Growth and impending decline in groundwater dependent agriculture: simulation modeling informs sustainability policies in Konya, Turkey

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PRIMA
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COMMENTARY:

The global groundwater crisis

J. S. Famiglietti

Groundwater depletion the world over poses a far greater threat to global water security than is currently acknowledged.

Groundwater — the water stored beneath Earth's surface in soil and porous rock aquifers — accounts for as much as 33% of total water withdrawals worldwide[1]. Over two billion people rely on groundwater as their primary water source[2], while half or more of the irrigation water used to grow the world's food is supplied from underground sources[1].

Groundwater also acts as the key strategic reserve in times of drought[3], in particular during prolonged events such as those in progress across the western United States (Fig. 1), northeastern Brazil and Australia. Like money in the bank, groundwater sustains societies through the lean times of little incoming rain and snow. Hence, without a sustainable groundwater

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Article

Rapid groundwater decline and some cases of recovery in aquifers globally

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Groundwater resources are vital to ecosystems and livelihoods. Excessive groundwater withdrawals can cause groundwater levels to decline[1–10], resulting in seawater intrusion[11], land subsidence[12,13], streamflow depletion[14–16] and wells running dry[17]. However, the global pace and prevalence of local groundwater declines are poorly constrained, because in situ groundwater levels have not been synthesized at the global scale. Here we analyse in situ groundwater-level trends for 170,000 monitoring wells and 1,693 aquifer systems in countries that encompass approximately 75% of global groundwater withdrawals[18]. We show that rapid groundwater-level declines (>0.5 m $year^{-1}$) are widespread in the twenty-first century, especially in dry regions with extensive croplands. Critically, we also show that groundwater-level declines have accelerated over the past four decades in 30% of the world's regional aquifers. This widespread acceleration in groundwater-level deepening highlights an urgent need for more effective measures to address groundwater depletion. Our analysis also reveals specific cases in which depletion trends have reversed following policy changes, managed aquifer recharge and surface-water diversions, demonstrating the potential for depleted aquifer systems to recover.

Nature, v. 265, 25 Jan 2024

Outline of the talk

Problem and purpose of the study

Research highlights

Research design

The field in a nutshell

Model elements and results

Research outcomes, lessons learned!

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- Groundwater is an “invisible”, spatially fragmented, uncertain, common-pool resource.
- Policies for sustainable groundwater management can be hard to implement, primarily due to common pool resource characteristics of groundwater.
- Resource users often lack a well-defined and shared understanding of the problems associated with water consumption, which typically results in “wait and see approach”.
- Policy experimentation in real life is often not feasible since the outcomes of interventions emerge extremely slowly and prohibitively costly.
- Modeling facilitates learning, align stakeholder perspectives, support informed decision-making through simulation on experimental platforms.

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"Living lab" approach is adopted in model development and testing!

Critical focus on the drivers of water demand and supply.

- Drivers of demand: farmers' choices of crops, technology and factor use
- Drivers of supply: water in aquifers, infrastructure for pumping

Partial model validation with a hydrogeological model.

Published online with a comprehensive user interface.

Model exploration reveals desirable policy interventions for sustainable futures.

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Activity	Dates	Purpose
Desktop Search	November 2020 – March 2021	Familiarization with the study area, governance, and groundwater management
1st Field Campaign	March 23-26, 2021	Familiarization with the stakeholders, snowballing, stakeholder mapping
2nd Field Campaign	July 4-9, 2021	Further snowballing, living lab building
1st Workshop	September 30, 2021	Trust building, dynamic problem identification
2nd Workshop	February 17, 2022	Conceptual model development
Modeling	October 2021 – March 2023	Model development, validation, analysis
3rd Field Campaign	January 16-18, 2023	Model testing and validation
3rd Workshop	March 21, 2023	Model-based policy analysis

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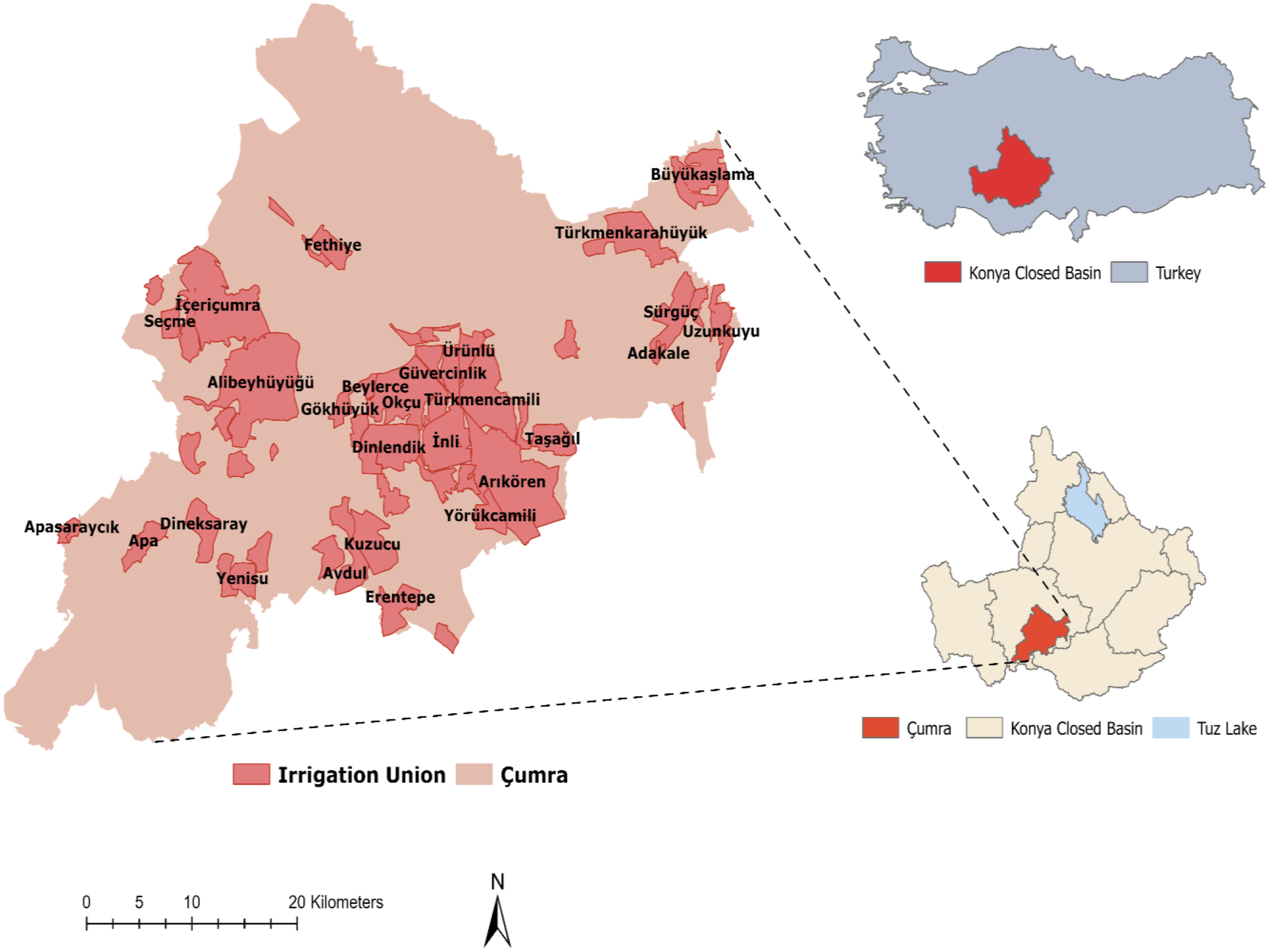

Büyükaşlama
Türkmenkarahüyük
Fethiye
İçeriçumra
Seçme
Sürgüç
Uzunkuyu
Adakale
Ürünlü
Güvercinlik
Alibeyhüyüğü
Beylerce
Gökhüyük
Okçu
Türkmencamili
İnli
Taşağıl
Dinlendik
Arıkören
Yörükcamili
Apasaraycık
Dineksaray
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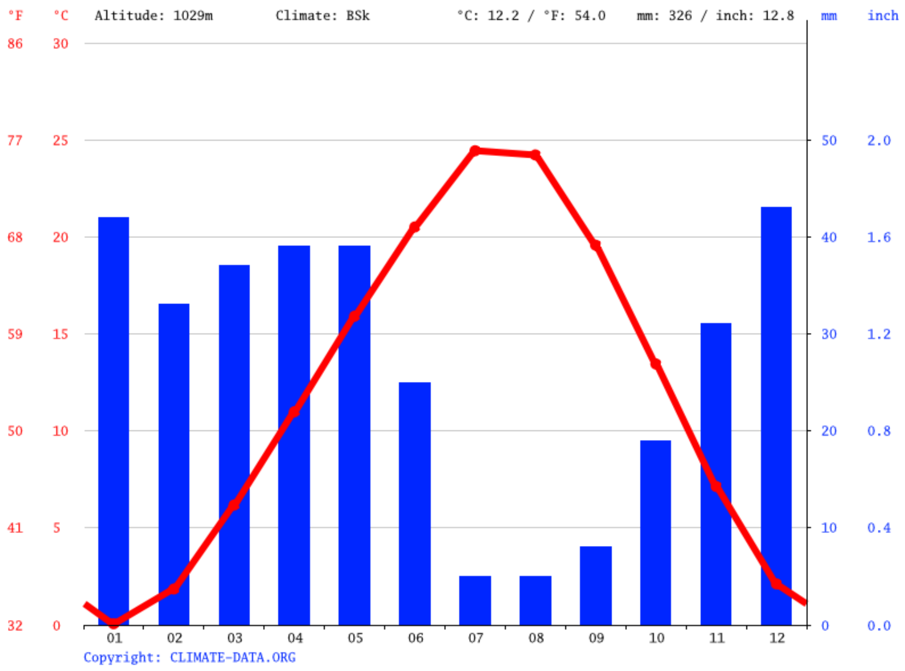

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mm: 326 / inch: 12.8
mm
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77 25
68 20
59 15
50 10
41 5
32 0
50 2.0
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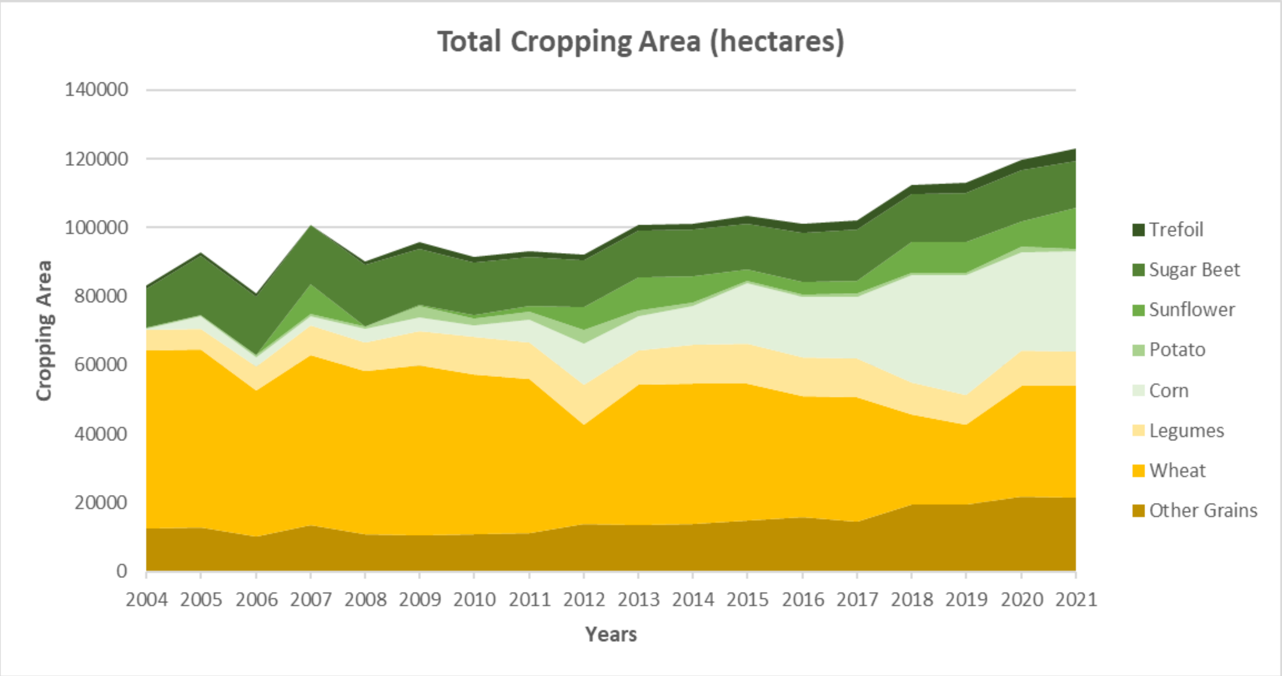
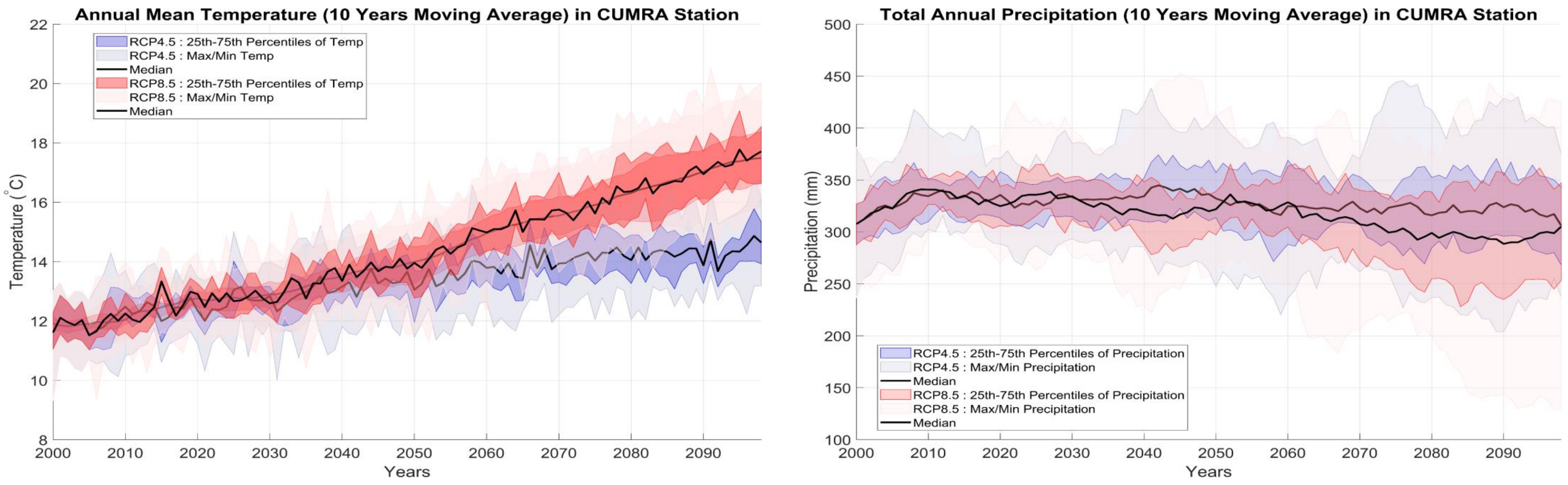
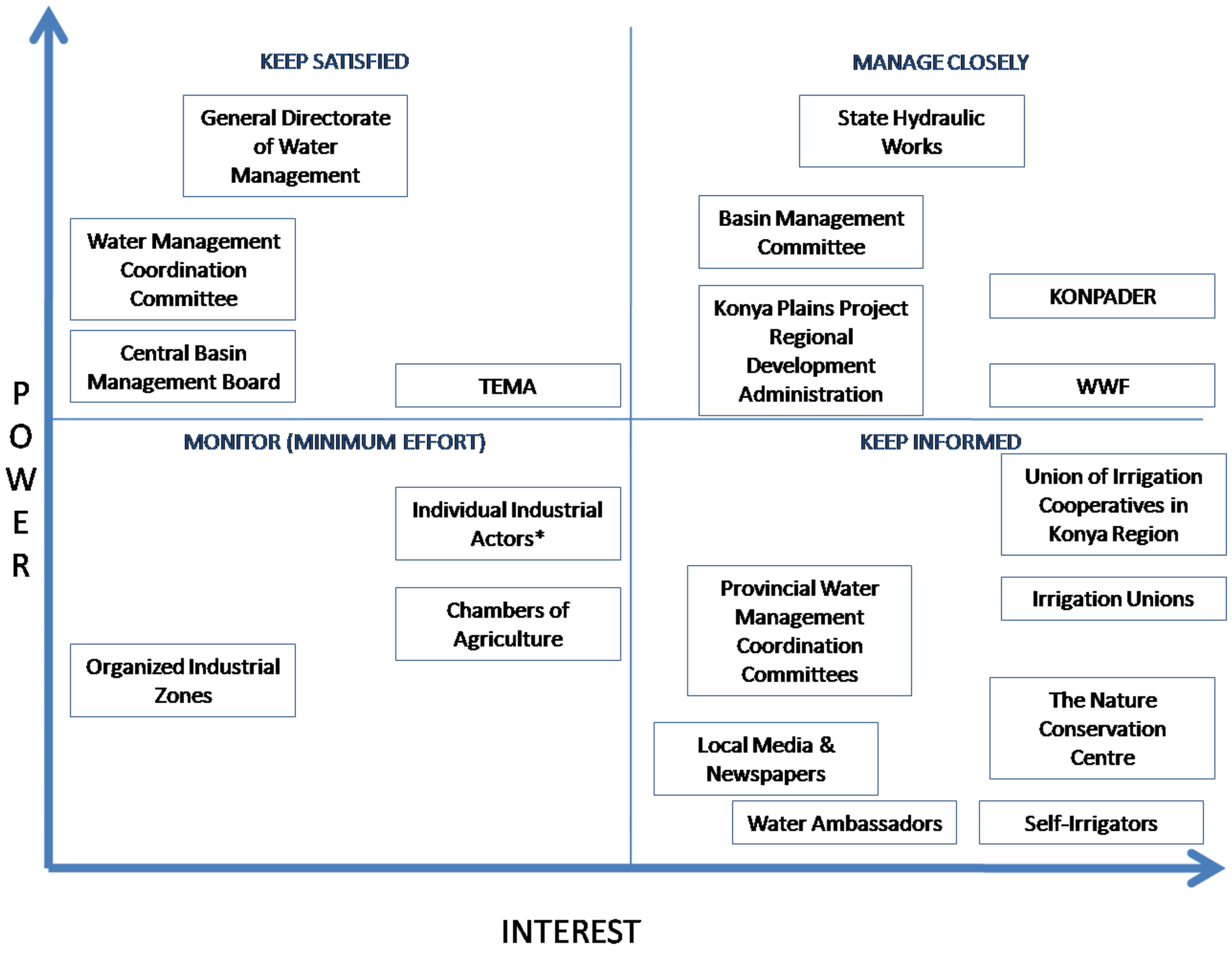


Temporal change in annual cropping area in Konya Closed Basin from 2004 to 2021 (Data source: TUIK, 2021)

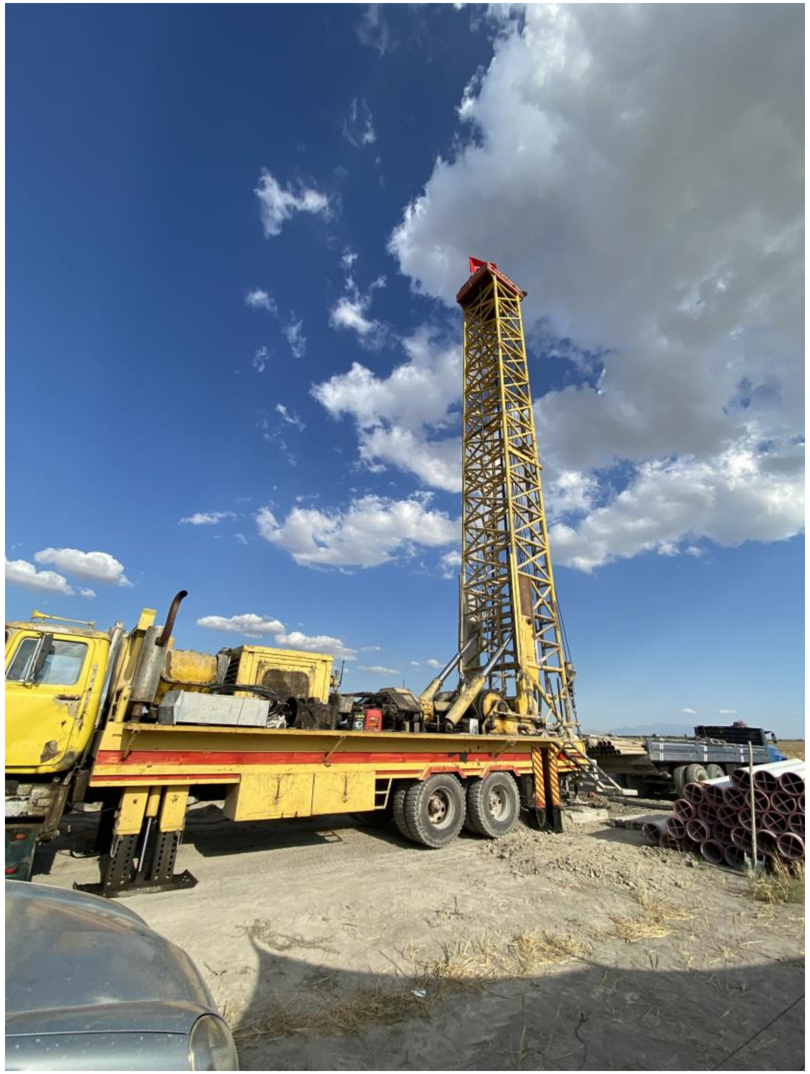
Annual average change in groundwater levels in Konya Closed Basin depicted in 5 year moving average (Source of data: DSI, 2021)



Future (2020-2100) change in annual mean temperature and precipitation in Çumra, in terms of 10-year moving average projected by the 17 RCMs for RCP 4.5 and RCP 8.5 (from Todaro et al. 2022).



Stakeholders overview with respect to relative power and interest (Murray-Webster and Simon, 2006)



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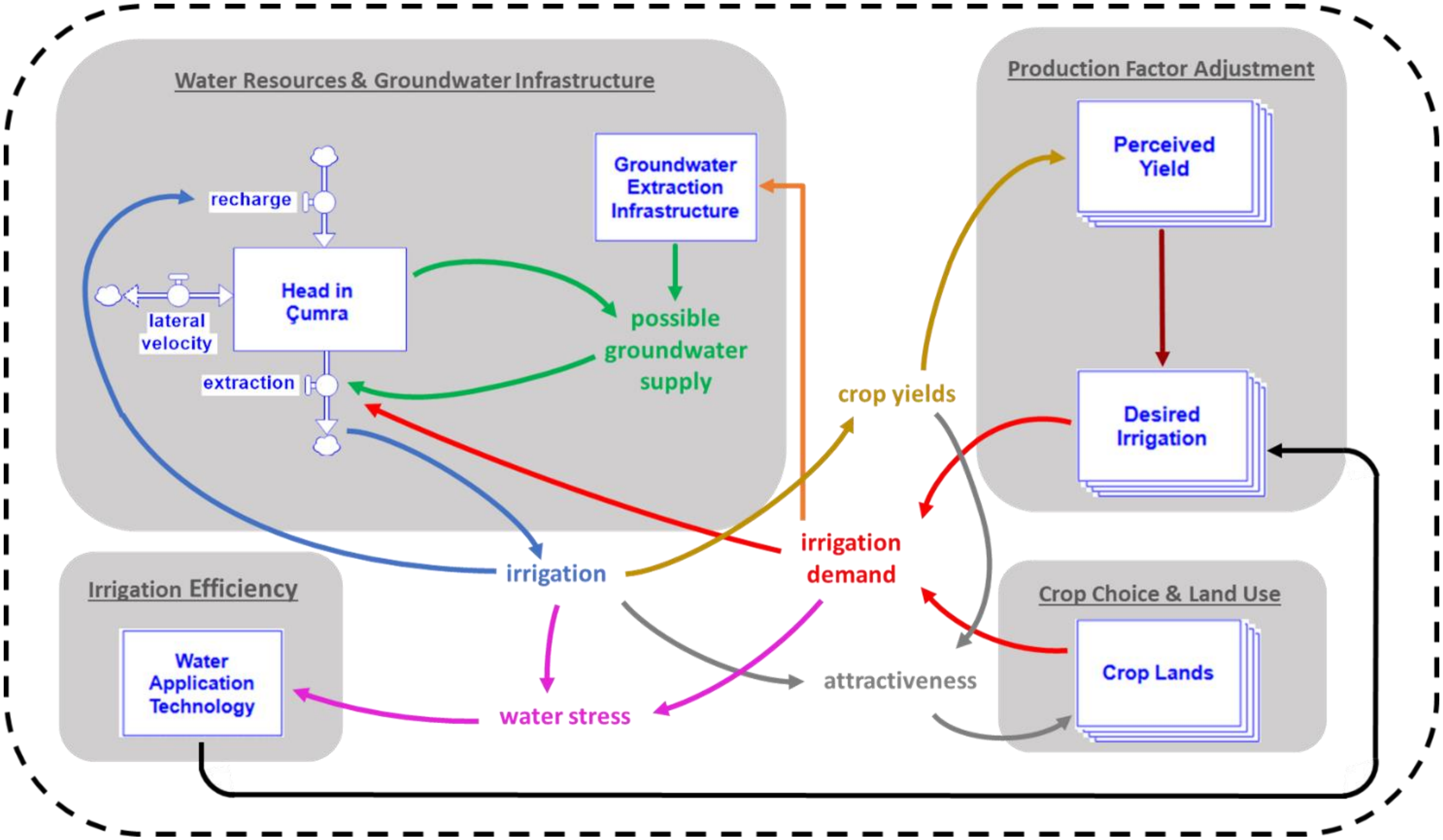
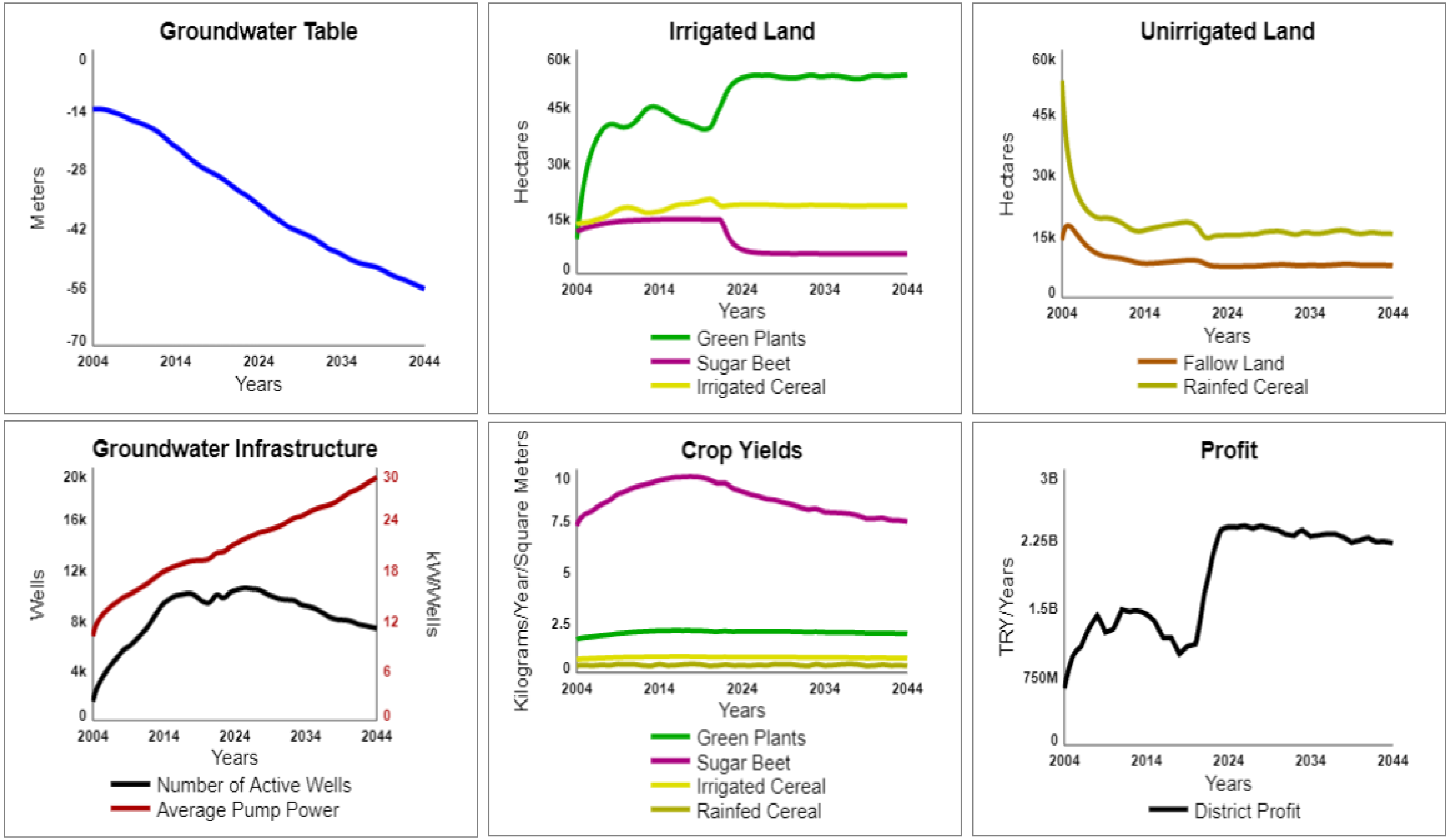
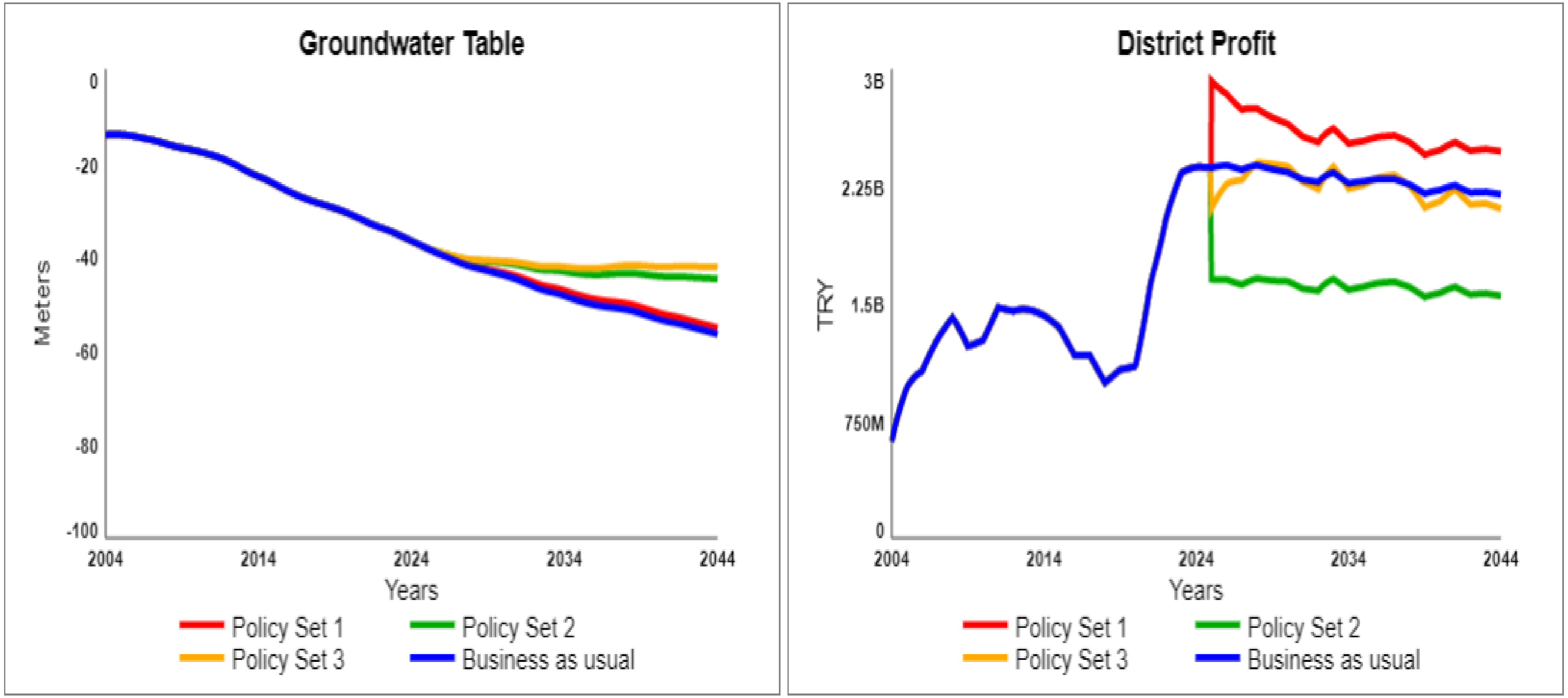


Model structure overview



Model reference behavior



Policy set 1: Farmers' favorite to save the short term
Policy set 1: The regulators' favorite to save the long term
Policy set 3: Explored compromise

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Client engagement and trust building in modeling and analysis

The field work and the "living lab” approach

Interdisciplinarity in applied research and role of system dynamics

Model results and its implications