Groundwater mining and food security: Challenges and opportunities

Claudia Ringler, with Nicos Perez, Hua Xie
Wei Zhang, Hagar Eldidi & Ruth Meinzen-Dick
Environment and Production Technology Division
International Food Policy Research Institute

Innovation Pathways to Sustainability
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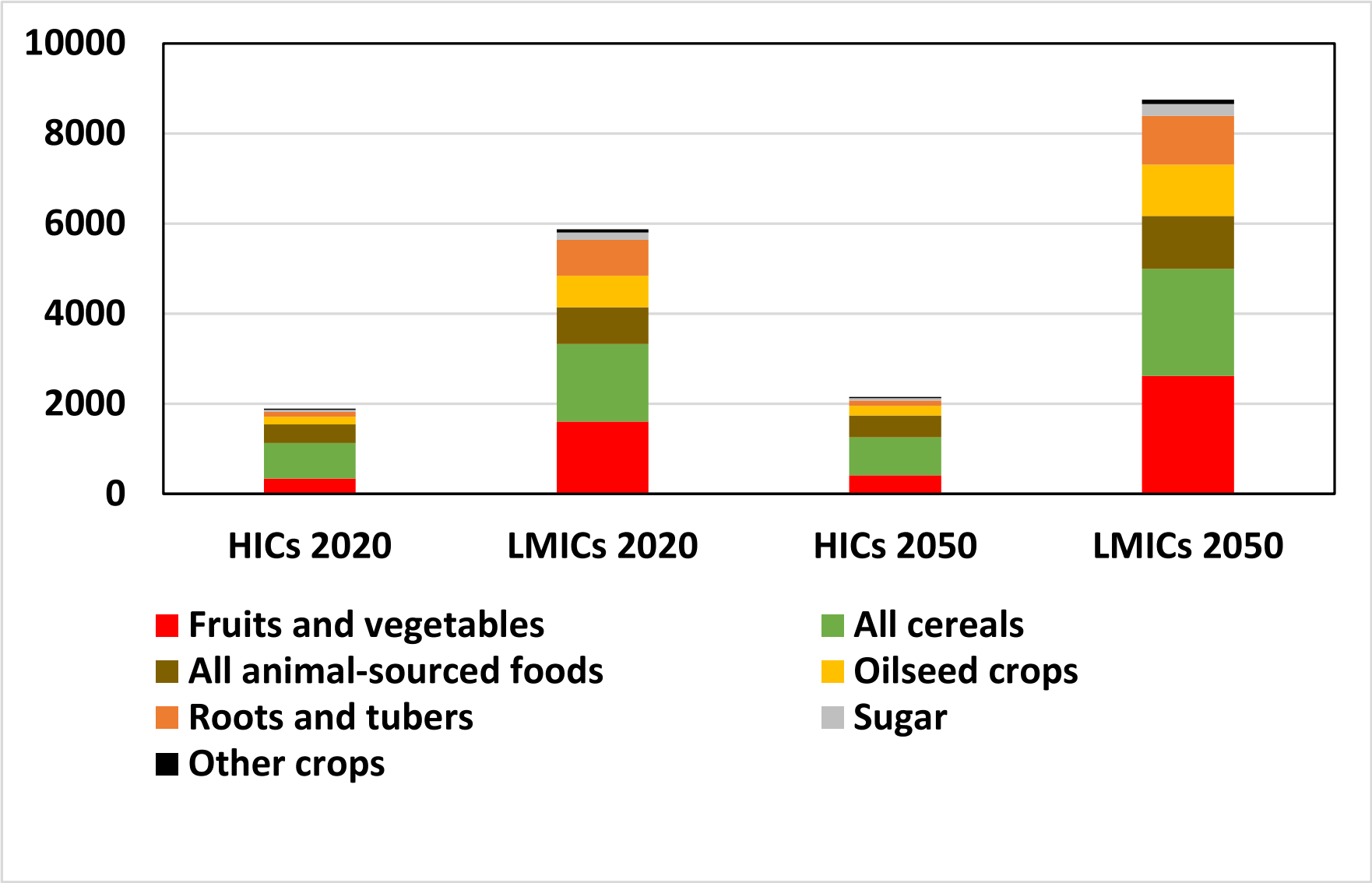
1. The Role of Groundwater for Food Security

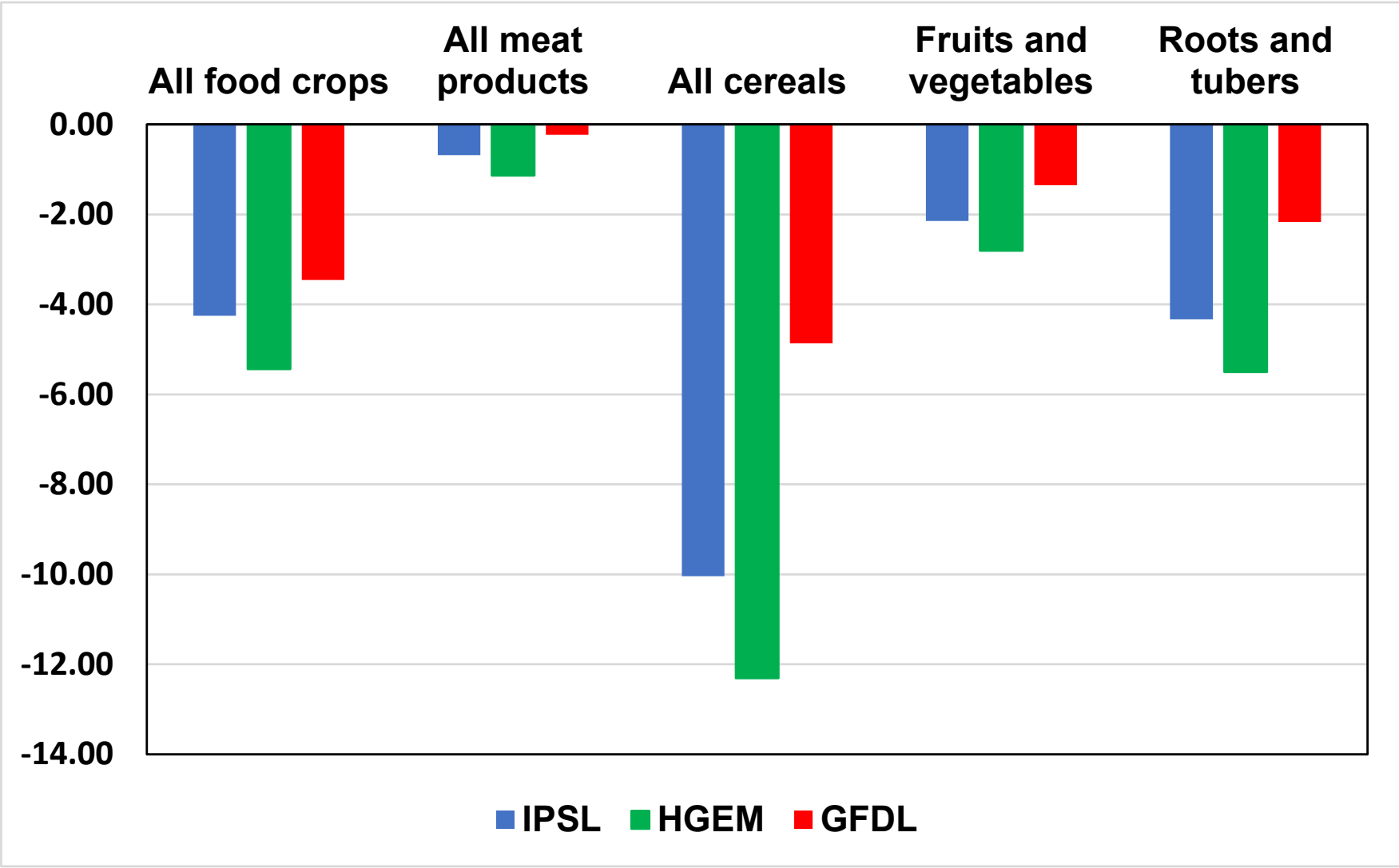
Photo credit: IFPRI Flickr

Large increases in total demand (in million metric tons, NoCC)



Source: IFPRI IMPACT

Impact of climate change on production (change from 2050 NoCC)



Source: IFPRI IMPACT

Why groundwater matters

- Irrigation accounts for more than 80% of consumptive use of withdrawn water
- Groundwater plays a large and growing role in total water withdrawals and use, and is now the source of 20-30% of irrigation withdrawals and a larger share of consumptive use
- This is due to cheaper well-drilling technology and cheaper individual pumps that became available during the late 1970s and 1980s
- Groundwater has an important buffer function during climate extreme events—storing flood waters, which can be pumped during the dry season
- Groundwater depletion (mining/overdraw) refers to groundwater extraction that is not returned to the aquifer through recharge

Image: Lyla Mehta

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Impacts of groundwater depletion

- Land subsidence
- Reduced well yield
- Increased pumping costs
- Salinization of coastal groundwater resources
- Groundwater degradation
- Reduced flows to surface water sources
- Outmigration out of areas where livelihoods are not possible anymore

Dr J. Poland's picture of land subsidence
in Mendota, San Joaquin Valley, California, USA, 1925-77

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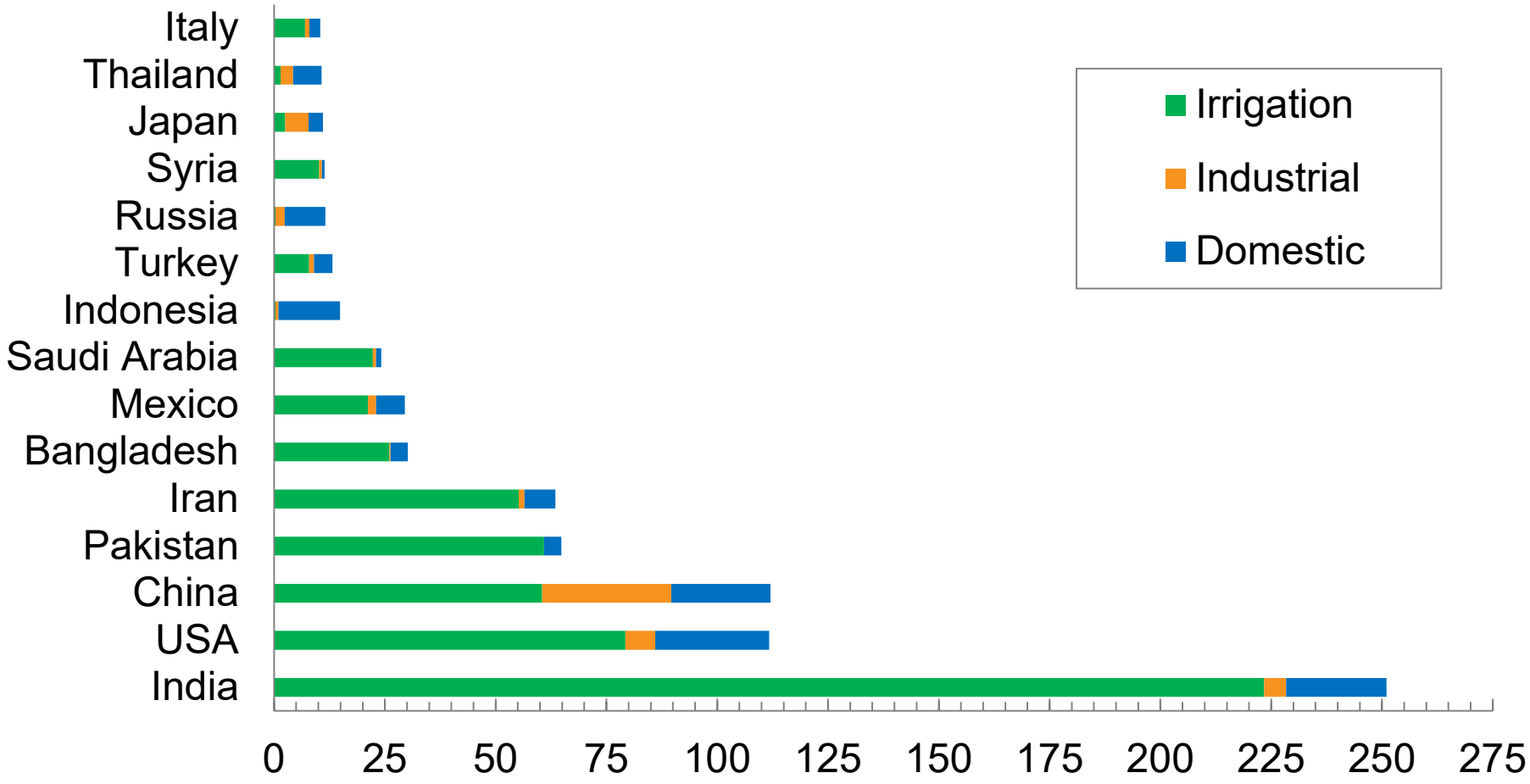
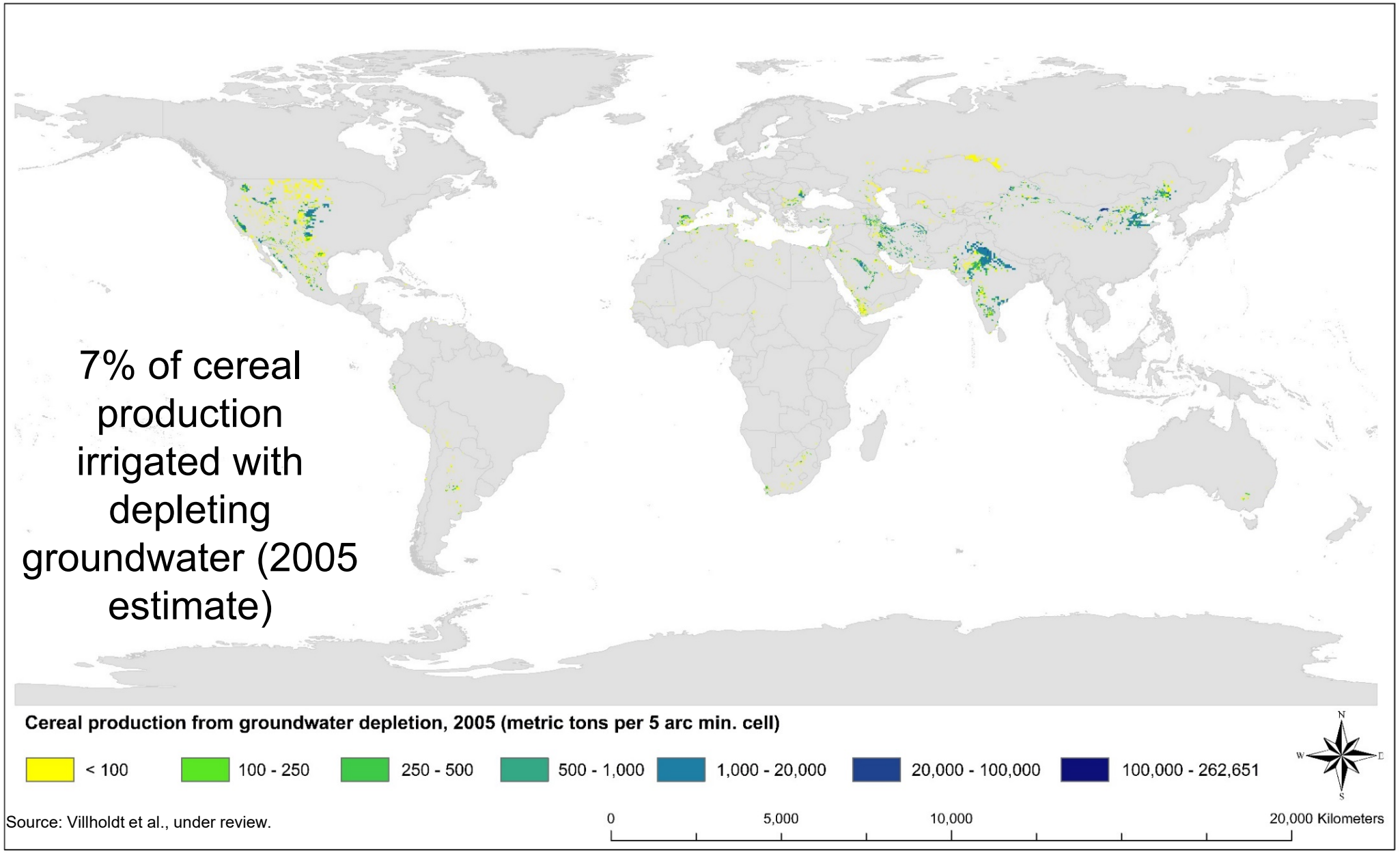
Largest groundwater users



Source: Margat and van der Gun (2013).

Groundwater depletion affects food security even today



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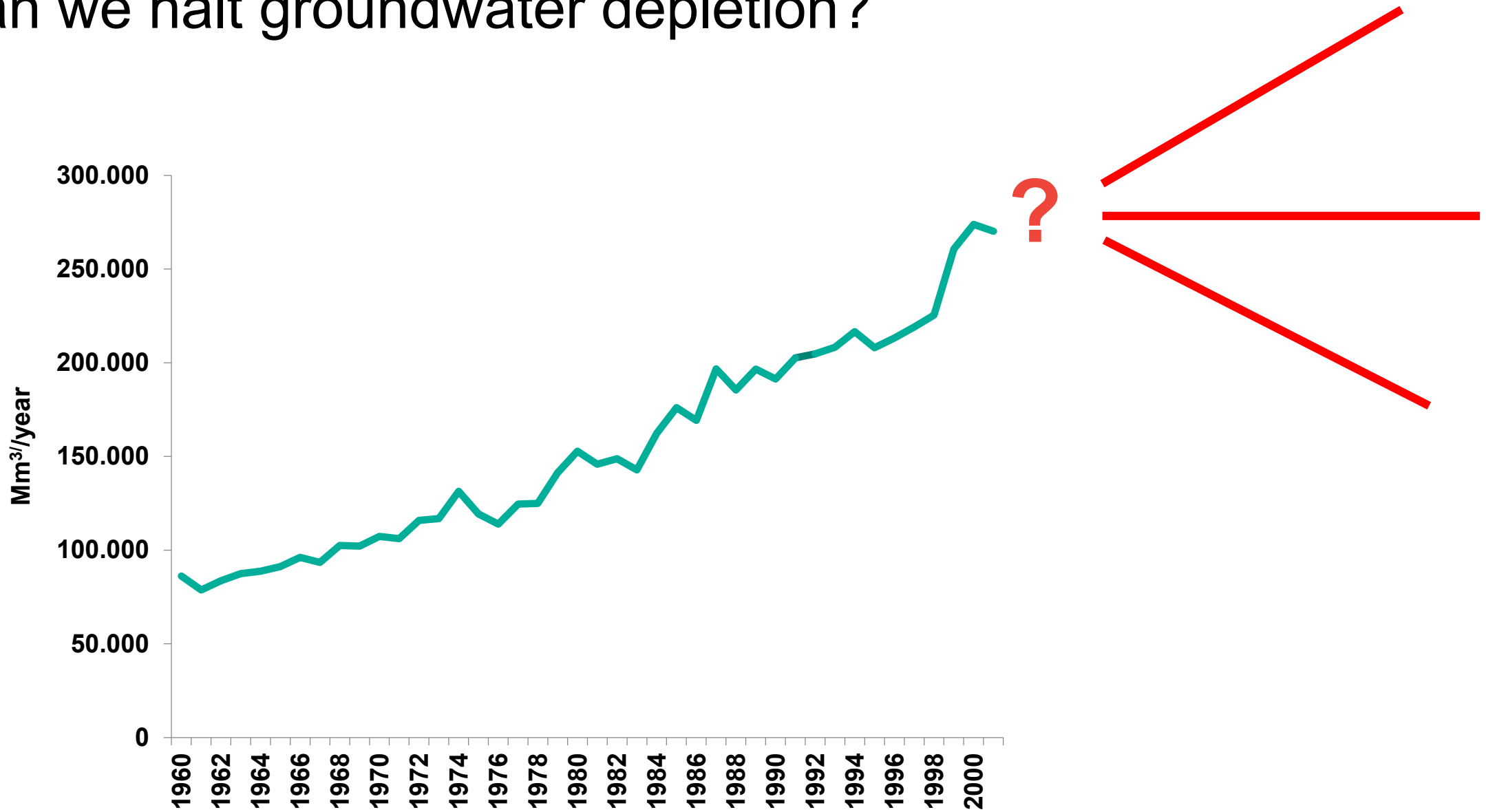
Can we halt groundwater depletion?



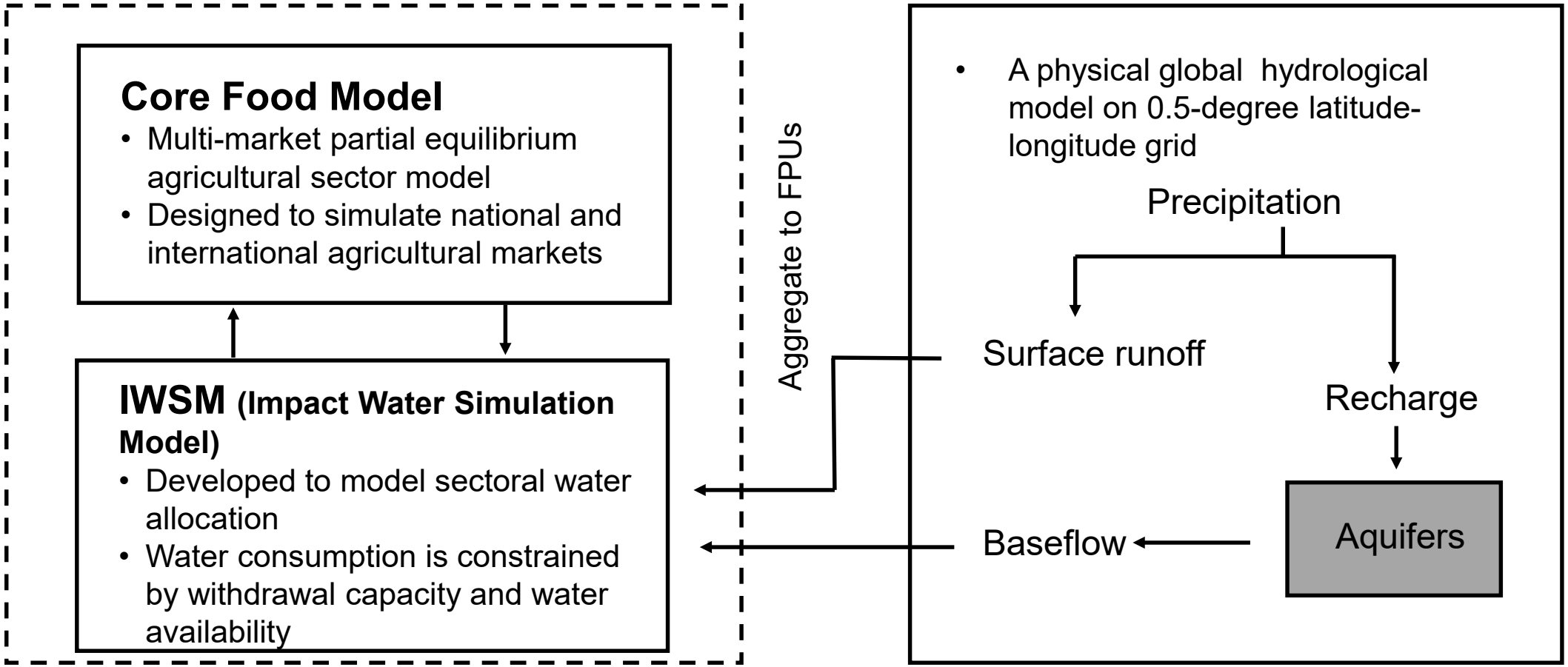
Source: Wada et al. (2012)

2. Alternative Groundwater Futures

Photo credit: IWMI

IMPACT Food Model

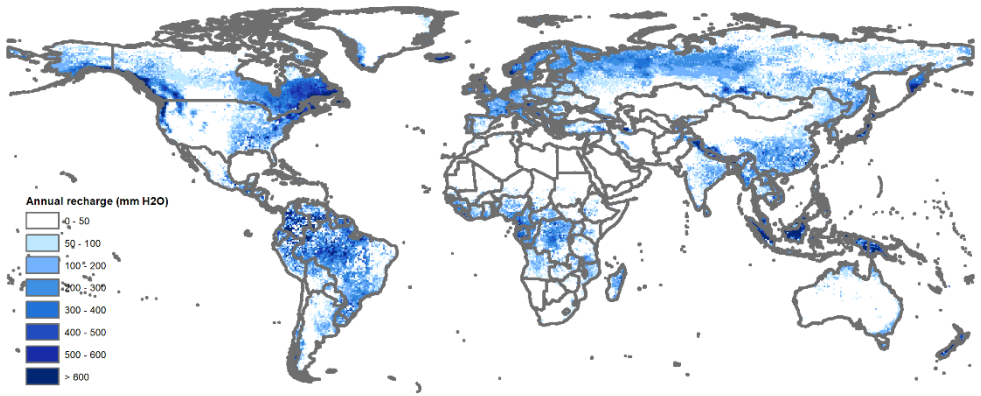
IGHM (IMPACT Global Hydrology Model)



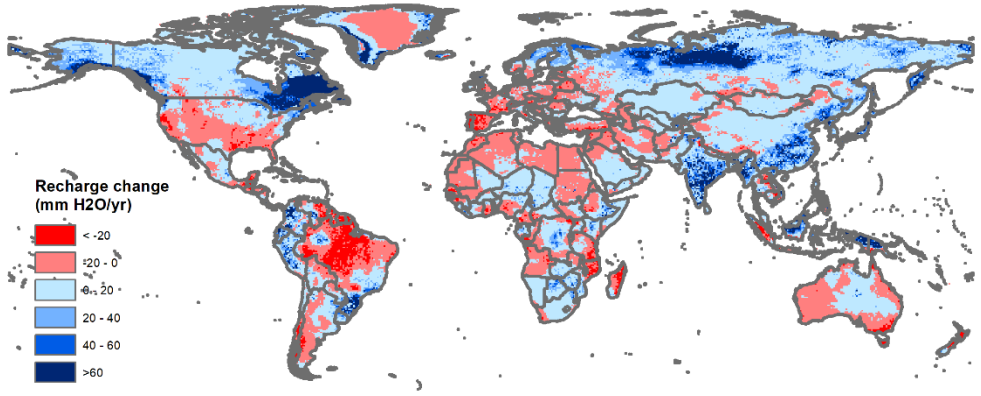
Source: IFPRI IMPACT

Groundwater recharge changes with climate change

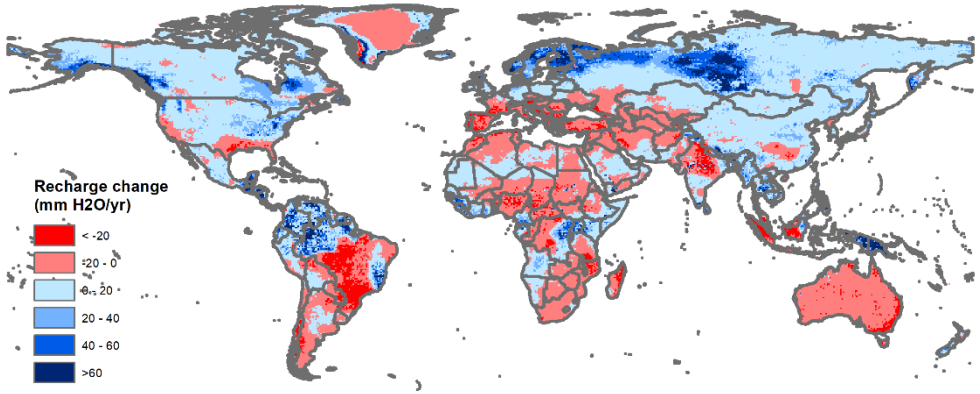
Annual recharge in base year



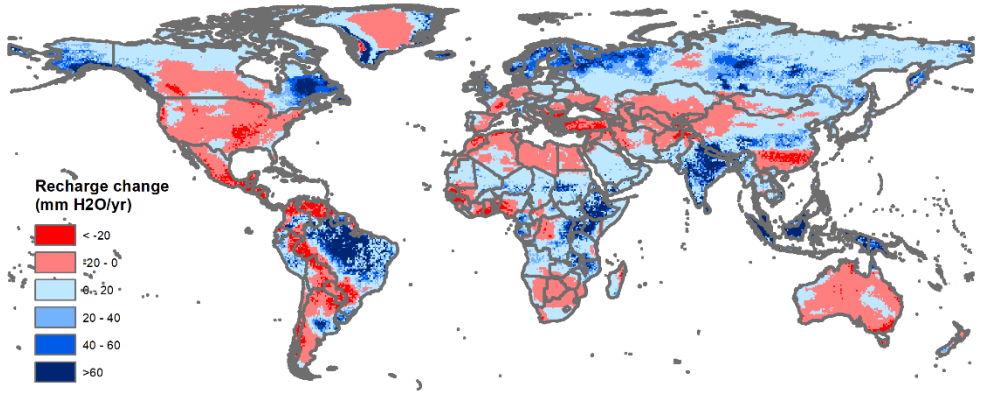
Annual recharge change – HADGEM+RECP8.5



Annual recharge change – GFDL+RECP8.5



Annual recharge change – IPSL+RECP8.5



Source: IFPRI IMPACT

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The role of groundwater in global food security

2020

Climate/Region		Rain water	Surface water	Ground water
		billion cubic meters		
NoCC	World	5,978	1,598	650
	HICs	943	268	87
	LMICs	5,034	1,330	563
IPSL	World	6,164	1,600	650
	HICs	947	270	88
	LMICs	5,217	1,330	563
HGEM	World	6,074	1,612	653
	HICs	933	268	91
	LMICs	5,141	1,344	562
GFDL	World	6,016	1,611	654
	HICs	944	269	88
	LMICs	5,072	1,342	566

2050

Climate/Region		Rain water	Surface water	Ground water
		billion cubic meters		
NoCC	World	6,673	1,866	749
	HICs	945	309	96
	LMICs	5,729	1,557	653
IPSL	World	7,299	1,879	761
	HICs	956	310	100
	LMICs	6,343	1,569	661
HGEM	World	7,020	1,909	758
	HICs	917	308	107
	LMICs	6,102	1,601	651
GFDL	World	6,809	1,878	765
	HICs	951	308	101
	LMICs	5,859	1,570	664

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Source: IFPRI-IMPACT

Groundwater conservation—what does it take?
Explorative scenario development

- Reference scenario: continued growth in groundwater use and depletion
- Conservation without compensation (use = recharge – EF)
- Conservation with increased GW use in areas without overdraft
- Conservation with increased investment in agricultural R&D (short duration/dwarf varieties, drought and heat stress tolerance, etc.
- Conservation with more effective use of precipitation – Share of effective rainfall used increased by 5% on rainfed lands through zero till, mulching, rainwater harv
- Conservation with declining demand for animal-sourced food in HICs +China + Brazil (income elasticities -10%)

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3. Impact on Food Security

Photo credit: IWMI

Global crop water management needs to focus on improving productivity of rice, wheat, sugarcane and maize (BCM, calculated 2020)

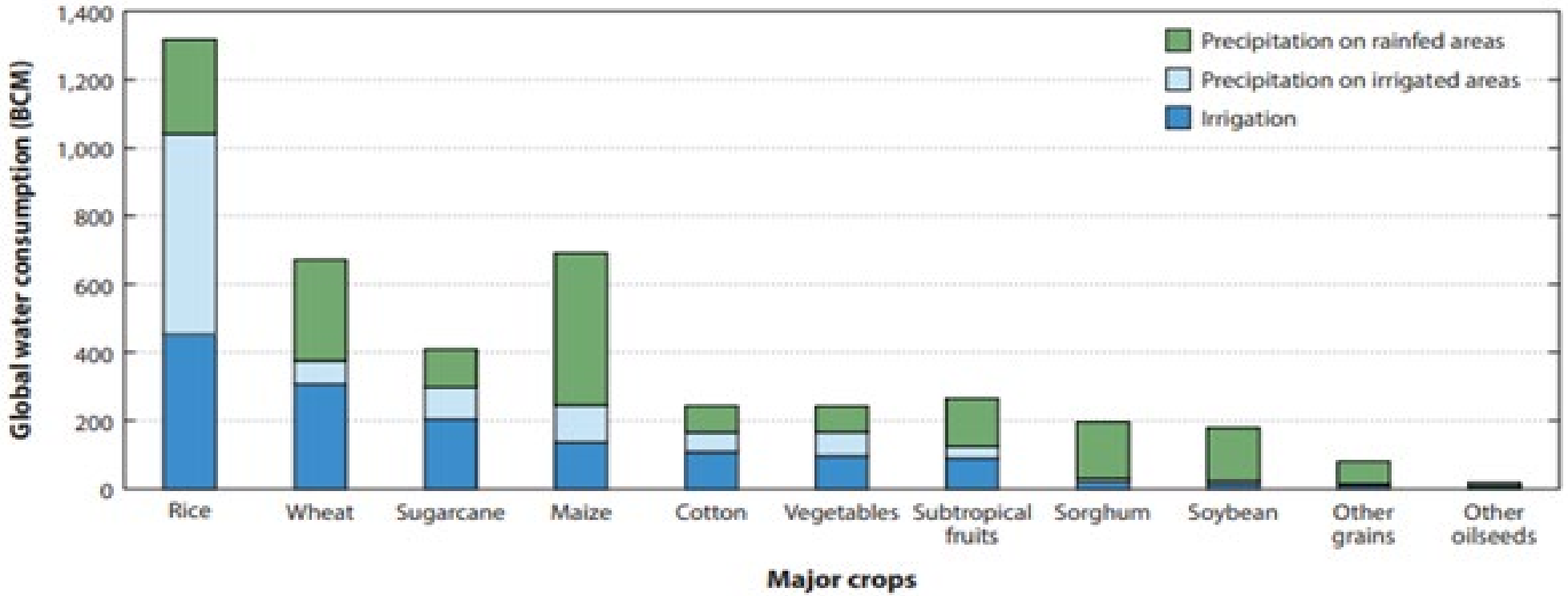


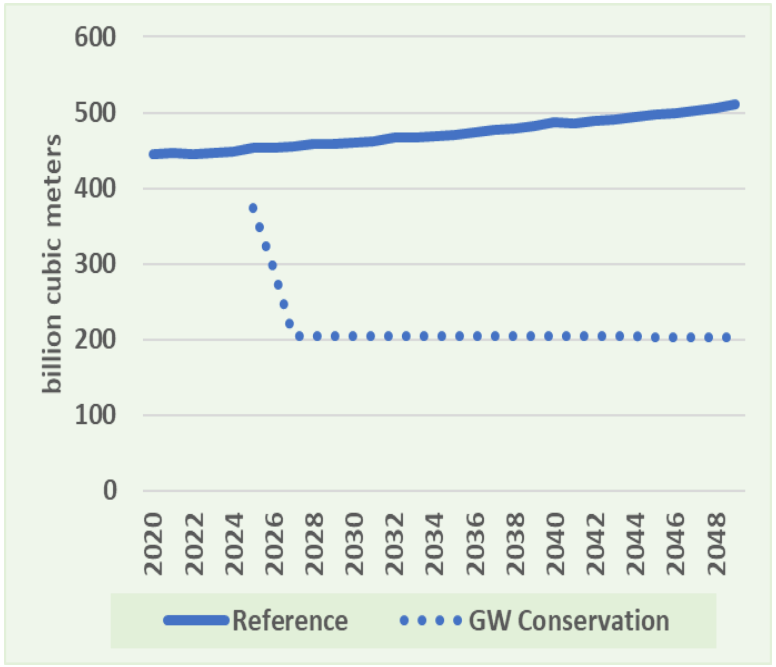
Figure 1

Global water consumption by major crops (consumptive use, BCM, calculated for 2020). Abbreviation: BCM, billion cubic meters or km^3. Data from IFPRI (2020).

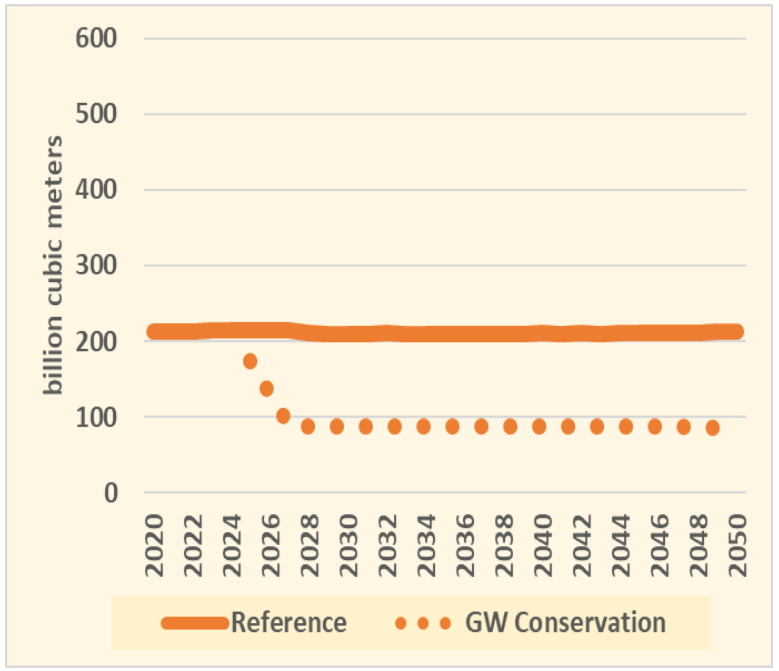
Source: IFPRI. 2020

Groundwater conservation—what does it take? (HGEM)

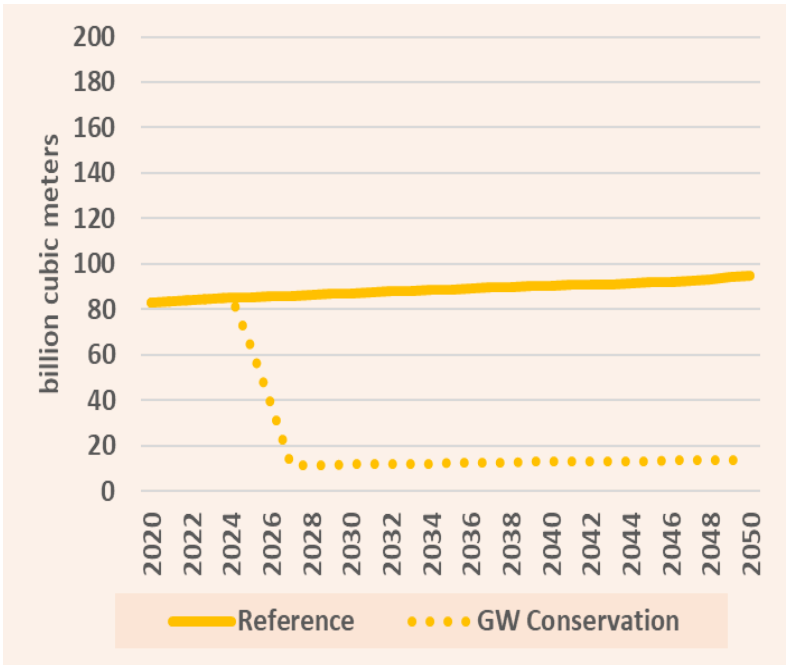
India



China



USA



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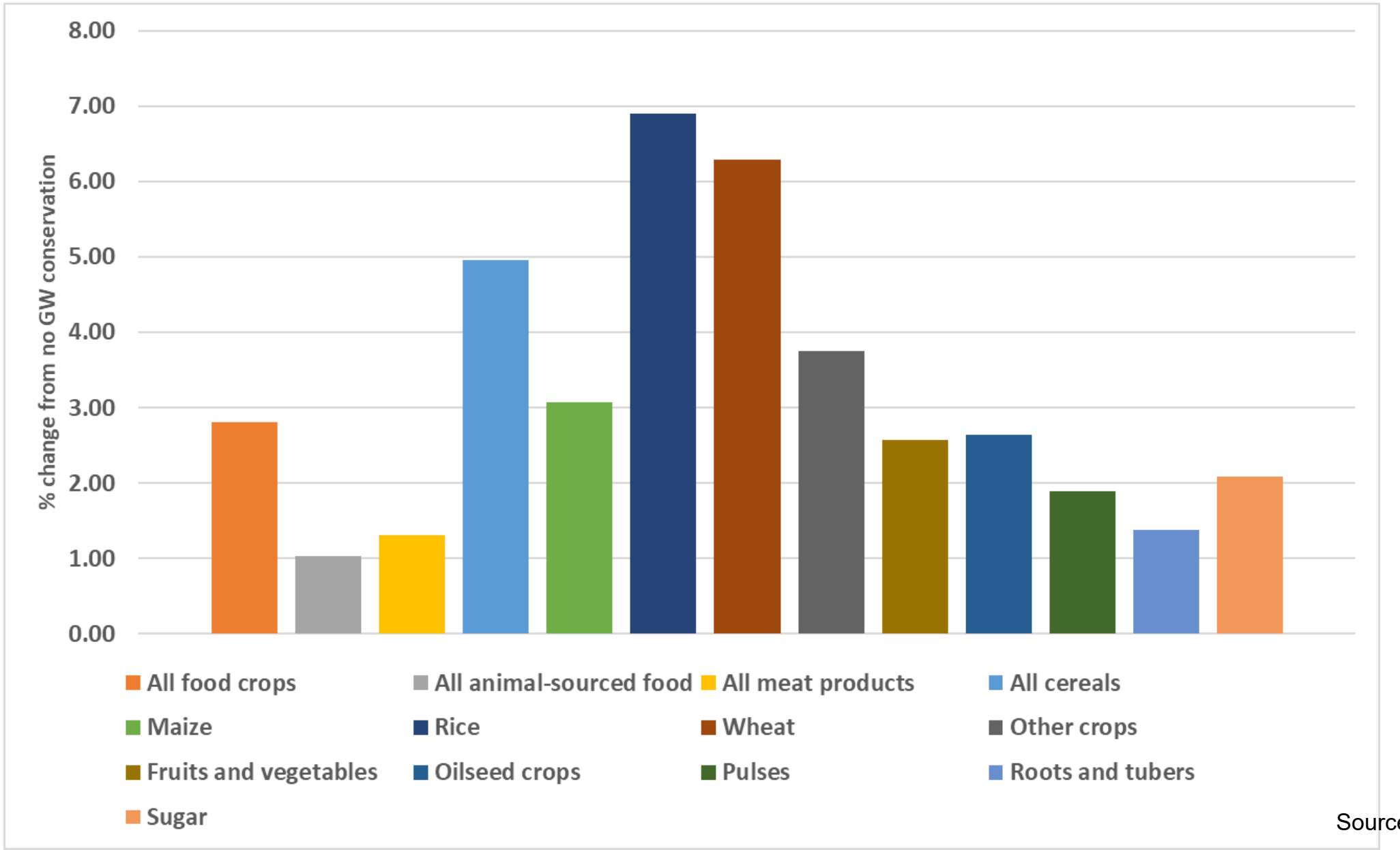
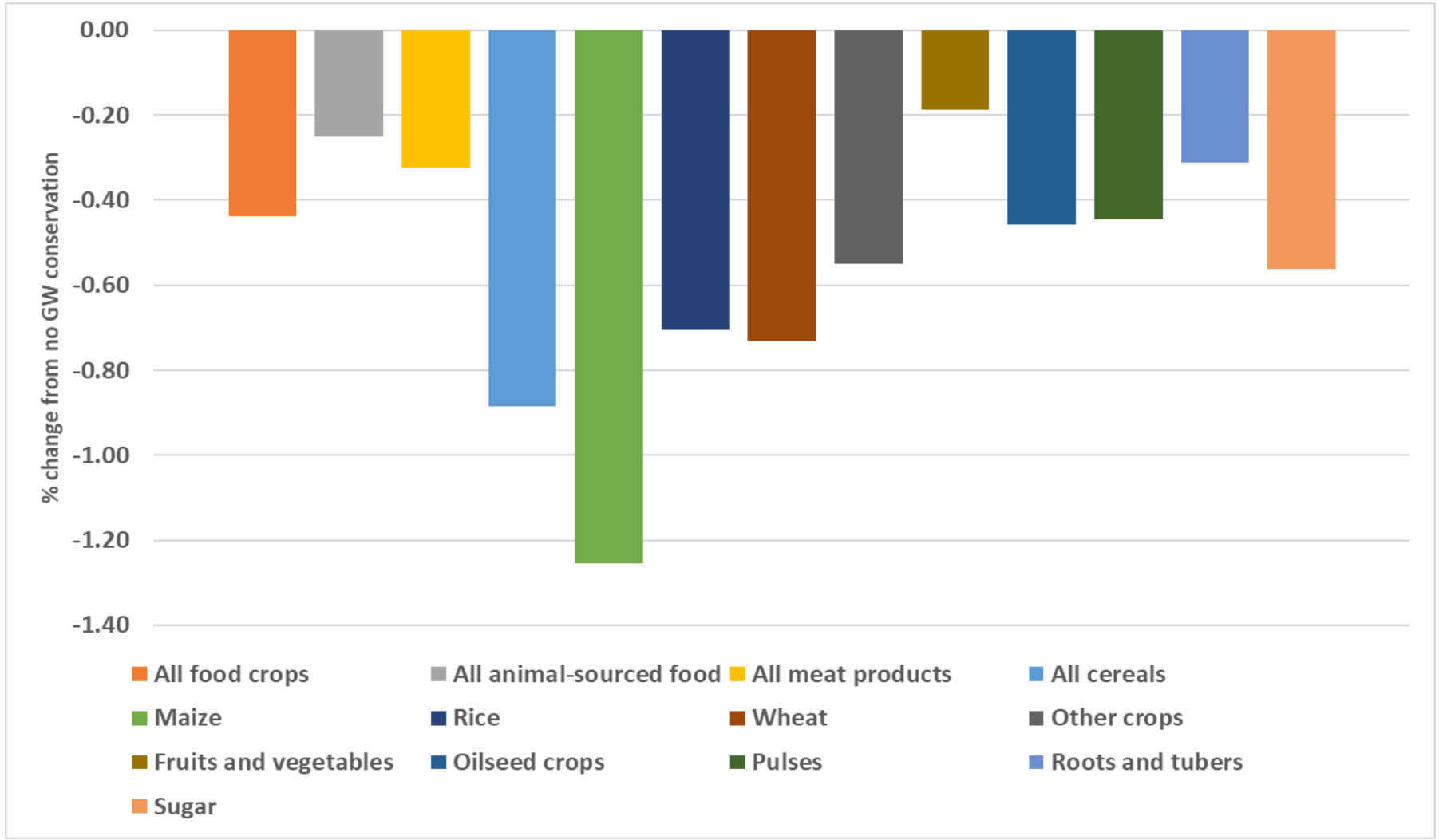
Impacts on food prices: HGEM +GW Conservation (GWC)



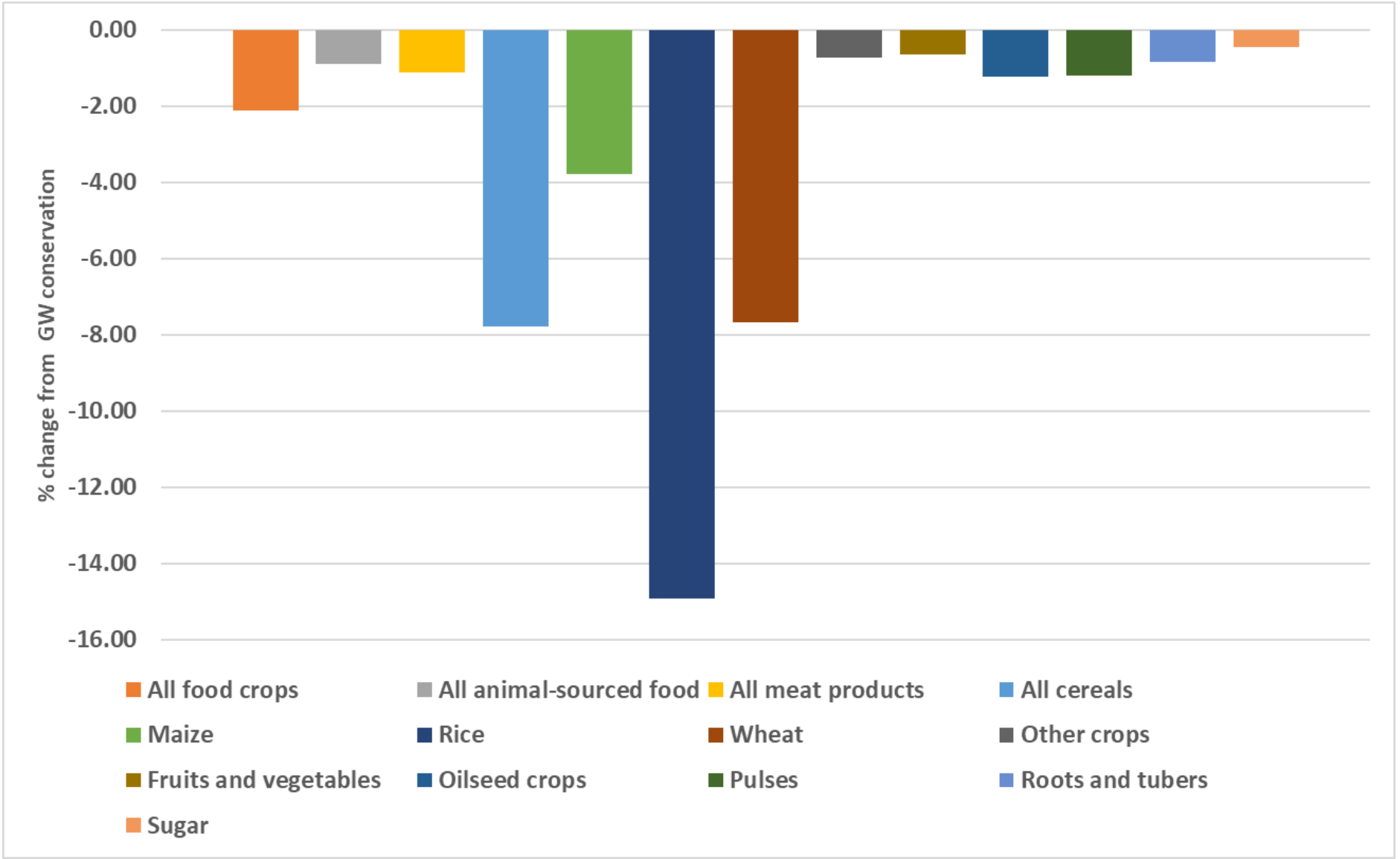
Source: IFPRI IMPACT

Impacts on food prices: HGEM GWC with selected, increased exploitation in areas without overdraft



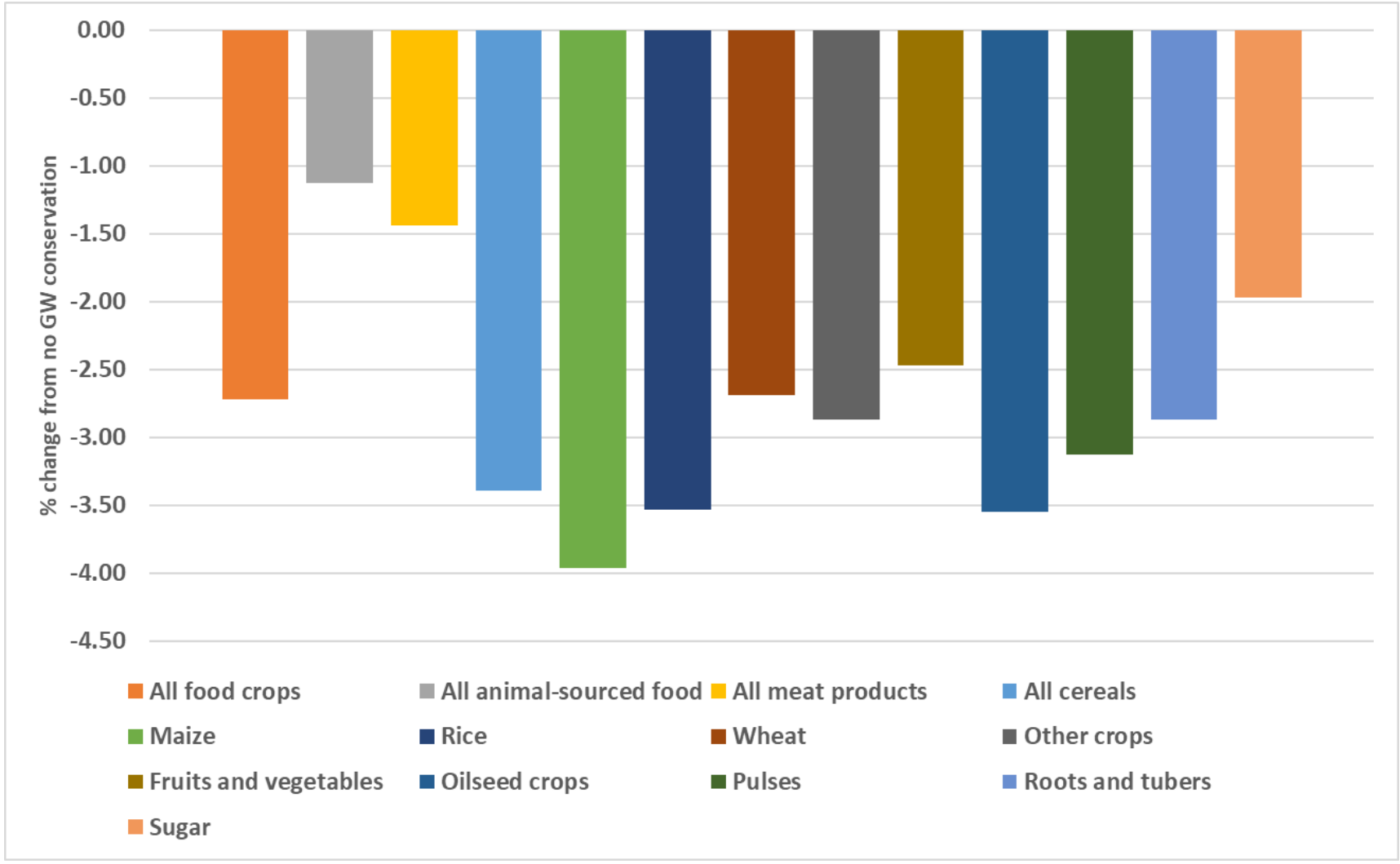
Source: IFPRI IMPACT

Impacts on food prices: HGEM GWC with increased investment in wheat, rice and maize R&D



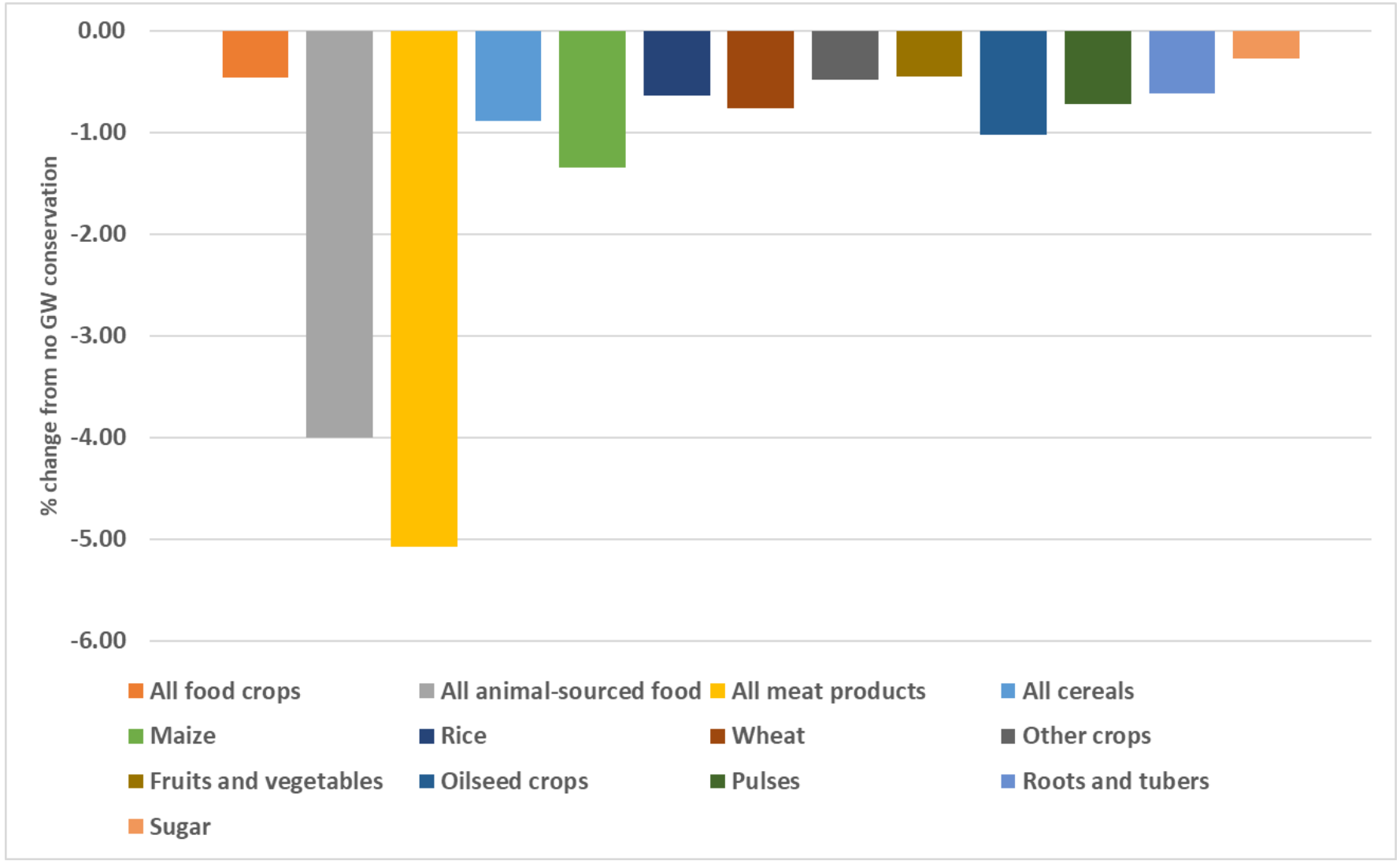
Source: IFPRI IMPACT

Impacts on food prices: HGEM GWC with increased ER use in rainfed areas



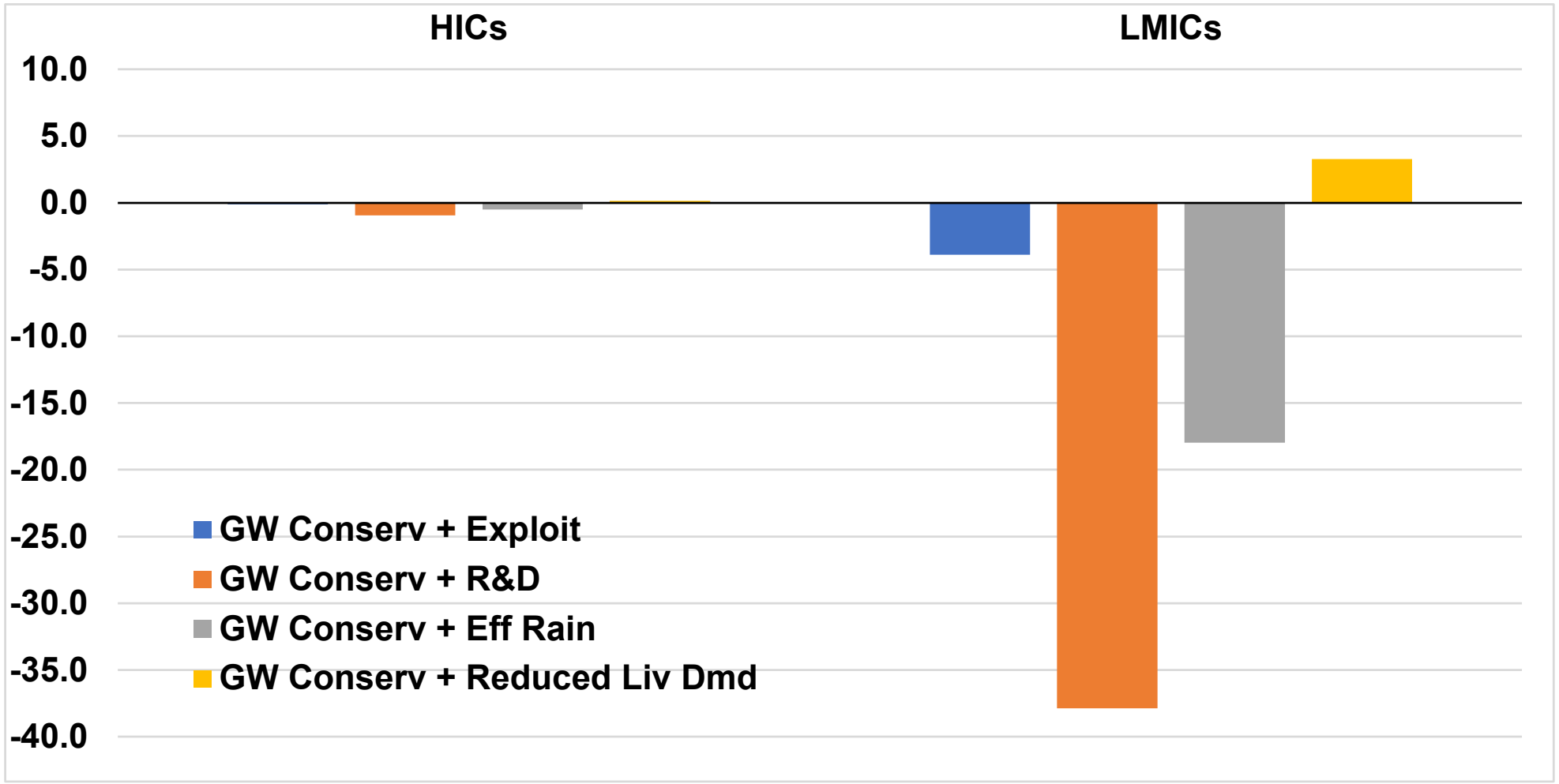
Source: IFPRI IMPACT

Impacts on food prices: HGEM GWC with reduced demand for ASF in HICs & Brazil & China



Source: IFPRI IMPACT

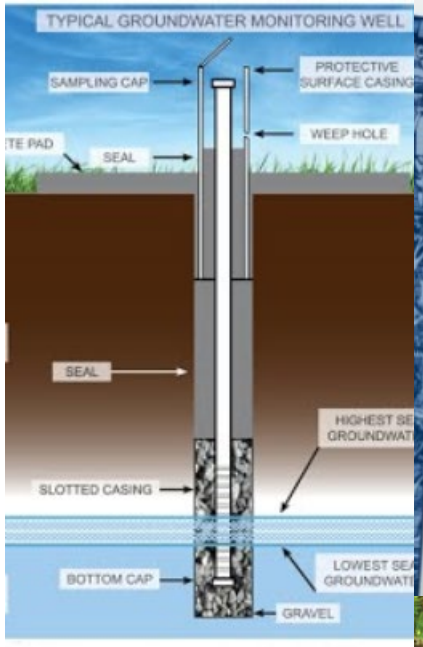
Impacts on the population at risk of hunger: Alternative groundwater futures, compared to GWC (million people)



Source: IFPRI IMPACT

Measures to stimulate groundwater conservation

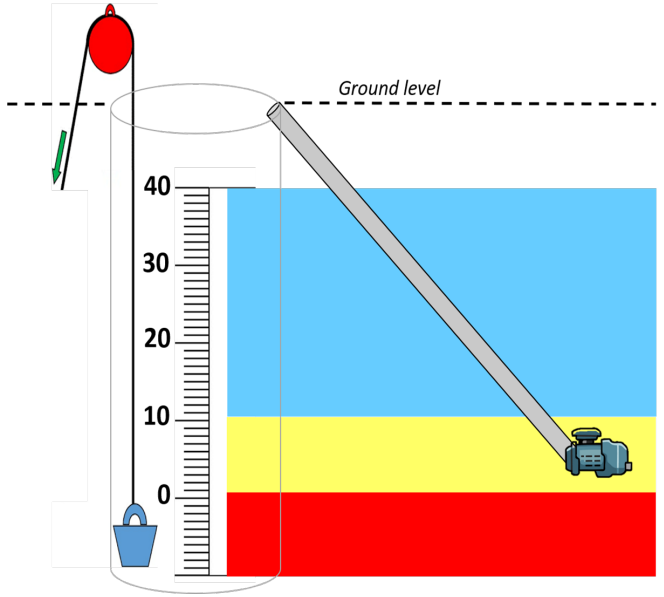
- Improved measurement and monitoring
- Legislation and regulation—example California (Sustainable Groundwater Management Act)
- Grow solar rather than food crops
- Social learning interventions to stimulate groundwater governance
- MAR
- Remove perverse incentives



Groundwater games and collective action

Adapted from a game developed/piloted in India (Meinzen-Dick et al. 2018)

- Games
  - Groups of 5 men or 5 women
  - Choose crop A or B with different water use & returns (locally relevant crop types)
  - See effect on water table
  - Multiple years (rounds), 3 games (treatments)
    - Without communication
    - With communication
    - With communication and group election of rules



- Community debriefing
  - How this relates to own experiences and challenges in farming
  - Lessons and insights the participants gained from the experience
  - Possible solutions

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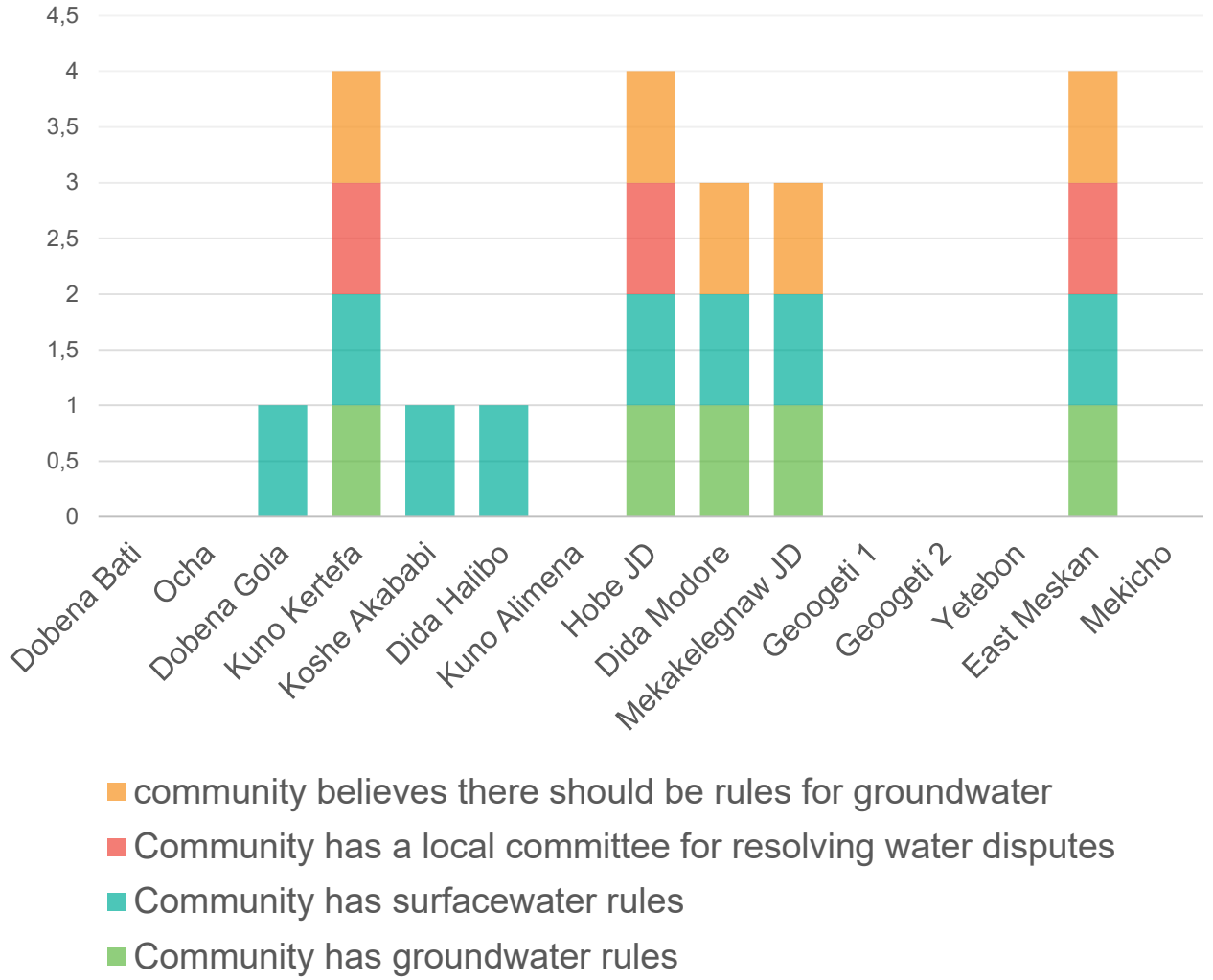
Existing water rules in communities (FGD)

- Surface water rules are more common in communities compared to groundwater rules
  - Most common: redirecting river canals/ building a dam is prohibited
- Few communities had a rule related to groundwater
  - Most common: digging more than one well on one's land not allowed
- Few communities believed that there should be rules governing water, particularly groundwater



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Mental model: Before and after game

Our current groundwater use will affect the sustainability of the resource	Before		After	
	Freq.	%	Freq.	%
Strongly agree	8	**5.3**	22	**14.7**
Agree	64	**42.7**	90	**60.0**
Disagree	66	**44.0**	37	**24.7**
Strongly disagree	9	**6.0**	1	**0.7**
Not applicable	3	**2.0**		

No need for rules restricting type of crops to be irrigated	Before		After	
	Freq.	%	Freq.	%
Strongly agree	41	**27.3**	16	**10.7**
Agree	55	**36.7**	31	**20.7**
Disagree	44	**29.3**	65	**43.3**
Strongly disagree	8	**5.3**	38	**25.3**
Not applicable	2	**1.3**		

Need collective action to establish and maintain community water structures	Before		After	
	Freq.	%	Freq.	%
Strongly agree	68	**45.3**	65	**43.3**
Agree	79	**52.7**	79	**52.7**
Disagree	3	**2**	1	**0.7**
Strongly disagree			5	**3.3**

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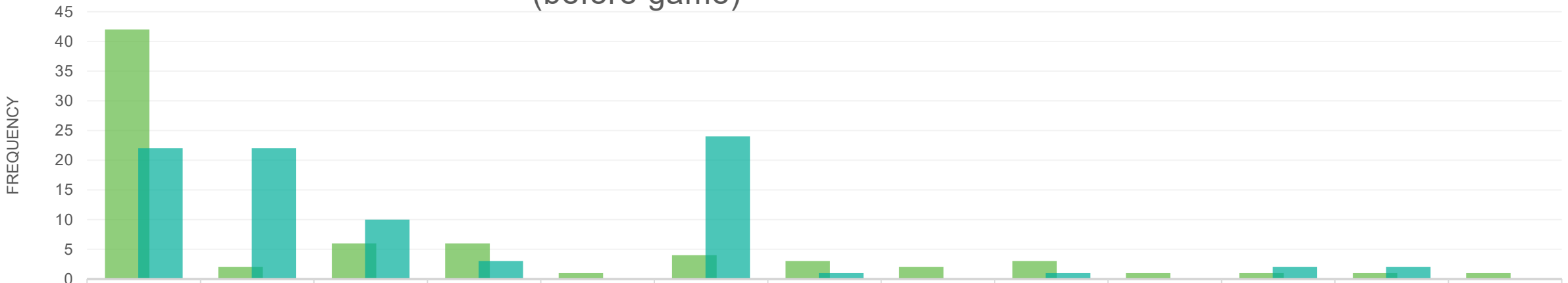
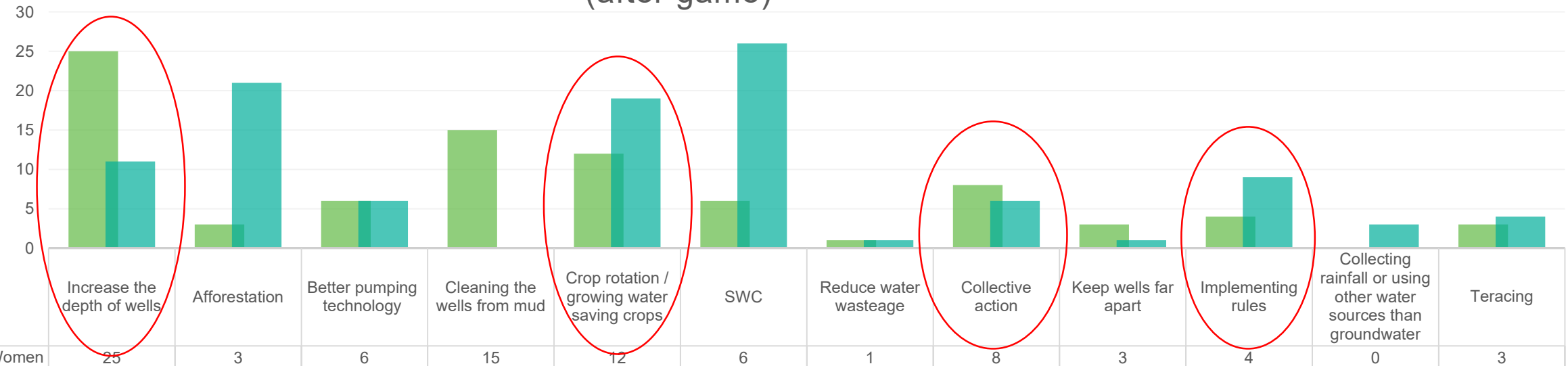
What do you think should be done to improve GW availability? (before game)



	Increase the depth of wells	Afforestation	Better pumping technology	Proper well management	Crop rotation	SWC	Reduce water wastage	Collective action	Keep wells far apart	Farmers training	Limit resource users	Increase the number of wells	Nothing
Women	42	2	6	6	1	4	3	2	3	1	1	1	1
Men	22	22	10	3		24	1	0	1	0	2	2	0

(after game)



	Increase the depth of wells	Afforestation	Better pumping technology	Cleaning the wells from mud	Crop rotation / growing water saving crops	SWC	Reduce water wasteage	Collective action	Keep wells far apart	Implementing rules	Collecting rainfall or using other water sources than groundwater	Teracing
Women	25	3	6	15	12	6	1	8	3	4	0	3
Men	11	21	6	0	19	26	1	6	1	9	3	4

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Post game player reflections

Game fun?	relatable?	Educational?
99%	97%	100%

"I learned that we have to use the groundwater equitably and fairly. There should be rules that govern the use of groundwater"

Male, Mekicho*

*Village community has no water rules; people don't think they should have rules

"I learned that groundwater has limits and thus, to use water for generations we have to start to use water wisely . Otherwise it can be exhausted"

Female, East Meskan*

*Village community already has some rules

"Before the game I didn't think that groundwater can get lower and lower by our crop choices in irrigation. But after the game I have a lot of information about how to save and use our groundwater."

Female, Googeiti 1*

*Village community has no water rules; people don't think they should have rules

"I suggest that this game shall be exercised by many farmers to let them have a good knowledge like us. So I recommend the game to include as many farmers as possible"

Female, East Meskan*

*Village community already has some water rules

Games to stimulate groundwater governance--An introduction and example from Ethiopia (vimeo.com)

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Conclusions

- Groundwater use in irrigation will continue to grow, particularly with cheaper solar pumps becoming more widely available
- Increased groundwater irrigation will accelerate groundwater depletion
- Arresting groundwater depletion would put upward pressure on cereal prices, particularly rice, and prices of fruits and vegetables
- Several options can mitigate price impacts, such as improving water management in rainfed areas, investing in agricultural R&D, or reducing meat consumption
- Effective measures on dealing with depletion are starting to be developed in parts of the globe, but GW depletion will likely continue to grow in much of the world

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