# Training on Water Allocation Scenarios for Irrigated Agriculture and Biodiversity Conservation

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HYDROCLIMATIC MODELLER

28TH AND 29TH JULY 2025

# Objective of the training

- Provide to the participants knowledge, tools, and collaborative skills needed to jointly develop and implement balanced water allocation scenarios.
- These scenarios aim to optimise water distribution between irrigated agriculture, ecological flows, and biodiversity conservation in the Lower Amu Darya and Aral Sea basin.
- This will be exemplified with a water allocation modelling carried out in the Lower Amu Darya.

# Agenda of the training

| Time | Monday 28th July 2025 | Tuesday 29th July 2025 |
|---|---|---|
| **09:00 - 12:00** | • Context of the assignment and presentation of the training objective.<br>• Analysis of collected river discharge data:<br>  o Flow of the Amu Darya.<br>  o Tuýamuyun reservoir.<br>  o Water withdrawn from irrigation canal systems.<br>  o Flow to the ecosystems.<br>• Estimation of drainage from the collectors.<br>• Estimation of water consumed for irrigation.<br>• Estimation of water allocated to the ecosystems.<br>• Analysis of Economic data. | • Setting the WEAP model.<br>• Scenarios examined in WEAP:<br>  o Greater allocation to the ecosystems.<br>  o Rehabilitation of canal systems<br>  o Climate change.<br>• Results of the modelling.<br>• Discussion:<br>  o Limitations of the modelling.<br>  o Conclusion and policy implications.<br>  o Improvement of the work. |

# Context of the assignment

- Context:
  - Project “Conservation and sustainable management of lakes, wetlands, and riparian corridors as pillars of a resilient and land degradation-neutral Aral basin landscape supporting sustainable livelihoods”
  - Implemented by UNDP, under GEF funding.

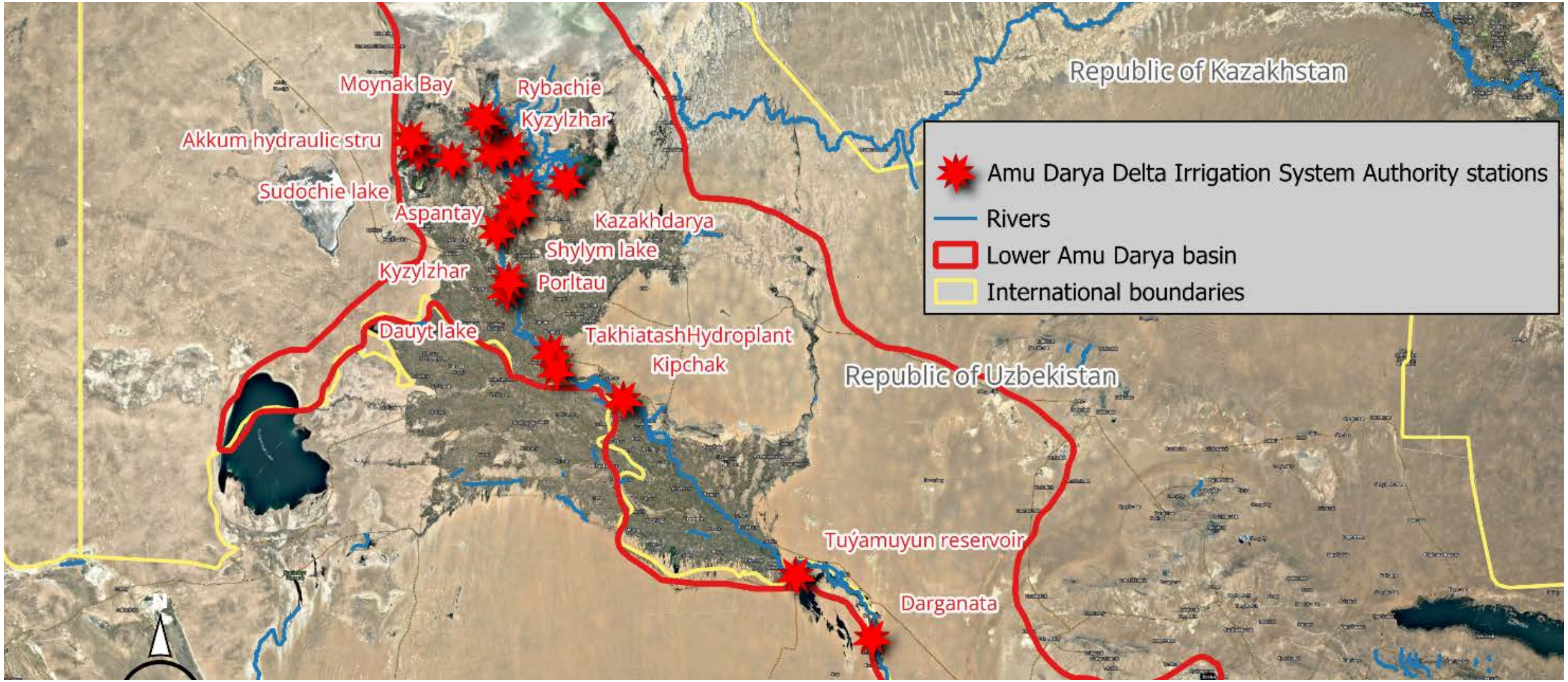
- Objective of the assignment:
  - Water allocation analysis and development of water supply scenarios for irrigated agriculture and biodiversity conservation.

# Context of the assignment

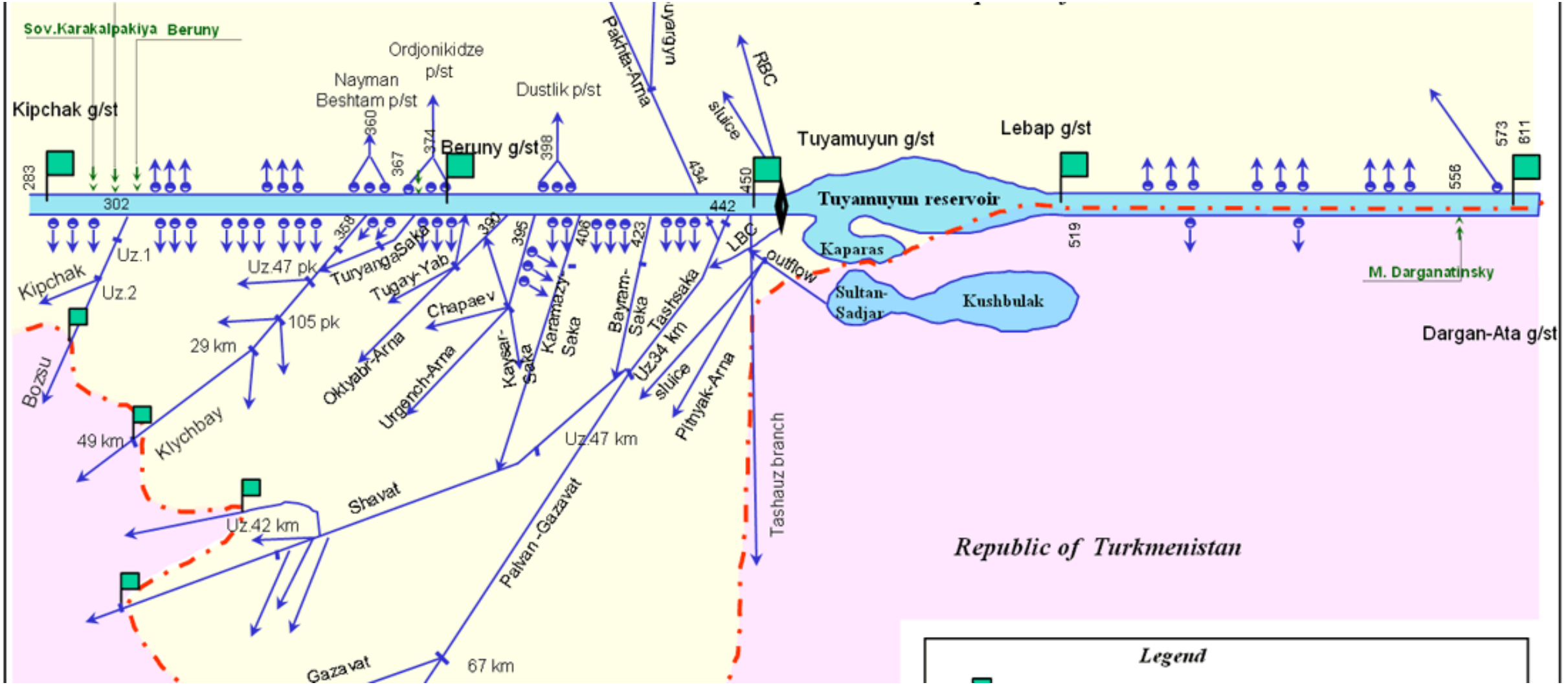
- Approach used:
  - Collecting various data to set a water allocation and hydroeconomic model:
    - River discharge.
    - Canal systems and capacity.
    - Water delivered to the ecosystems.
    - Costs and benefits for agricultural production.
    - Economic benefits from ecosystem services.
- Used the water allocation model Water Evaluation And Planning (WEAP).
- Examined different scenarios for irrigated agriculture and biodiversity conservation.

# Analysis of collected river discharge data

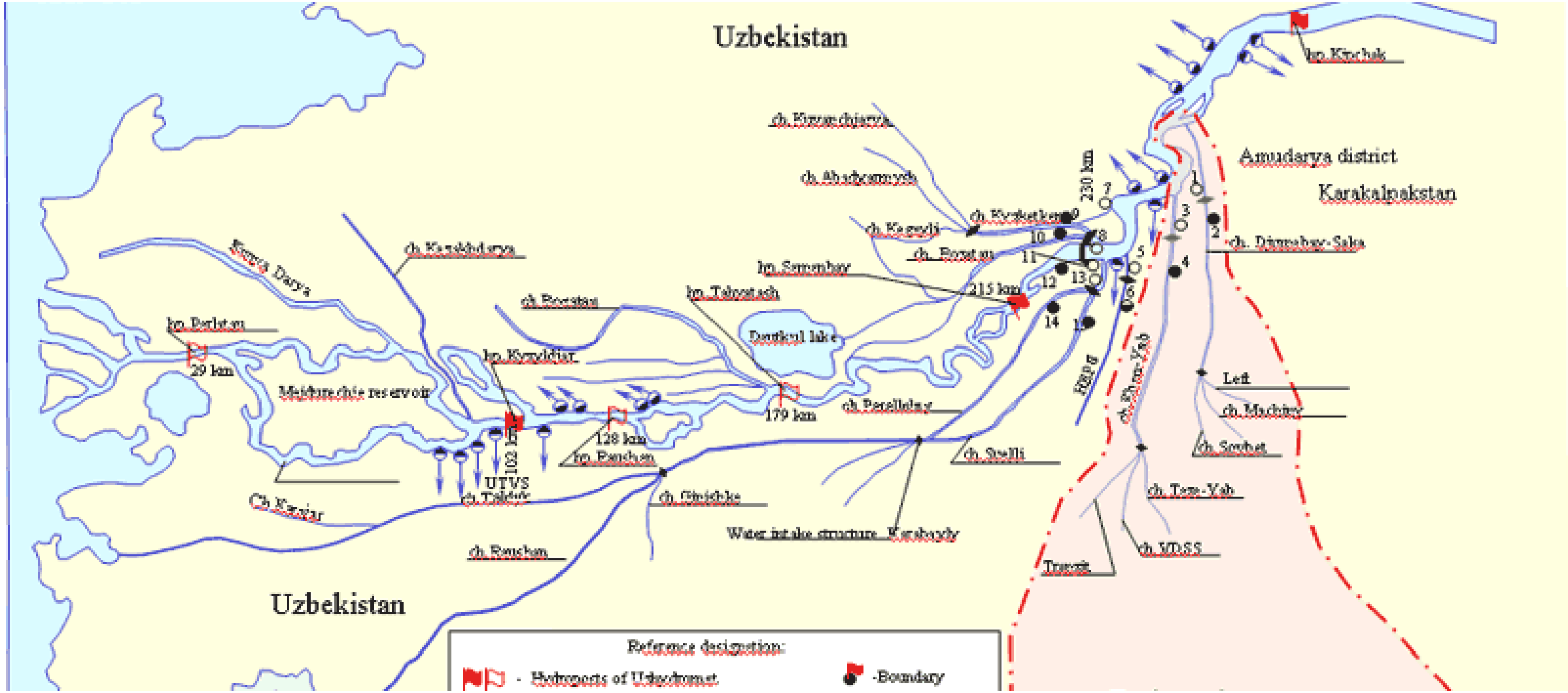
# Location of hydrostations



# Total volume of water withdrawn from the canals



# Total volume of water withdrawn from the canals



# Total volume of water withdrawn from the canals

| The total water withdrawn by the canal systems is… | | | | | |
|---|---|---|---|---|---|
| April | May | June | July | August | September |
| 92% of outflow | 95% of outflow, with a maximum of 3,500 $Mm^3$/month | 98% of outflow, with a maximum of 4,000 $Mm^3$/month | 98% of outflow, with a maximum of 5,500 $Mm^3$/month | 97% of outflow, with a maximum of 5,500 $Mm^3$/month | 96% of outflow, with a maximum of 2,500 $Mm^3$/month |
| October | November | December | January | February | March |
| 90% of outflow, with a maximum of 1,200 $Mm^3$/month | 80% of outflow | 94% of outflow | 88% of outflow | 98% of outflow | 98% of outflow |

# Volume of water consumed by irrigation

| The water allocated (consumed) to irrigation is… | | | | | |
|---|---|---|---|---|---|
| April | May | June | July | August | September |
| 89% of the total water withdrawn by the canals, with a maximum of 1,537 $Mm^3$/month | 95% of the total water withdrawn by the canals, with a maximum of 2,639 $Mm^3$/month | 96% of the total water withdrawn by the canals, with a maximum of 3,393 $Mm^3$/month | 97% of the total water withdrawn by the canals, with a maximum of 4,538 $Mm^3$/month | 96% of the total water withdrawn by the canals, with a maximum of 4,370 $Mm^3$/month | 92% of the total water withdrawn by the canals, with a maximum of 1,884 $Mm^3$/month |
| October | November | December | January | February | March |
| 85% of the total water withdrawn by the canals, with a maximum of 971 $Mm^3$/month | 72% of the total water withdrawn by the canals, with a maximum of 408 $Mm^3$/month | 80% of the total water withdrawn by the canals, with a maximum of 1,583 $Mm^3$/month | 80% of the total water withdrawn by the canals, with a maximum of 578 $Mm^3$/month | 92% of the total water withdrawn by the canals, with a maximum of 825 $Mm^3$/month | 94% of the total water withdrawn by the canals, with a maximum of 2,290 $Mm^3$/month |

# Volume of water to the ecosystems

- No real allocation to Khorezm's and Karakalpakstan's ecosystems in the current situation.
- The amount reaching the lakes, wetlands and the Aral Sea is rather:
  - the remaining flow in the Amu Darya, after all canal diversions,
  - and the drainage flow out of the canal/collectors systems.
- Both terms will be calculated dynamically during the modelling.

# Analysis of economic data

# Volumetric Net Benefit for agricultural production

| | (UZS/year/$m^3$) | |
|---|---|---|
| | Khorezm | Karakalpakstan |
| **2021** | 178 | 90 |
| **2022** | 276 | 125 |
| **2023** | 231 | 99 |
| **Average** | 228 | 104 |

# Benefits from ecosystems

- Total economic benefit from the ecosystem services in the Amu Darya delta amounts to approximately 5 to 7 million USD per year. The value of 6 million USD per year is considered.
- Ecosystems in the Khorezm province collectively generate around 0.7 to 1 million USD per year. 0.8 million USD per year is used.
- => in total about **6.8 million USD ≈ 87 billion UZS per year**.

# Benefits from ecosystems

- This benefit of 87 billion UZS per year is expected to be attained only when the ecosystems receive sufficient water.
- As we will see later, it corresponds when ecosystems receive 6.3 billion $m^3$/year.
- 87 billion UZS / 6.3 million $m^3$ = **14 UZS/$m^3$/year**.
- This is much smaller than volumetric benefit from agriculture:
  - 228 UZS/year/m3 in Khorezm.
  - 104 UZS/year/m3 in Karakalpakstan.
- Ecosystems do not only provide services that can be quantified in economic terms; they also possess cultural, social, religious and natural values that cannot be measured economically but are of significant importance.

# Setting the WEAP model

# Scenarios examined in WEAP

# Two categories of scenarios

- Principal scenarios in which essential changes are examined, where policymakers have leverage:
  - Greater allocation to ecosystems.
  - Rehabilitation of canal systems is analysed.

- Sensitivity scenario, where the consequences of the principal scenarios are examined under changes in the background with no leverage.
  - Scenarios of climate change.

# Scenario of greater allocation to the ecosystems

- Greater allocation of water to the ecosystems in Khorezm and Karakalpakstan.
- Several sources of information support this flow requirement to maintain the ecological balance of the Amu Darya delta:
  - Project Document for the UNDP project: between 3.6 to 4.75 $Bm^3$/year.
  - Scientific Information Center of the Interstate Commission for Water Coordination of Central Asia (SIC-ICWC): 5.9 $Bm^3$/year.
  - CAREC: 5.2 to 6.3 $Bm^3$/year.

# Scenario of greater allocation to the ecosystems

- Considered 3 ranges:
  - Low flow requirement: 3.6 $Bm^3$/year, to be applied for low flows of the Amu Darya.
  - Average flow requirement: 4.75 $Bm^3$/year, to be applied for average flows of the Amu Darya.
  - High flow requirement: 6.3 $Bm^3$/year, to be applied for high flows of the Amu Darya.
- Two sub-scenarios to satisfy this flow requirement:
  - With flow from the collectors and the remaining flow of the Amu Darya (current situation – issue with water quality).
  - With flow only from the Amu Darya river, while the collectors can supply additional water beyond this minimum amount (different to the current situation – ensure better water quality into the ecosystems).

# Scenario of rehabilitation of canal systems

| Province | Canal system | Main features | Investment cost (million USD) |
|---|---|---|---|
| **Khorezm** | P-8 | • Modernisation of 27 km of canal.<br>• Reconstruction of hydraulic structures.<br>• Efficiency improved from 56% to 90%. | 34 |
| **Karakalpakstan** | Kegeyli | • Concrete lining of the whole canal.<br>• Restoration of hydraulic structures.<br>• Efficiency improved from 65% to 90%. | 72.9 |
| | Quo'anish Jarma | Improved water supply | 43 |
| | Suenly and Parallel canals | • Concrete lining of the whole canal.<br>• Restoration of hydraulic structures.<br>• Introduction of SCADA system.<br>• Improved irrigation efficiency by 15% to 30%. | 118 |

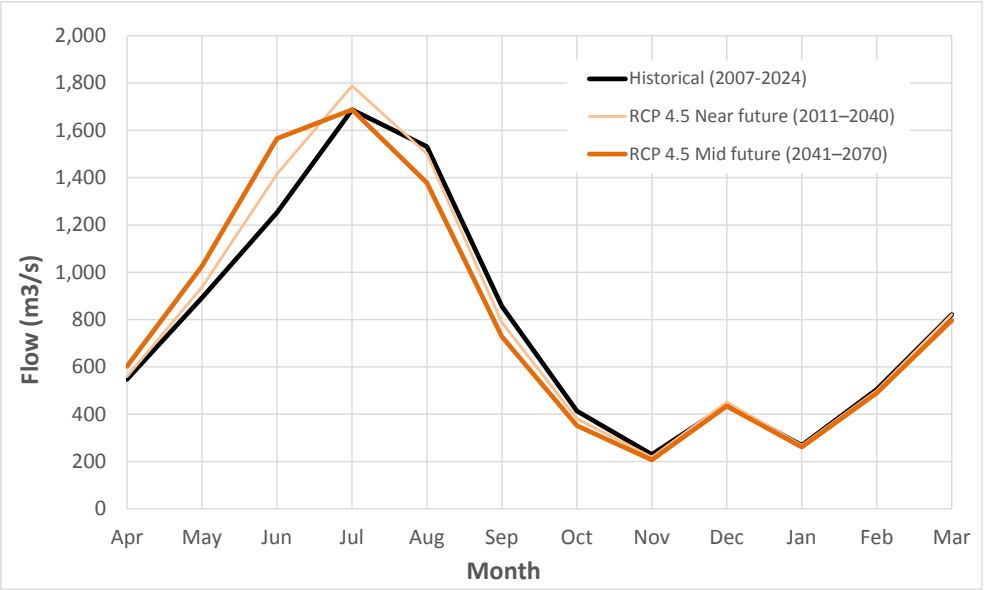
# Scenario of rehabilitation of canal systems

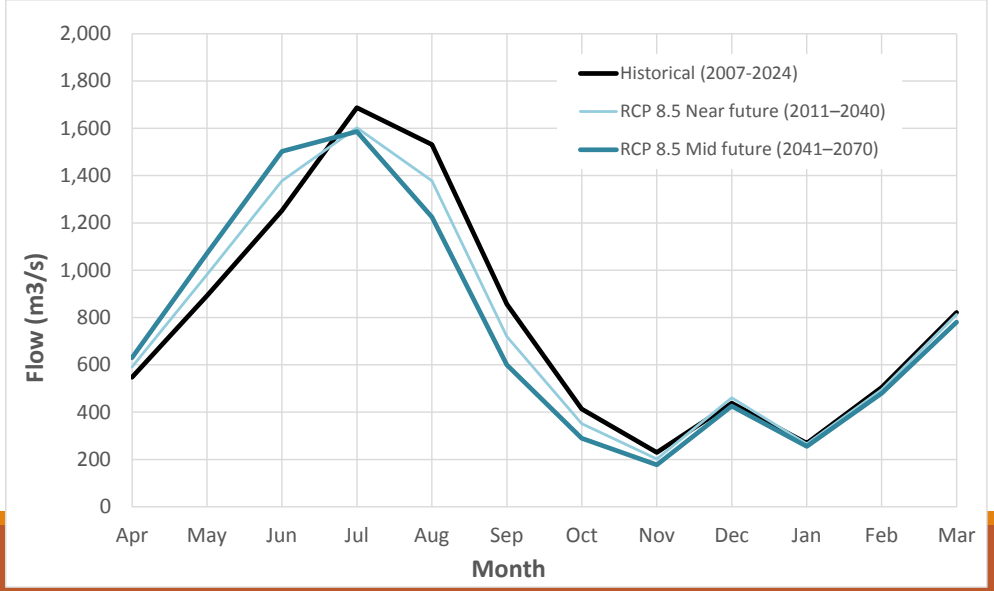
- The following is assumed:
  - The anticipated improvement in Khorezm is expected to be negligible in the context of the entire province.
  - For Karakalpakstan, it is anticipated that each project will enhance irrigation efficiency by 20%, taking a conservative approach, for a total cost of 234 million USD.
- Rehabilitations in Karakalpakstan are planned for four of the seven main canals in the province.
- To assess the aggregated impact for the entire province, information provided by the Water Resources Ministry of Karakalpakstan
- A weighted average are used to evaluate the impact at the provincial scale, with canal capacity serving as the weight => improvement of 10.5% for the entire province.

# Scenario of climate change

- Based on existing scientific articles, for some sub-basins of the Amu Darya basin.

- Main impact:
  - Reduction in the average annual streamflow occurs simultaneously with greater variation in streamflow.
  - Shifting peaks in river discharge to occur earlier (by up to one month).



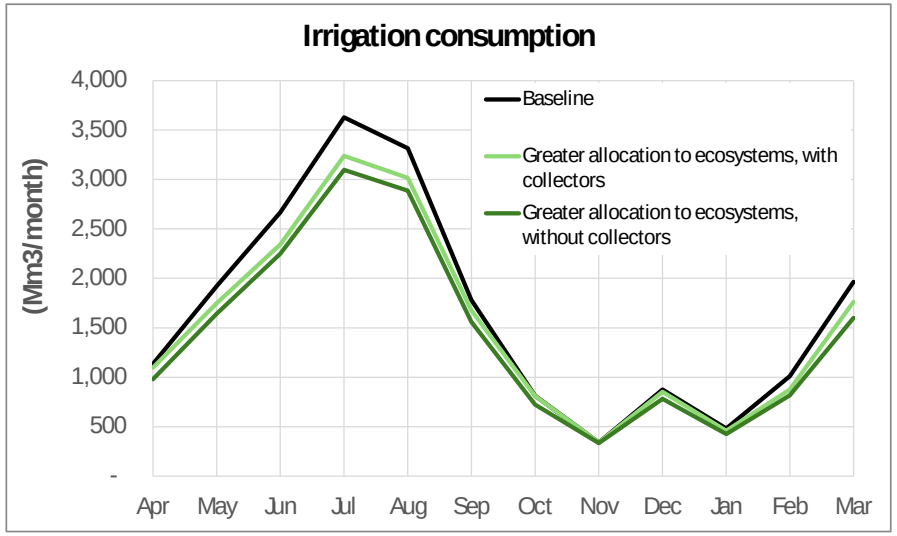



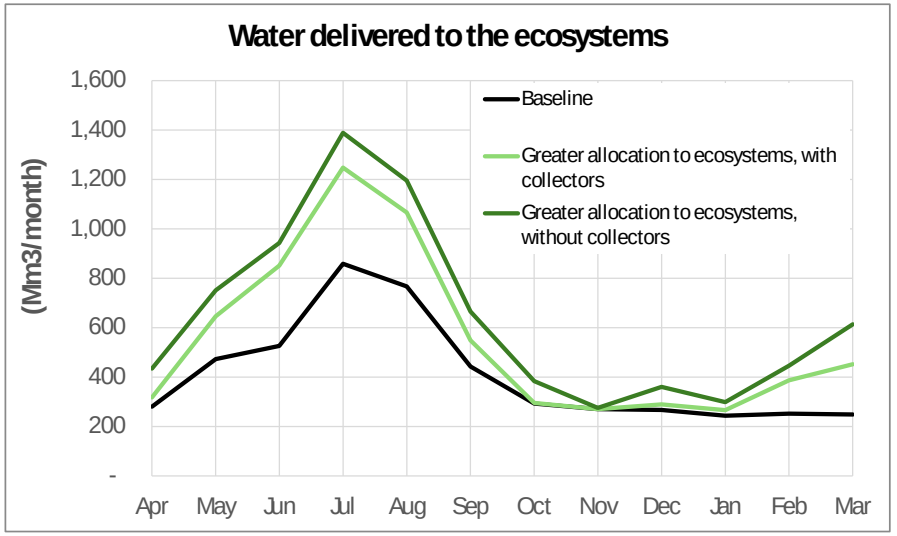
# Results of the modelling

# Discussion

# Discussion on the results

- Scenario of greater allocation to ecosystems, without contributions from collectors, yields the greatest allocation to ecosystems.




| | 6.3 Bm³ | 4.75 Bm³ | 3.6 Bm³ |
|---|---|---|---|
| Baseline | 24% | 29% | 35% |
| Greater allocation to ecosystems, with canals | 29% | 59% | 100% |
| Greater allocation to ecosystems, without canals | 47% | 94% | 100% |

Number of years when the streamflow to the Amu Darya delta is greater than or equal to the Ecosystem flow requirement

| | (billion UZS/year) | | |
|---|---|---|---|
| | Agriculture | Ecosystems | Total |
| Greater allocation to ecosystems, with canals | -190 | 24 | -166 |
| Greater allocation to ecosystems, without canals | -314 | 39 | -274 |

Change in Net Benefit

# Discussion on the results

- Scenario of canal rehabilitation:
  - Does not produce significant benefits for ecosystems, given its high capital cost.
  - Furthermore, the water saved through improved irrigation efficiency would likely be reused for additional irrigation.

- Effect of climate change:
  - Expected to cause an earlier shift in the peak of streamflow (from July to June), more significantly for RCP8.5 than for RCP4.5.
  - In both RCP 4.5 and 8.5, the water supply increases from April to June, while it is reduced from July to October.
  - Under RCP 4.5, the increase in volume during spring offsets the decrease in summer, but this is not the case for RCP8.5

# Limitations

- Due to data unavailability:
  - Absence of information on operational rules for water management and distribution => the modelling was based neither on operational rules nor on physical processes, but rather on empirical relations derived from the collected data. This implies that the model merely simulates the operation in the LADAB as it was in the past, without any capacity to adapt to changes.
  - The operational rules of the Tuýamuyun reservoir were unavailable, as was the time series data on the water budget in the reservoir. Modelling the reservoir's operation would enable better allocation in the scenarios, particularly allowing for a greater buffering of climate impacts.
  - Based on information provided by stakeholders, the allocation of water from the reservoir was one-third each for Khorezm, Turkmenistan, and Karakalpakstan. However, data collected from the Amu Darya Delta Irrigation System Authority suggest that this equal share may not occur systematically every year, resulting in some variation from year to year.

# Limitations

- Due to data unavailability:
  - Assessing the economic valuation of ecosystems is cumbersome. The resulting volumetric Net Benefit used in the modelling (14 UZS/year/m3) may not be exhaustive, and some monetary benefits may not have been accounted for. Furthermore, ecosystems possess much greater value beyond monetary benefits, which are not captured in the modelling.
  - Individual canal systems were not represented in the model due to their high complexity and lack of data. Two aggregated canal systems were considered instead: one for Khorezm and Turkmenistan, and another for Karakalpakstan.
  - The various lake and wetland systems in Khoreszm and Karakalpakstan were not included in the model. Although this does not affect the results, the allocation to the ecosystems could be further disaggregated, at least for the main lakes (e.g., Sudoche, Zholdyrbas, Mashankul–Khojakul).

# Limitations

- In the scenario analysis:
  - It was assumed in the scenario of canal rehabilitation that saved water from improved irrigation efficiency would be reallocated to ecosystems. This may be unlikely, as saved water would typically be reused to irrigate lands facing water deficits before the rehabilitation.
  - The scenarios of climate change were based on the available papers at the time of writing this report, namely CMIP5 simulations, while the latest results from the IPCC rely on CMIP6, and the IPCC is also working with CMIP7 ensemble => should be updated when latest climate change results for the Amu Darya are available.

# Conclusion

- Policy implications:
  - Tradeoff between agriculture and ecosystems.
  - Impact of greater allocation to the ecosystems:
    - On Agriculture: -14% in irrigation supply and Net Benefit.
    - On the Ecosystems: +58% increase in flow to Amu Darya delta
  - => the tradeoff is substantial improvement to ecosystems for a relatively small impact on agriculture.
  - There is potential that the losses in livelihood from agriculture could be compensated by advantages provided by ecosystems.
  - Additionally, ecosystems offer non-monetary benefits that can enhance the lives of local inhabitants.

# Conclusion

- Improving this work:
  - This is a first modelling attempt providing initial insights into options for increasing ecosystem allocation.
  - This work would greatly benefit from further efforts to address some of its limitations:
    - Providing the operation rules and water budget of the Tuýamuyun reservoir.
    - Gathering the operational rules for the various canals and collectors system, as well as the actual water flow.
    - Account for future plans and scenarios for agriculture and irrigation in the LADAB.
    - An extensive valuation of the monetary benefits provided by the ecosystems in the LADAB is necessary (e.g., accounting for revenues from ecotourism).

# Thanks for your attention and for UNDP's support in collecting the data!