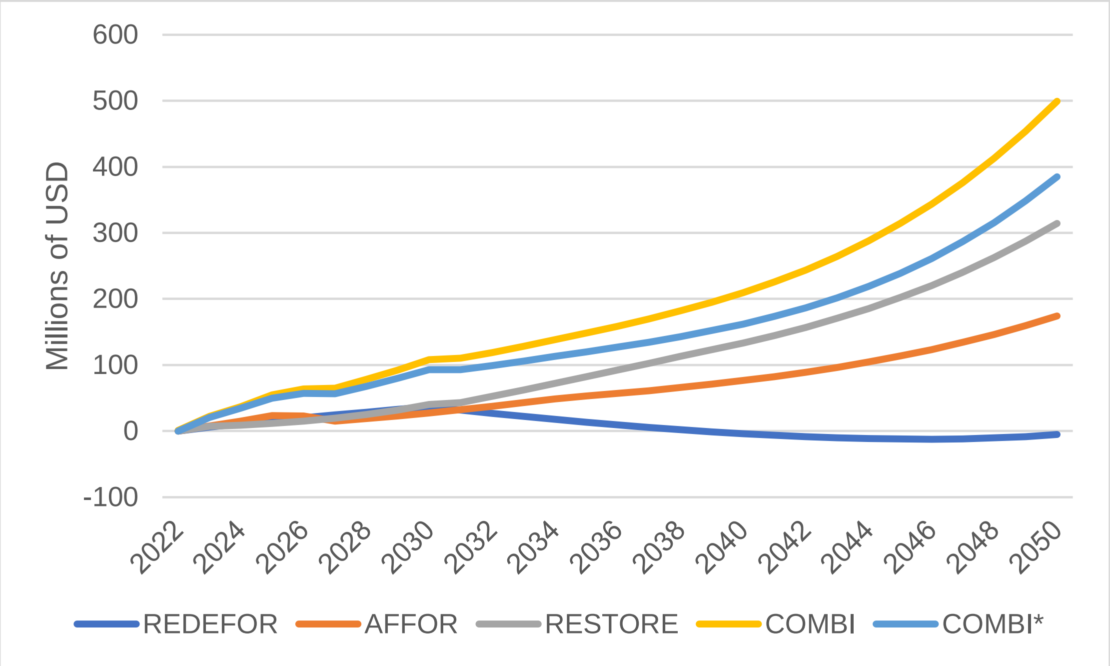
Regulating ES contribution to cumulative GDP and wealth.



# ECONOMIC IMPACTS

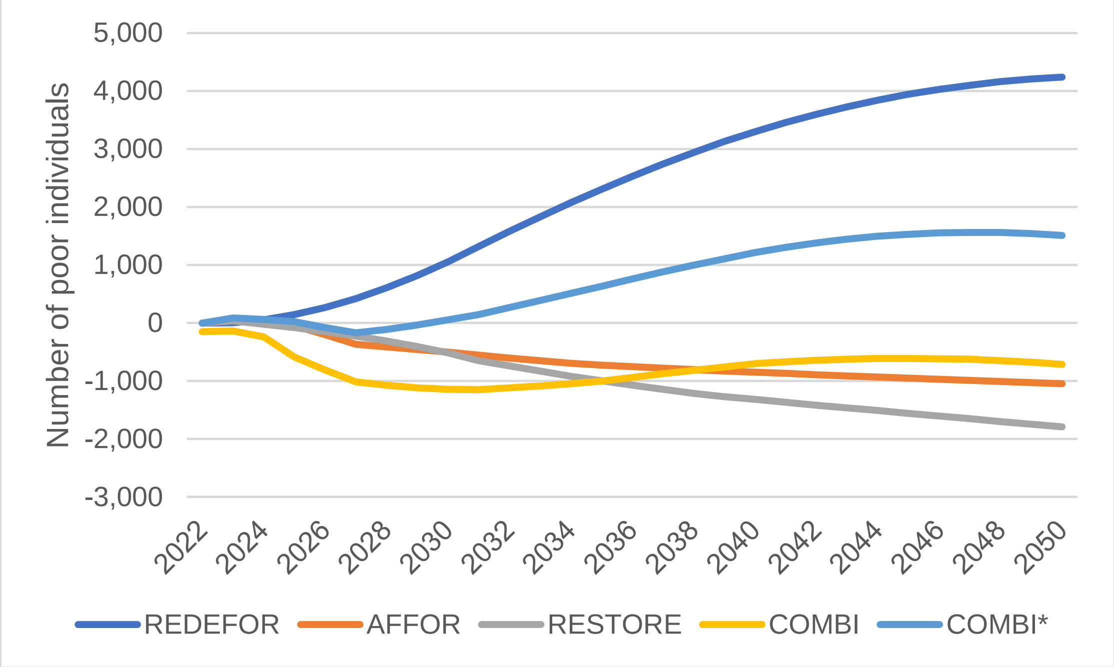
- Trajectory of GDP (left) and wealth (right) impacts.



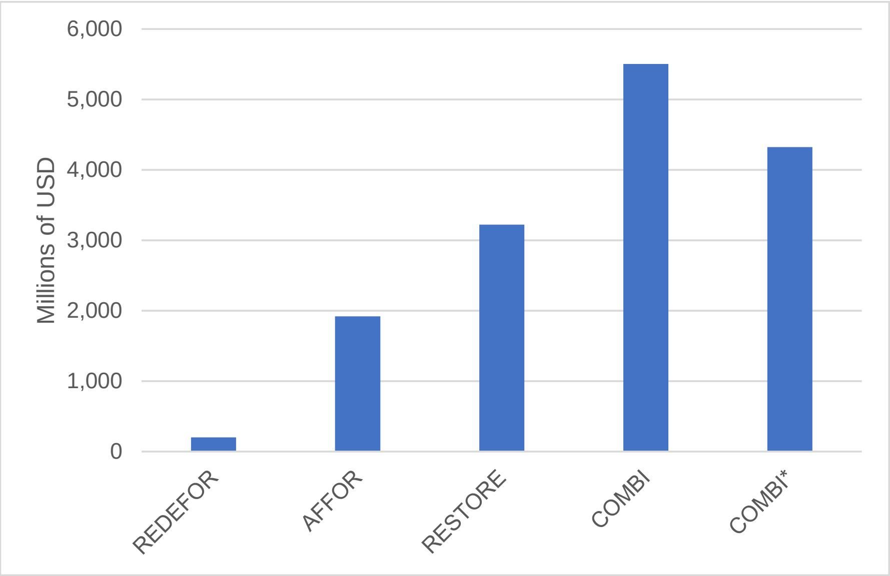
# POVERTY IMPACTS

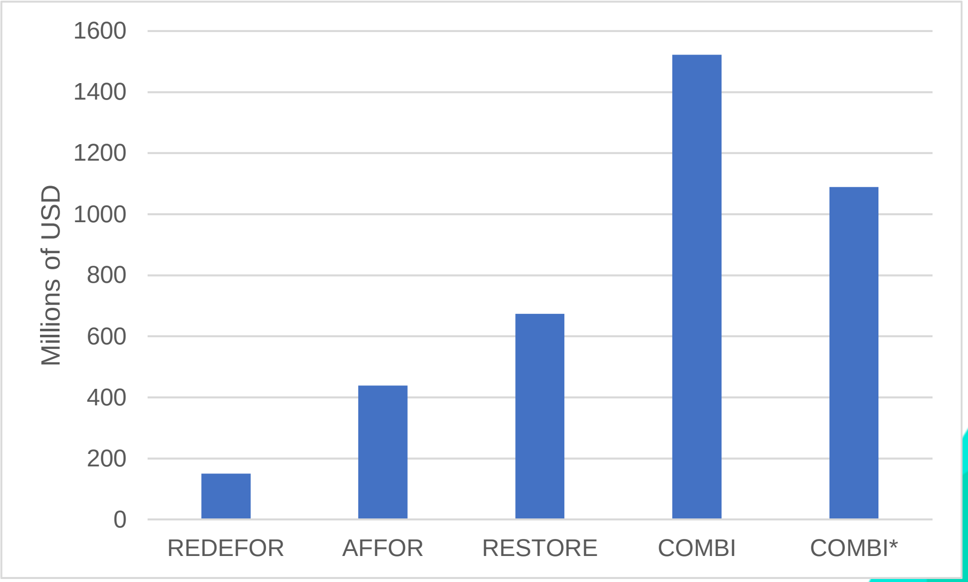
- Poverty impact in 2050 (left) and trajectory (right).

# ECONOMIC IMPACTS

- Cumulative wealth impact (left) and Net Present Value (right) with 10% discount rate, millions of USD..

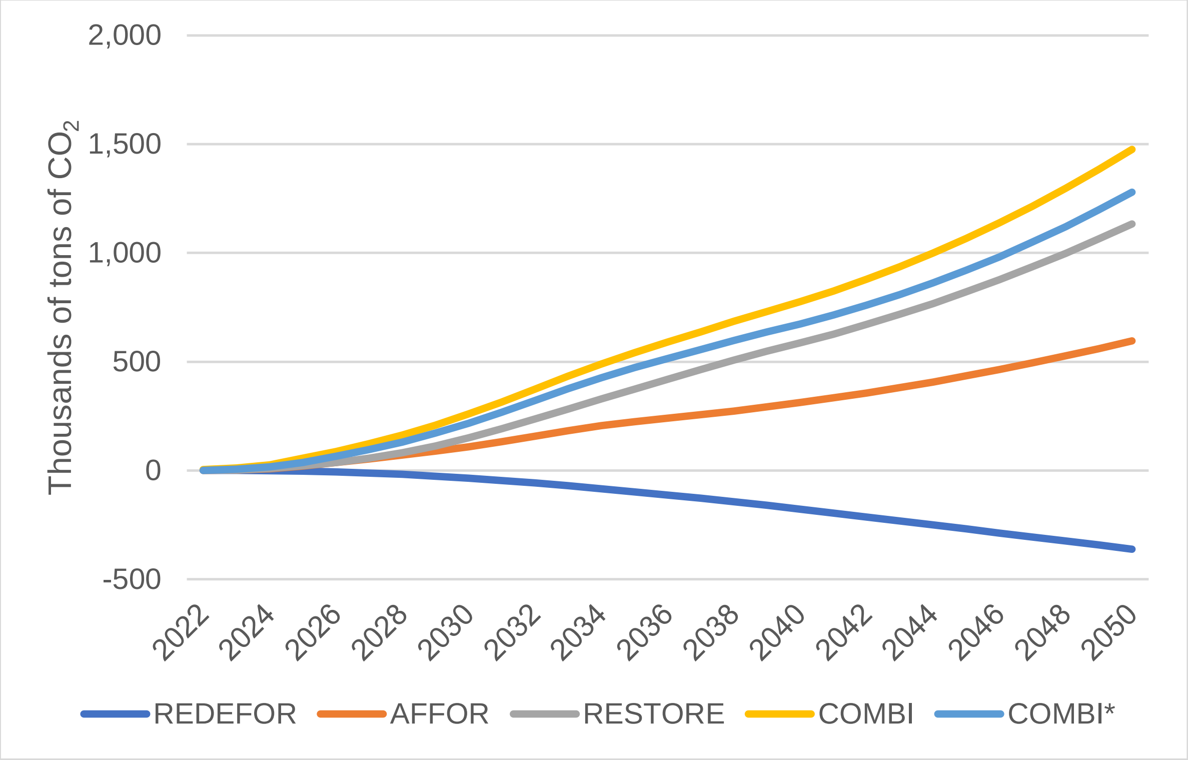


# ES IMPACTS: CLIMATE CHANGE MITIGATION

- $CO_2$ emissions from combustion of fossil fuels.
- Changes in carbon storage are also calculated in IEEM; coming soon (ISIM).
- Change in LULC for class X multiplied

by carbon coefficient for that class.



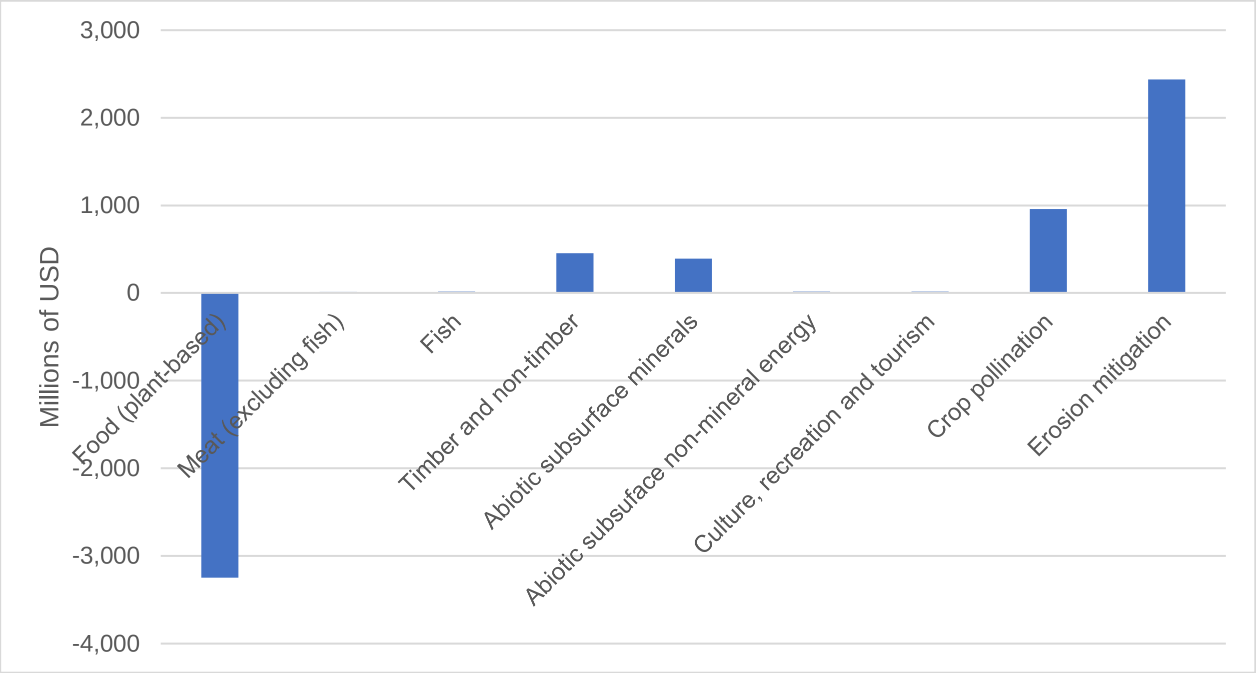
# ES IMPACTS: ALL SERVICES

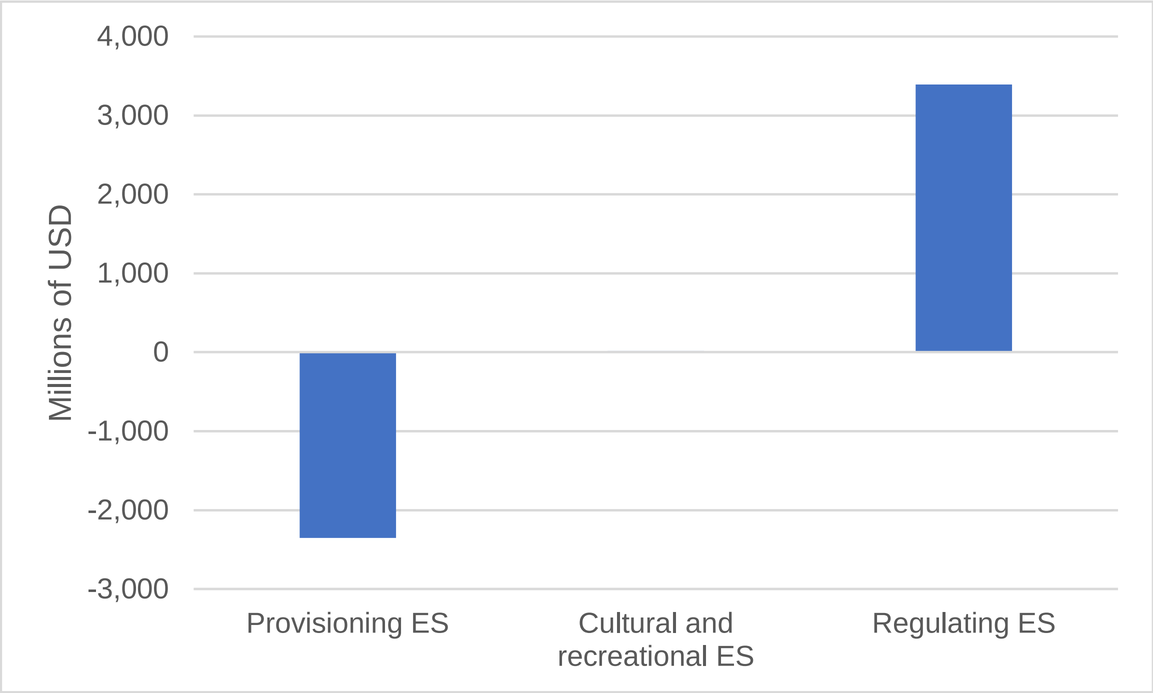
- Millions of USD

| ES Section | ES Class | Scenario | | | | Code | |
|---|---|---|---|---|---|---|---|
| | | REDEFOR | AFFOR | RESTORE | COMBI | CICES | IPBES |
| Provision ecosystem services | | | | | | | |
| | Food (plant-based) | -5,775 | 96 | 163 | -3,248 | 1.1.1.1 | 12 |
| | Meat (excluding fish) | 13 | 2 | 2 | 14 | 1.1.3.1 | 12 |
| | Fish | 22 | 1 | 0 | 17 | 1.1.4.1 | 12 |
| | Timber and non-timber | 16 | 164 | 299 | 455 | 1.1.1.2, 1.1.5.1, 1.1.5.2 | 12, 13, 14 |
| | Abiotic subsurface minerals | 624 | 17 | -12 | 391 | 4.3.1.3 | |
| | Abiotic subsuface non-mineral energy | -4 | 5 | 8 | 18 | 4.3.2.2 | |
| Cultural and recreational ecosystem services | | | | | | | |
| | Culture, recreation and tourism | -64 | 34 | 48 | 16 | 3.1.1.1 | 6, 16 |
| Regulating ecosystem services | | | | | | | |
| | Crop pollination | | | | 958 | 2.2.2.1 | 2 |
| | Erosion mitigation | | | | 2,436 | 2.2.1.1, 2.2.1.2 | 9 |

# ES IMPACTS: ALL ES

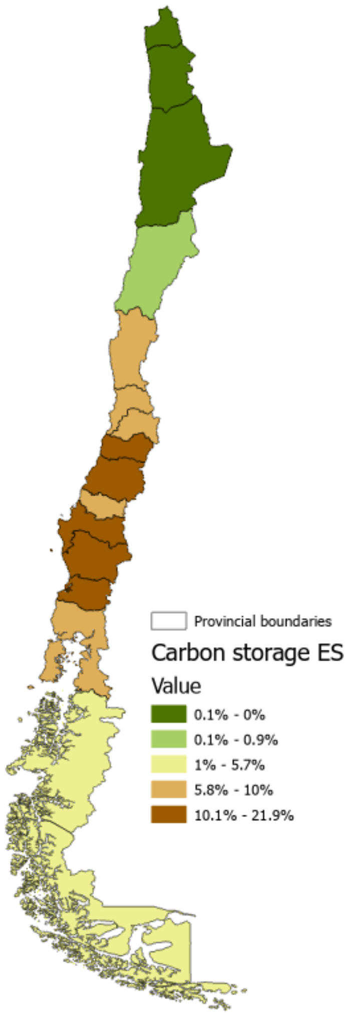
- Millions of USD/

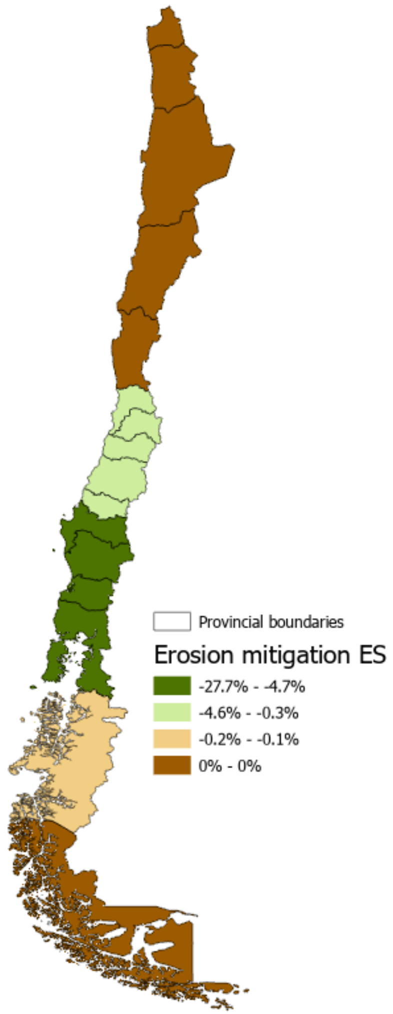


# ES IMPACTS

- ES model runs based on Dyna-CLUE generated maps.
- Summary results at regional level as COMBI percent difference from BASE.
- Modeled carbon storage, erosion mitigation, crop pollination, water regulation and water purification with InVEST and IEEM+ESM Datapackets.
- Both carbon and erosion can be reported in tons per pixel.



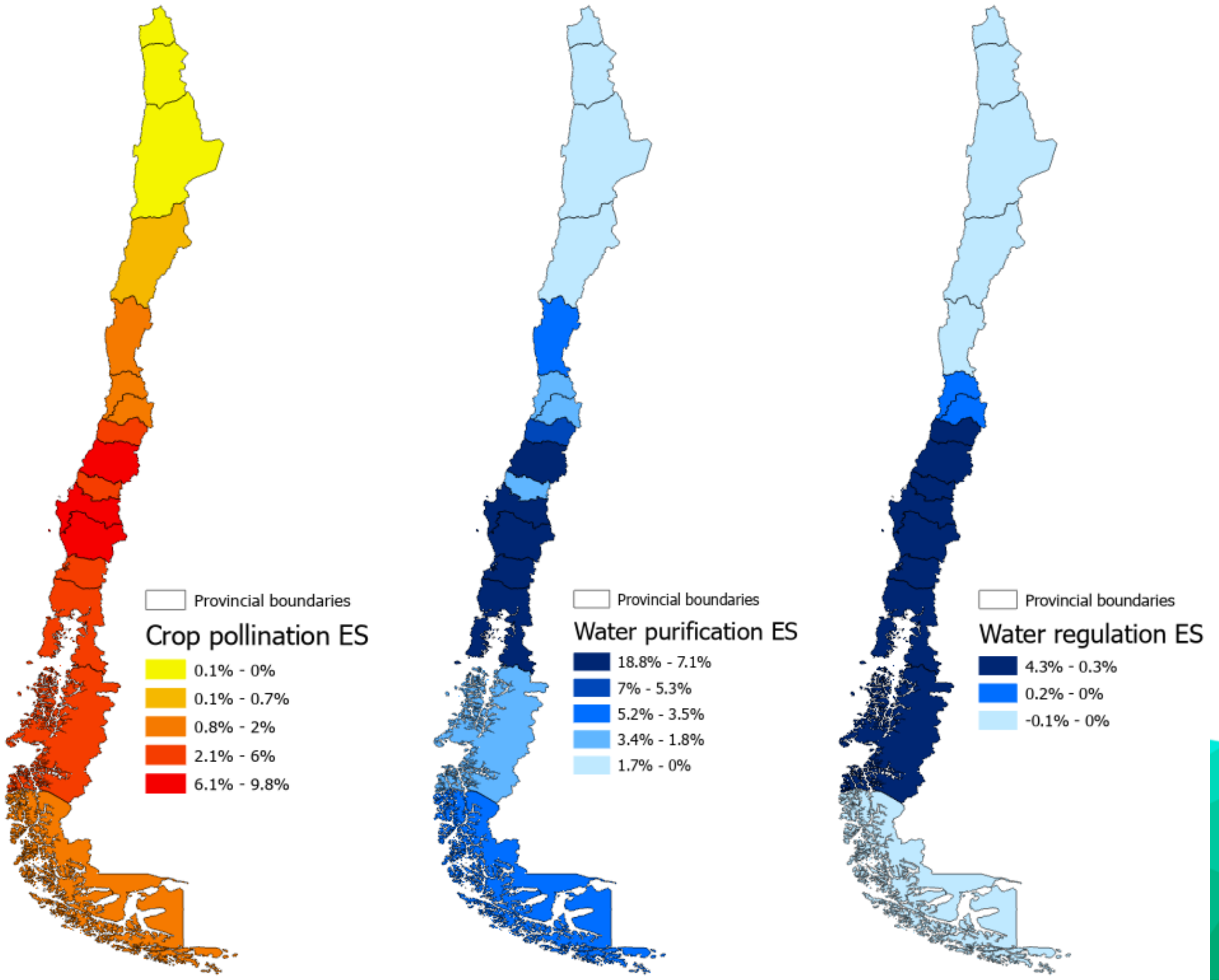



# ES IMPACTS

- COMBI percent difference from BASE.
- Other reporting formats:

-Crop pollination reported in index of abundance.

-Water purification reported in units of kg/pixel and water regulation in units of mm per pixel.



# CONCLUDING REMARKS

- Reducing deforestation restricts land supply; critical assumption is what proportion of deforested land is used for agriculture or other ‘productive’ purposes.
- Afforestation and restoration contribute positively to economy with increase in forest sector output and enhanced ES provision.
- ES flows increase across the landscape the concentrated in central section of Chile.
- Implications of area-based targets vs. $CO_2$ targets; timing matters with the latter.
- ES results and IEEM+ESM tools can be used for spatial targeting of policies.

# Developing IEEM Modeling Infrastructure and Capacity Around the World.

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