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GROUNDWATER IN GLOBAL IRRIGATED FOOD PRODUCTION - THE ROLE OF DEPLETING AQUIFERS

Karen G. Villholth^a, Aditya Sood^b, Tingju Zhu^c

^a Principal Researcher, IWMI, South Africa

^b Researcher, IWMI, Sri Lanka

^c Senior Research Staff, IFPRI, Washington DC





Objective/Research questions

- 1. How much does depleting groundwater contribute to global food production?**
- 2. What is the impact of unsustainable groundwater irrigation on future global food security? Are there alternatives?**

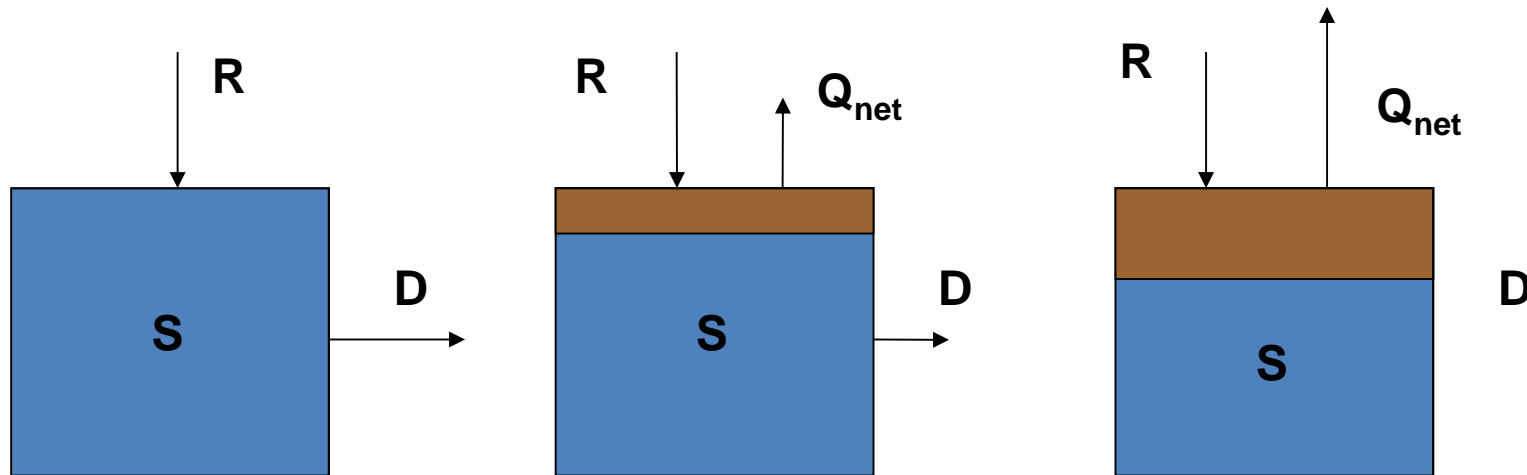


Groundwater depletion

What is it?

Groundwater depletion occurs when the rate of groundwater abstraction is greater than the rate of replenishment

Fundamental groundwater balance



Natural conditions

Averaged over long term, $R=D$ and S is constant

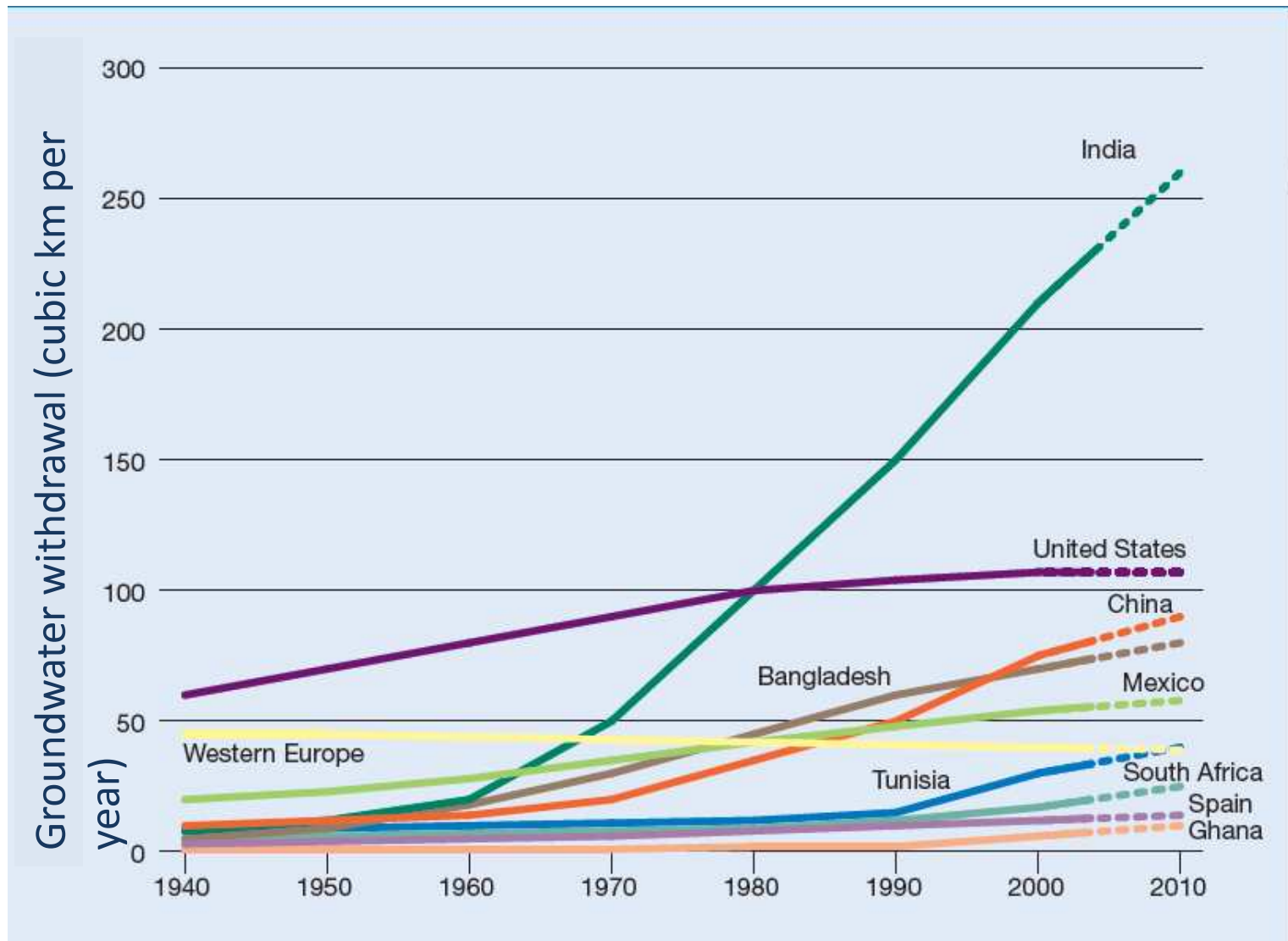
Stable groundwater pumping

Q_{net} is equivalent to reduction in D and S

Unsustainable condition

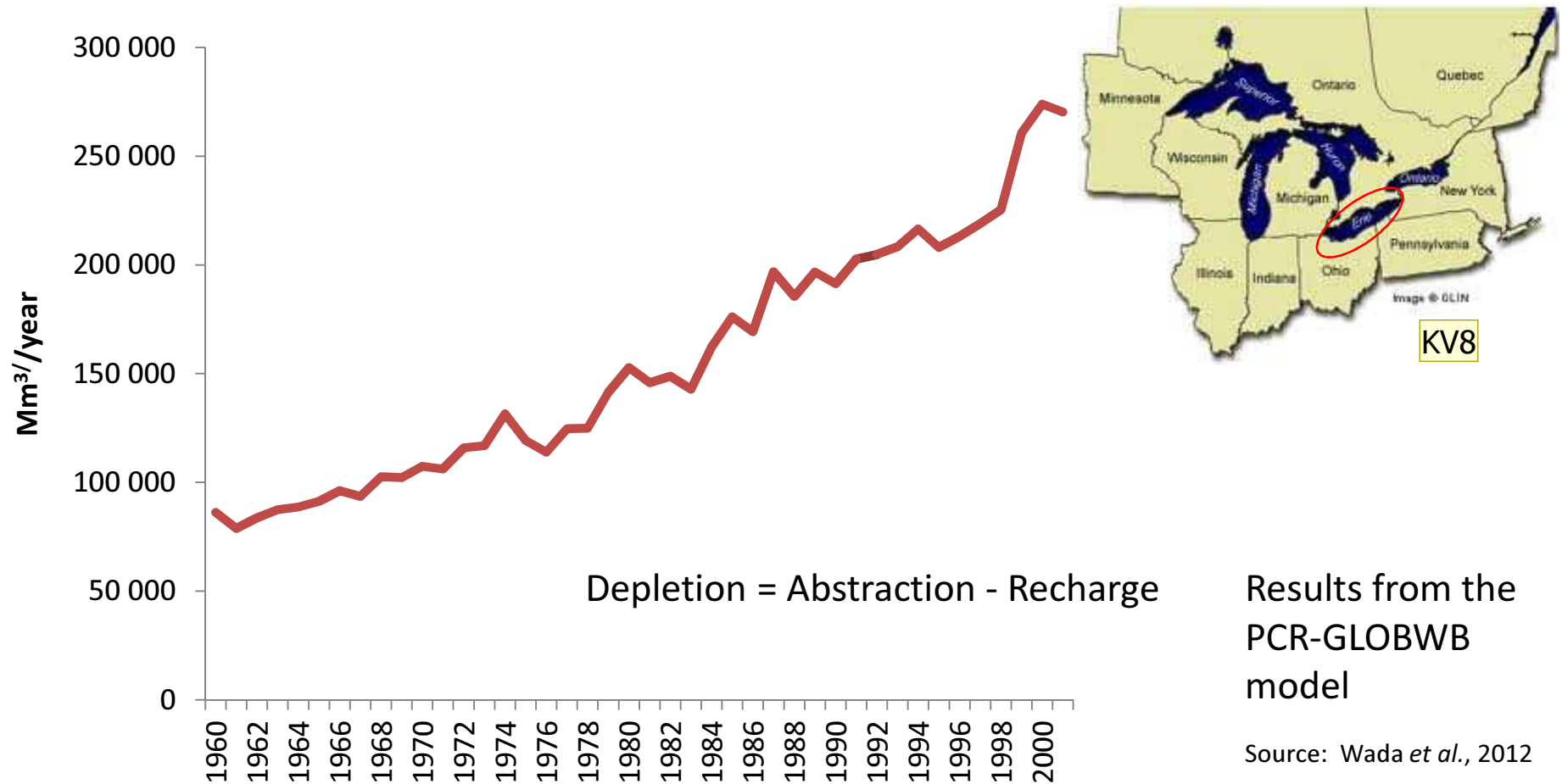
Q_{net} is greater than R , D reduces to 0 and S decreases continuously

Development in groundwater withdrawal in selected countries



Source:
Shah *et al.*, 2007

Total groundwater depletion at global scale



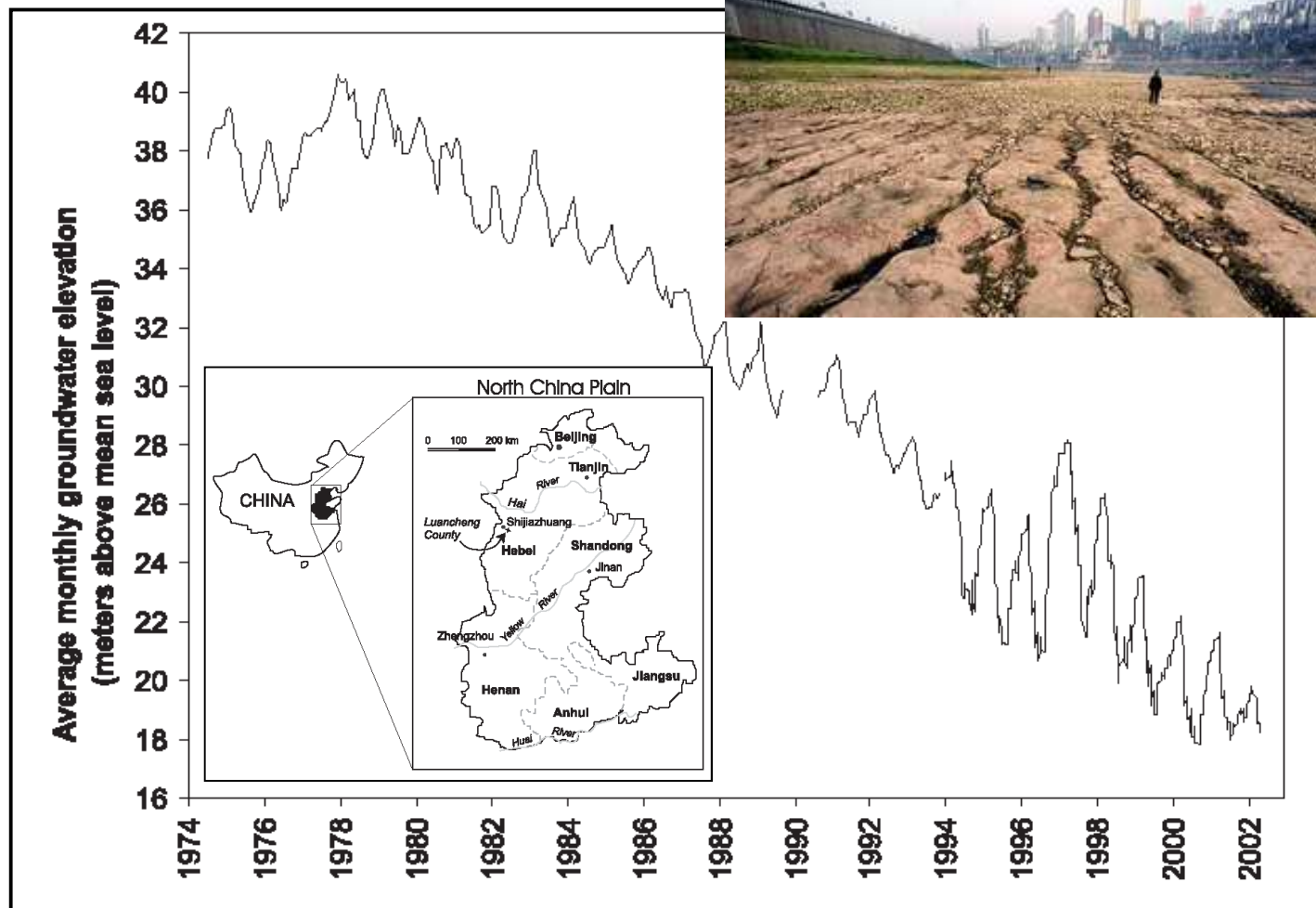
Slide 6

KV8

256 km³/year is equivalent to half of the storage of Lake Erie in Canada (545 km³).

Karen Villholth, 2014/02/08

GWL decline, example from China



Hydrograph depicting water-table elevations beneath Luancheng Agro-Ecological Research Station (Chinese Academy of Sciences, Luancheng County, Hebei Province, 1974-2002)



Earlier Estimates of the Role of GW in Global Irrigated Food Production

- Larger than 10%, inferred from Shah *et al.* (2007)
- 40% of all cultivated land under irrigation is 'water well equipped' (Foster and Shah, 2012)
- About 10% of global **food production** depends on using **mined** GW (FAO, 2003)



Is Groundwater Depletion Linked to Food Production Decline in Recent Times?

KV20

- Saudi Arabia: Between 2007 and 2010, the wheat harvest of nearly 3 mill. tons dropped by more than two thirds
- Yemen: the grain harvest has shrunk by one third over the last 40 years
- Similar trends in USA, India, China, Pakistan, Mexico, Jordan, Israel, Afghanistan, Syria

Slide 9

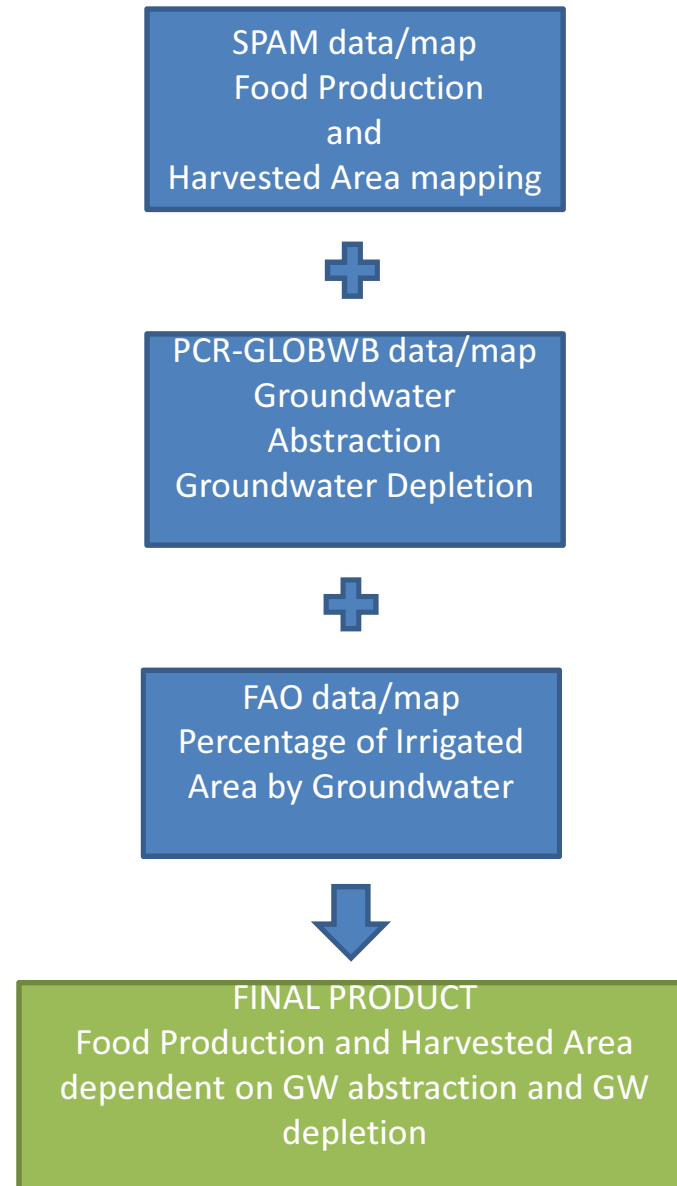
KV20

Falling food production and decreasing irrigated area can be due to other reasons: soil degradation, salinisation, generally increased water scarcity and water reallocation to urban areas.

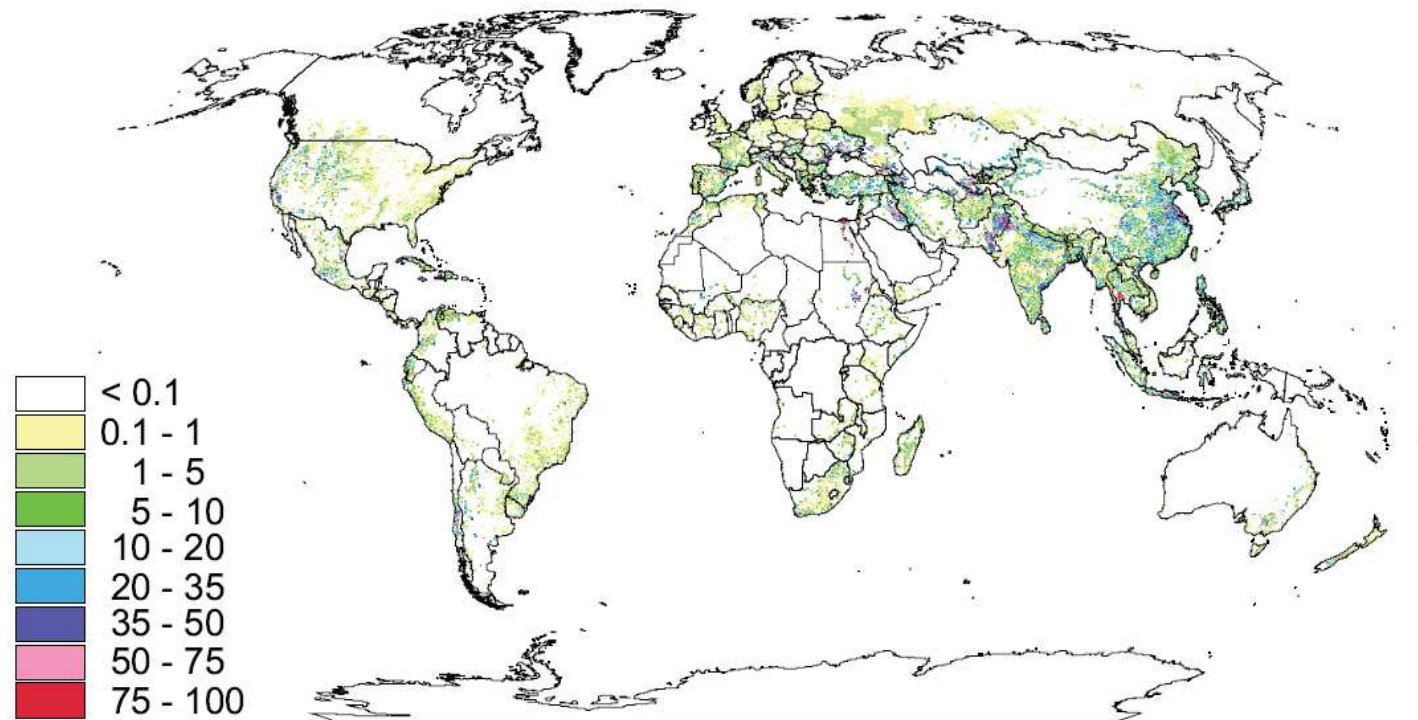
Karen Villholth, 2014/02/12



METHODOLOGY GIS analysis



Global Groundwater Irrigation

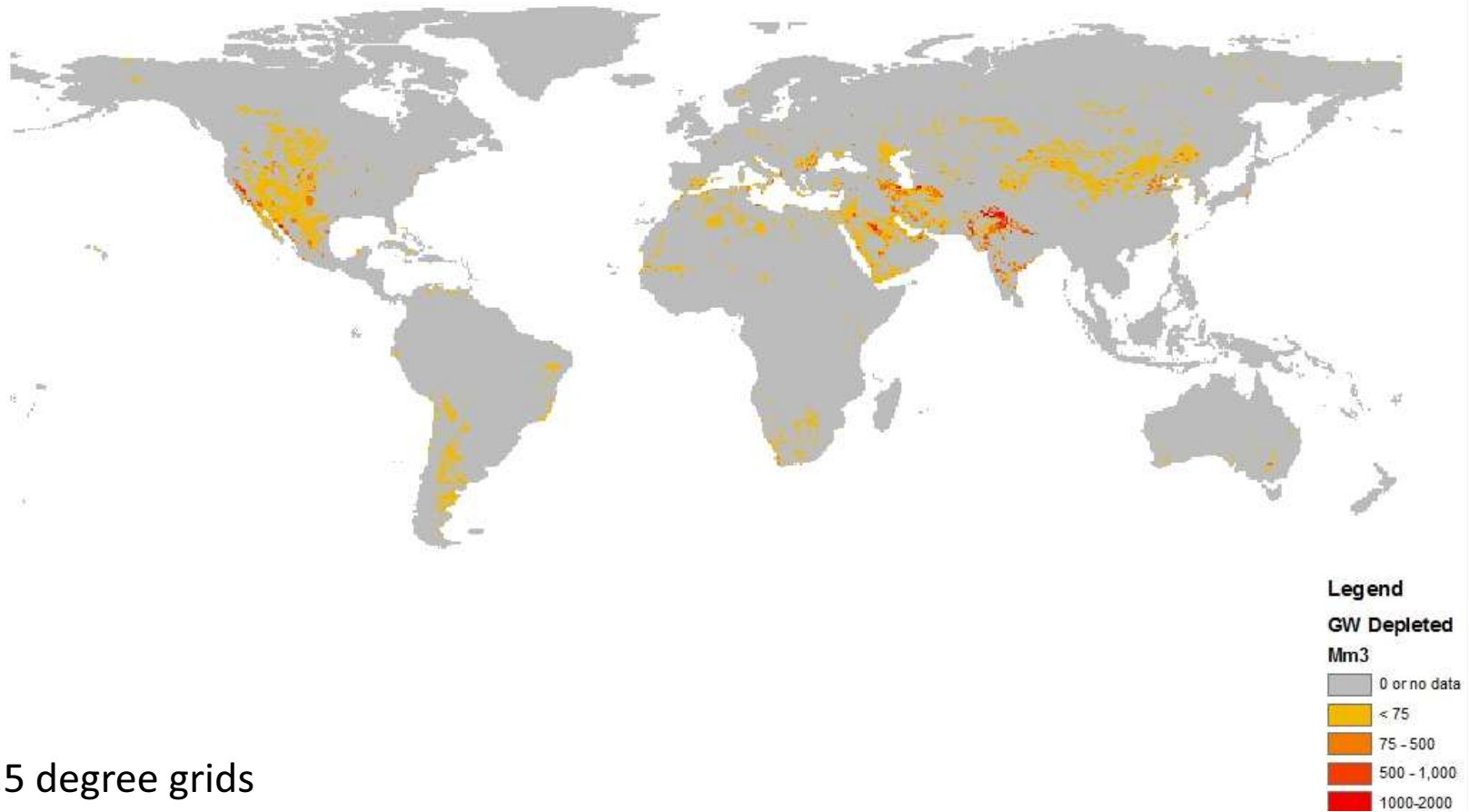


Percentage of 5 arc min grid cell area equipped for irrigation with groundwater out of total irrigated area

Source: Siebert *et al.*, 2010



Global Annual Groundwater Depletion – 2000 data



0.5 degree grids

Based on PCR-GLOBWB



Approach and Assumptions

- 5 minute grids as the working unit
- Only irrigated crop production considered
- 'Food production' aggregated into 11 crop groups
- Food production attributed to surface or groundwater irrigation based on share of area of each
- If depletion occurs, all GW-derived food production is from depletion
- Irrigated water divided between crops based on weighted average of harvested area and crop coefficient
- Groundwater productivity equal to surface water productivity



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Crop groups

FAO 2010 Crop Classification	Crop Name
Cereals	wheat
	rice
	maize
	barley
	pearl millet
	small millets
	sorghum
	other cereals
	Root/tuber crops with high starch or inulin content
	sweet potatoes
	yams
	cassava
	other roots and tubers
Leguminous crops	phaseolus beans (dry)
	chickpeas
	cowpeas
	pigeon peas
	lentils
	other pulses
Oilseed crops	soybeans
	groundnuts
	coconuts
	oil palm
	sunflower
	rape and mustard seed
	sesame seed
	other oilcrops
Sugar Crops	sugarcane
	sugarbeet
Fibre crops	cotton
	other fibre crops
Beverage and spice crops	coffee Arabica
	coffee robusta
	cocoa
	tea
Tobacco	tobacco
Fruit and nuts	bananas
	plantains
	tropical fruit
	temperate fruit
Vegetables and melons	vegetables
Other Crops	rest of crops



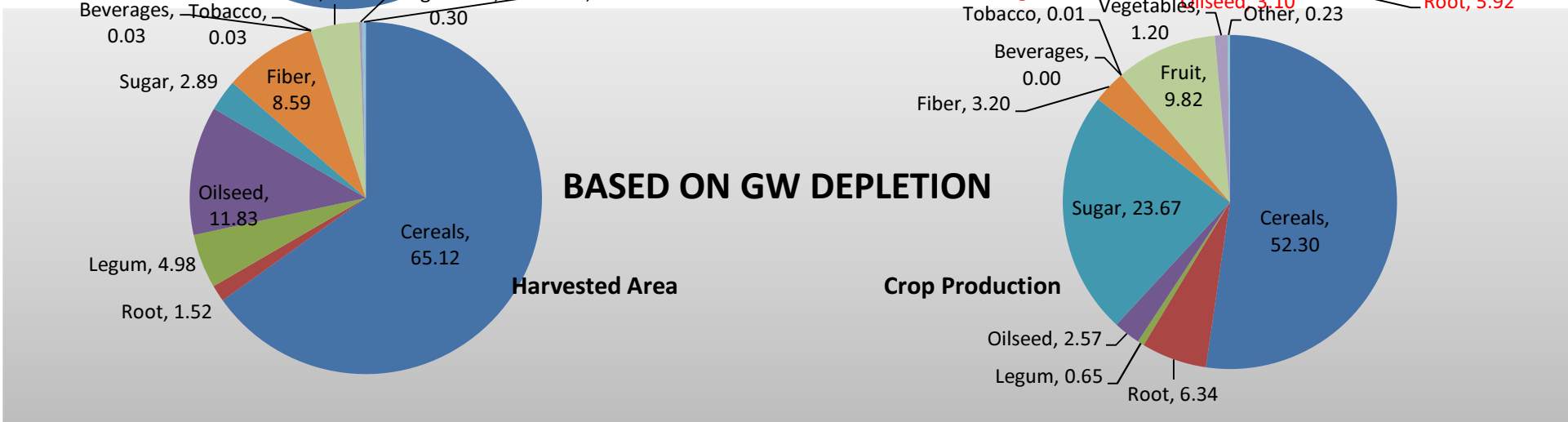
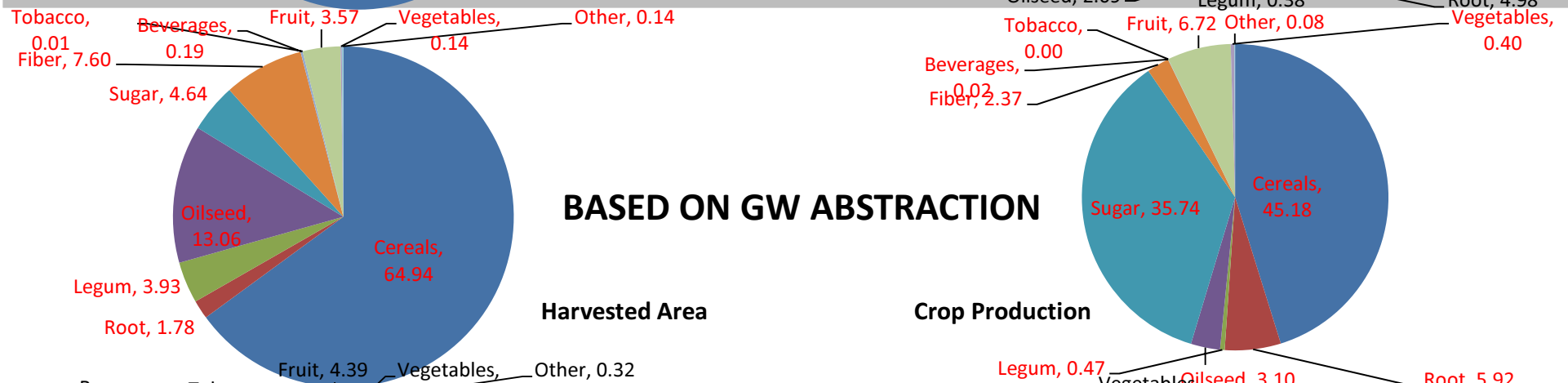
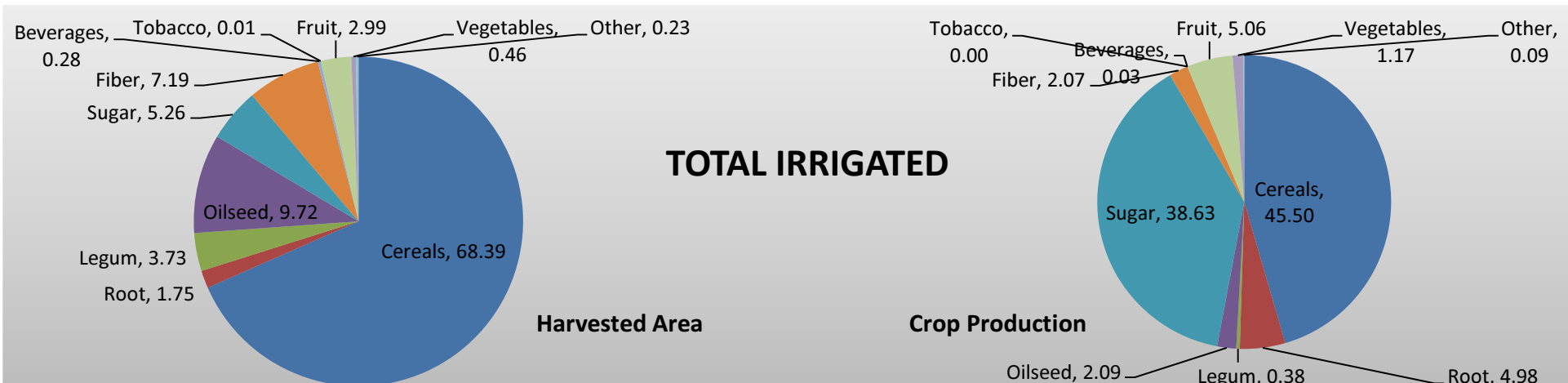
Harvested Area

	Cereals	Root	Legume	Oilseed	Sugar	Fiber	Beverages	Tobacco	Fruit	Vegetables	Other	TOTAL
Total Irrigated Area (Mha)	138.71	3.54	7.56	19.71	10.66	14.59	0.56	0.01	6.07	0.94	0.46	202.82
Irrigated area based on GW abstraction (Mha)	46.07	1.26	2.79	9.26	3.29	5.39	0.14	0.01	2.53	0.10	0.10	70.94
Irrigated area based on GW Depletion (Mha)	11.88	0.28	0.91	2.16	0.53	1.57	0	0	0.8	0.05	0.06	18.24



Production

	Cereals	Root	Legume	Oilseed	Sugar	Fiber	Beverages	Tobacco	Fruit	Vegetables	Other	TOTAL
Total Irrigated Production (Million Mt)	856.49	93.83	7.13	39.39	727.23	38.89	0.57	0.02	95.19	22.06	1.63	1882.4
Irrigated Production based on GW abstraction (Million Mt)	292.33	38.29	3.05	20.05	231.23	15.36	0.15	0.01	43.49	2.57	0.49	647.02
Irrigated Production based on GW Depletion (Million Mt)	68.91	8.36	0.85	3.39	31.19	4.21	0	0.01	12.94	1.58	0.31	131.76





Totals for GW irrigation contribution to total irrigated food production

	Harvested Area (%)	Crop Production (%)
Abstracted/Total Irrigated	34.97	34.37
Depleted/Abstracted	25.72	20.36
Depleted/Total Irrigated	8.99	7.00

Share of GW Abstraction and Depletion by Crop Group

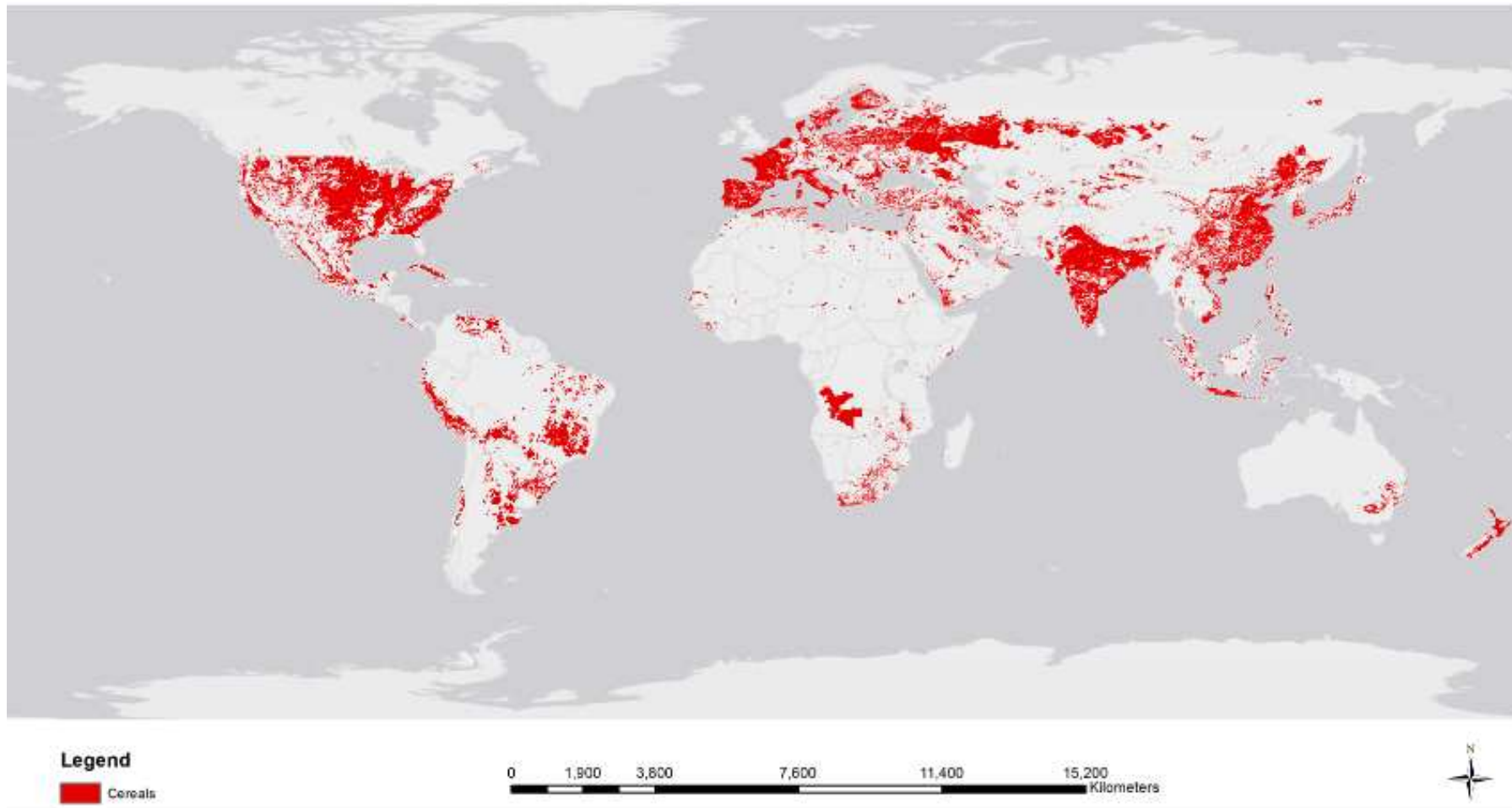
Crop Group	Abstraction (%)	Depletion (%)
Beverages	0.09	0.01
Cereal	68.04	64.03
Fiber	10.61	15.50
Fruit	0.14	0.21
Legume	4.21	4.85
Oil	8.95	8.27
Rest	0.77	1.18
Root	3.20	2.05
Sugar	3.84	3.63
Tobacco	0.01	0.01
Vegetables	0.14	0.26
<u>SUM</u>	<u>100</u>	<u>100</u>



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Global Cereal Production

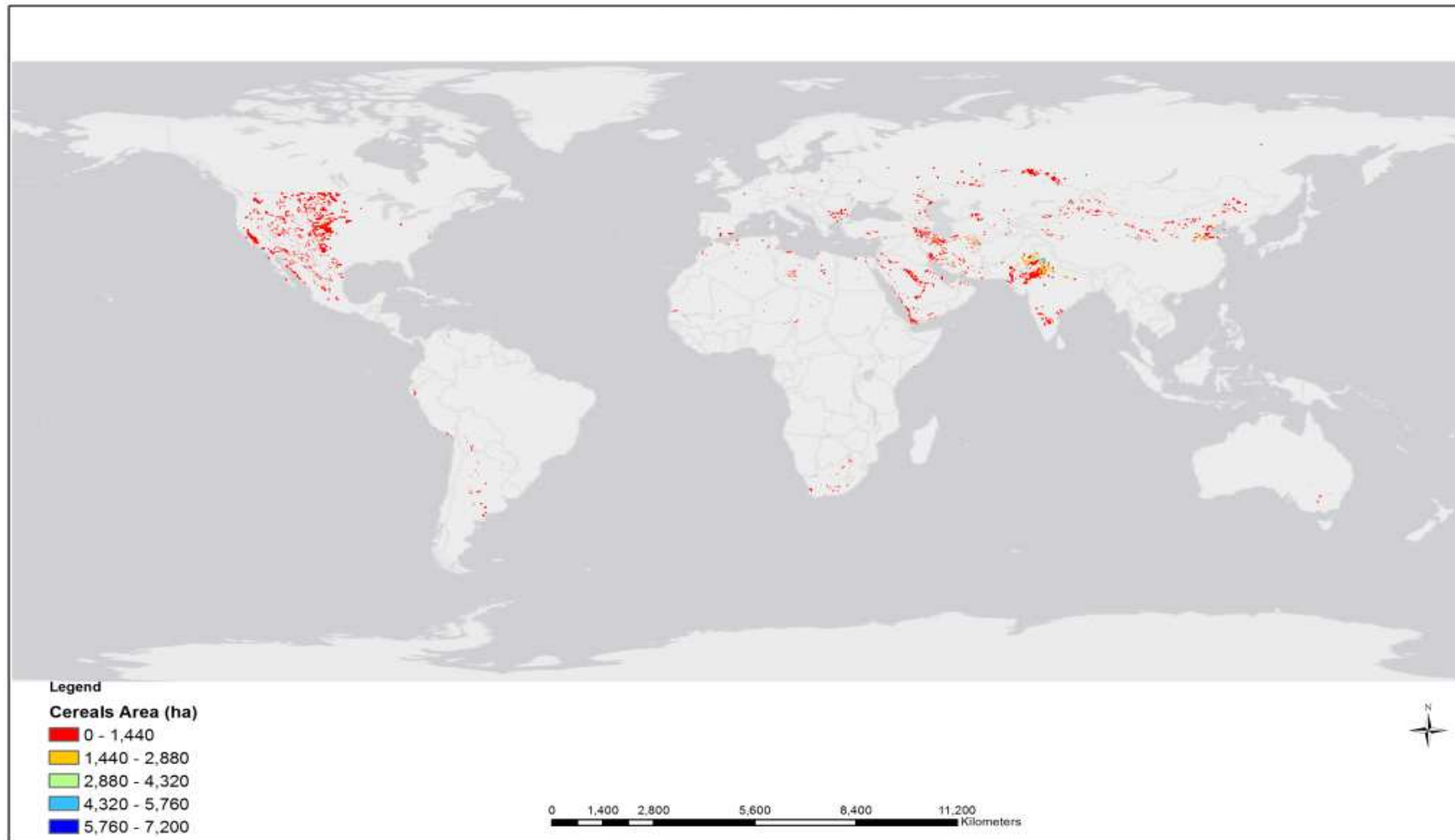


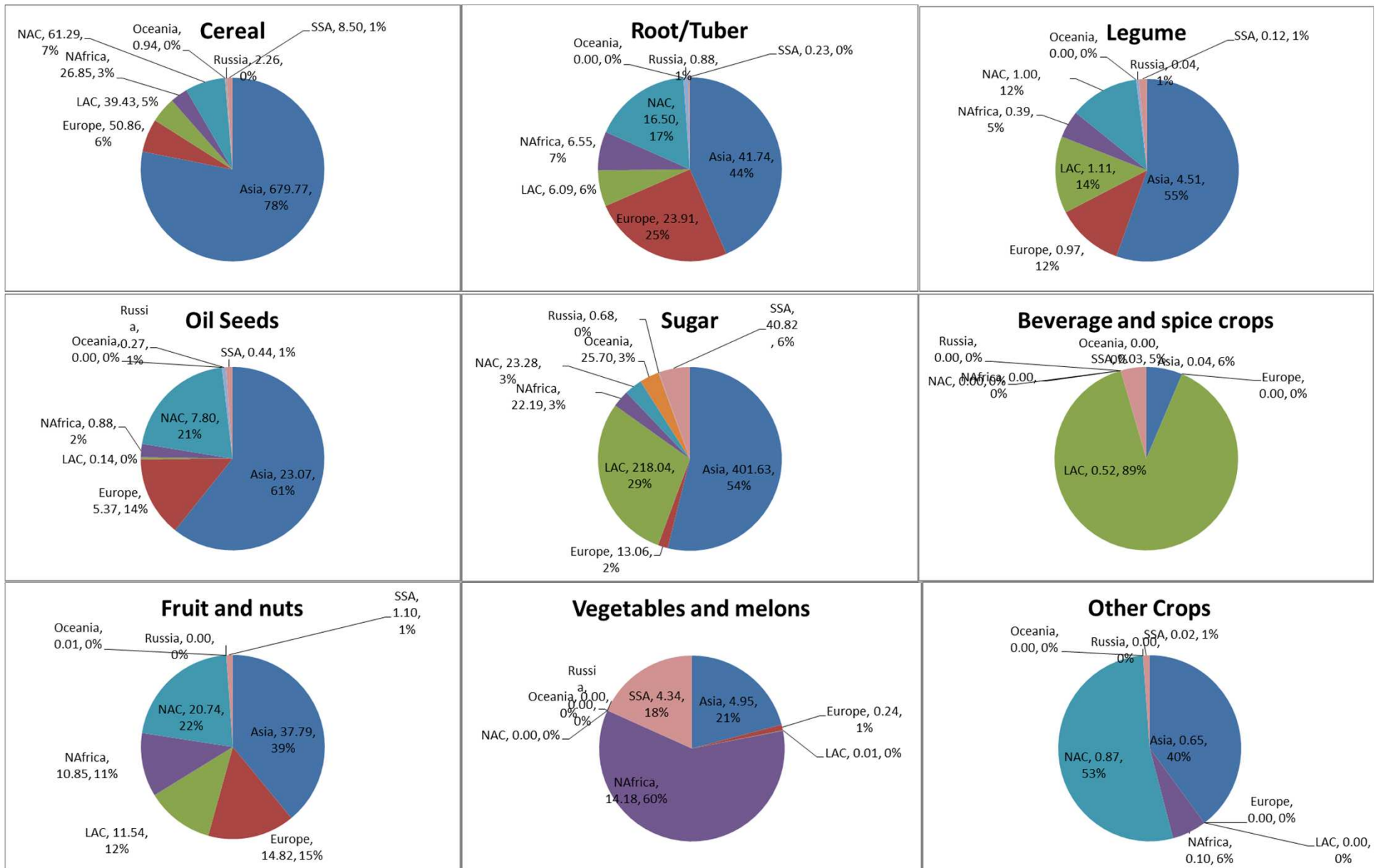


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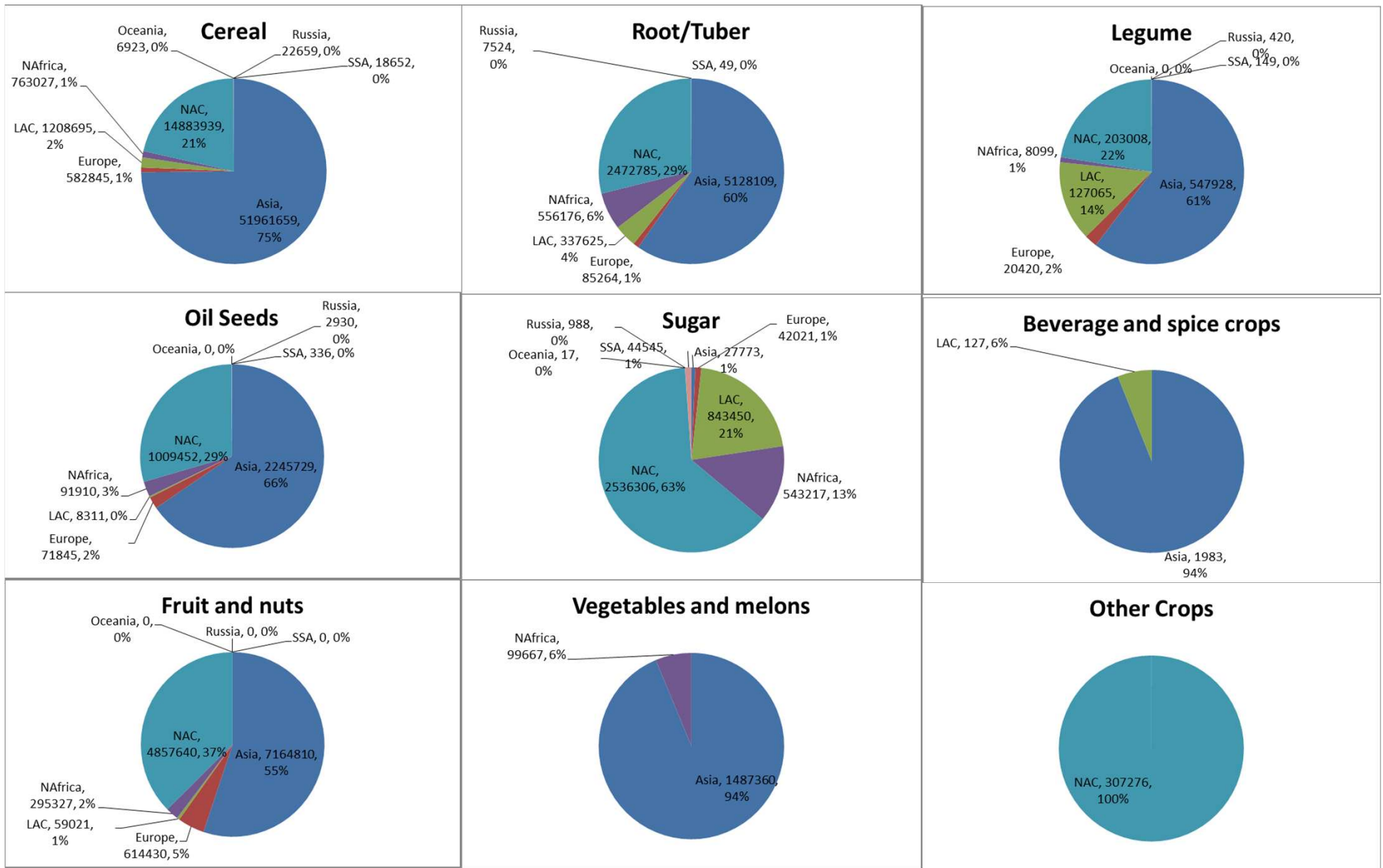
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Groundwater Depletion for Cereals





Regional Share of Crop Production from Irrigation, per Crop Group



Regional Share of Crop Production Dependent on Depleted GW, by Crop Group



Share of each crop based on GW depletion, in terms of production, at regional level

Crop Groups	Asia	Europe	LAC	NAfrica	NAC	Oceania	Russia	SSA
Cereals	7.64	1.15	3.07	2.84	24.28	0.74	1.00	0.22
Root/tuber crops	12.29	0.36	5.55	8.49	14.98	0.00	0.86	0.02
Leguminous crops	12.14	2.10	11.46	2.06	20.37	0.00	1.09	0.13
Oilseed crops	9.73	1.34	6.14	10.39	12.95	0.00	1.08	0.08
Sugar Crops	0.01	0.32	0.39	2.45	10.89	0.00	0.15	0.11
Fiber crops	7.64	0.93	13.62	0.23	30.44	0.93	1.55	0.04
Beverage and spice crops	5.36	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Tobacco	59.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Fruit and nuts	18.96	4.14	0.51	2.72	23.42	0.00	0.00	0.00
Vegetables and melons	30.05	0.00	0.00	0.70	0.00	0.00	0.00	0.00
Other Crops	0.00	0.00	0.00	0.05	35.38	0.00	0.00	0.00



Shortcomings/further work

- Dataset for GW abstraction and depletion at 0.5 degrees, rather than at 5 minutes
- GW irrigation areas probably underestimated => GW depletion contribution to global food production may be underestimated
- GW depletion data from 2000 => GW depletion contribution to global food production may be underestimated
- Correct for higher productivity of GW



Further work

- Global hydro-economic/food production models assume infinite physical GW storage. Modification is needed to build/test realistic scenarios for future alternatives for curtailing/optimizing GW abstraction and keeping up food production



Conclusions

- 34 % of global irrigated food production derives from GW irrigation
- 7 % of global irrigated food production derives from depleting groundwater
- 20 % of all GW-based food production is based on unsustainable abstraction
- Asia is responsible for the largest share of food production from depleting groundwater
- Cereals and sugar are the GW-irrigated crops most widely grown unsustainably, in terms production
- Results imply the critical importance of analysing and developing congruent policies at multiple levels that account for the nexus between groundwater and food security



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