Supplement

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S1 Exogenous demands

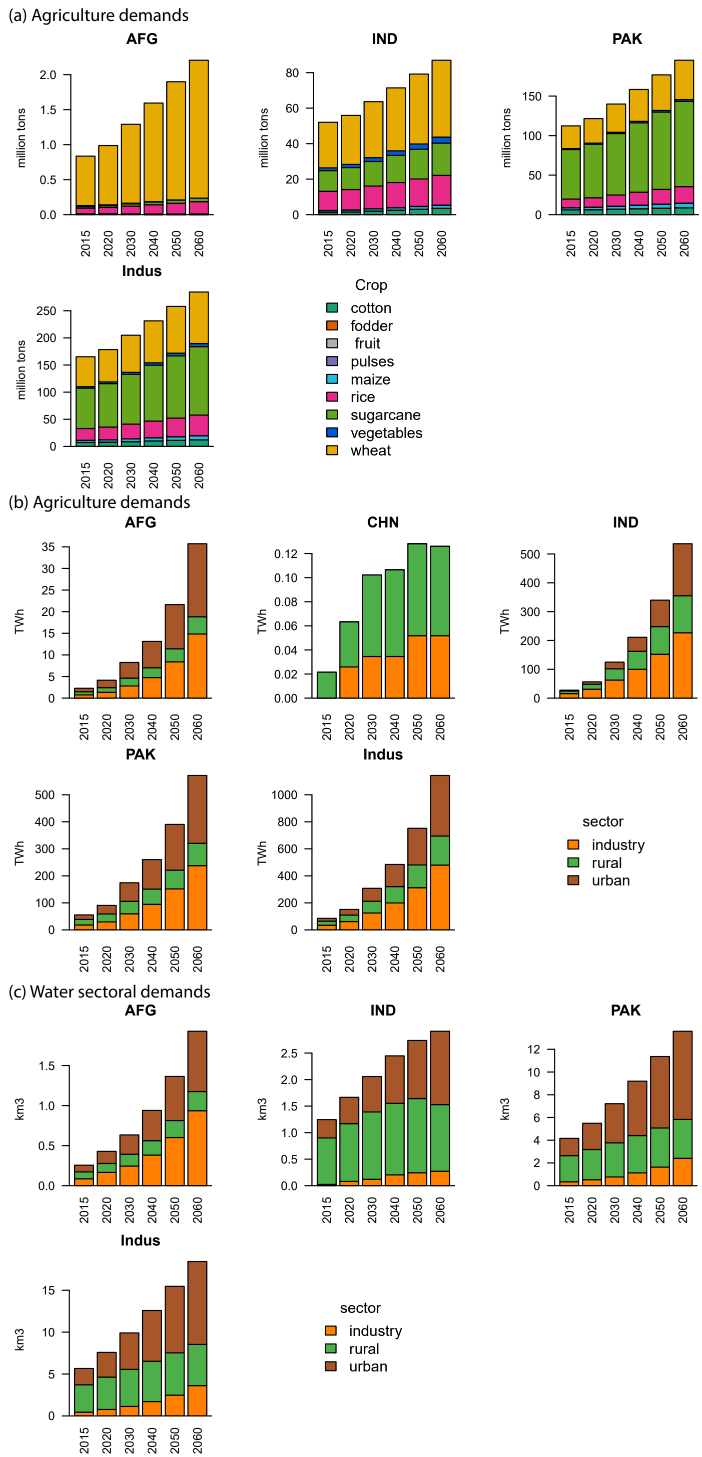


Figure S1. Exogenous agriculture products (a), electricity (b) and water (c) demands. For each country and the whole Indus basin, from 2010 to 2060.

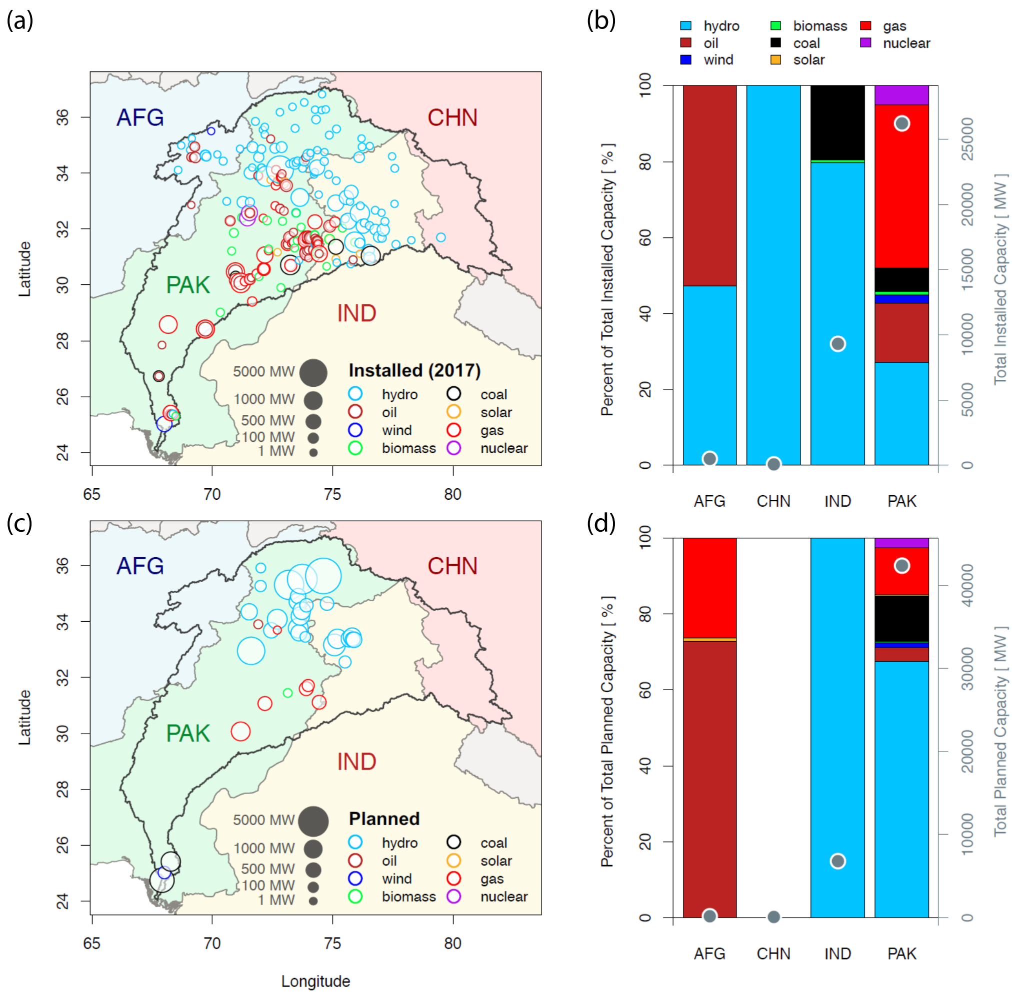
S2 Canals, hydroelectric projects and power plants data

Project	Capacity [m^3 / sec]	Length [km]	Long. In [°E]	Lat. In [°N]	Long. Out [°E]	Lat. Out [°N
Rasul-Qadirabad	538	44	73.5187	32.6830	73.7135	32.3370
Qadirabad-Bulloki	527	129	73.6858	32.3228	73.9138	31.2982
Balloki-Sulemanki	524	87	73.8590	31.2226	73.9241	30.4953
Trimmu-Sidhnai	312	64	72.1462	31.1450	72.1933	30.5690
Sidhnai-Mailsi	283	94	72.1582	30.5713	72.2459	29.7278
Chashma-Jhelum	615	135	71.3837	32.4358	72.2214	31.9680
Taunsa-Panjnad	340	72	70.8505	30.5137	71.3677	30.2735
Marala-Ravi	622	97	74.4698	32.6699	74.6239	31.8966
Ravi-Bedian	142	82	74.4701	31.7212	74.1755	30.7265
Bambanwala-Ravi	142	82	74.2941	32.3609	74.4701	31.7212
Chenab-Bambanwala	453	28	74.4698	32.6699	74.2941	32.3609
Chenab-Ravi	311	44	74.2941	32.3609	74.0820	31.4142
Keenjhar-Karachi	31	44	68.0500	24.9500	-	-
Indira Gandhi	138	602	75.0111	31.1628	-	-

Table S1. Major conveyance canals in the NEST implementation of the IRB that are linking river systems or for interbasin transfers. Locations, capacities and lengths are approximate and estimated by the authors based on reported technical data. Interbasin transfers are occurring where no outlet location is defined.

Project	Country	Longitude [°E]	Latitude [°N]	Capacity [MW]	Storage [km^3]	Opening
Azad Pattan	Pakistan	73.5715	33.7678	700	-	2022
Patrind	Pakistan	73.4288	34.3440	150	-	2017
Gulpur	Pakistan	73.8625	33.4553	102	-	2019
Suki Kinari	Pakistan	73.5427	34.7231	870	-	2022
Kohala	Pakistan	73.6546	34.2023	1100	-	2025
Athmuqam	Pakistan	73.9107	34.5891	350	-	2020
Golen Gol	Pakistan	72.0143	35.9212	58	-	2018
Mahl	Pakistan	73.5667	34.9167	590	-	2025
Neelum-Jhelum	Pakistan	73.7189	34.3928	968	-	2018
Diamer-Bhasha	Pakistan	73.7370	35.5207	4500	10.5	2023
Tarbela Extension	Pakistan	72.6983	34.0897	1410	-	2018
Karot	Pakistan	73.6012	33.5998	720	-	2021
Kalabagh	Pakistan	71.6136	32.9564	3600	7.5	proposed
Munda	Pakistan	71.5330	34.3532	740	0.9	proposed
Bunji	Pakistan	74.6159	35.6358	7100	0.2	proposed
Dasu	Pakistan	73.1933	35.3173	4320	0.8	2021
Akhori	Pakistan	72.4528	33.6905	600	8.6	2025
Sharmai	Pakistan	72.0053	35.2766	150	0.3	2023
Kishanganga	India	74.7647	34.6475	360	-	2018
Sawalkote	India	75.0759	33.1691	1856	-	proposed
Kirthai I	India	75.1994	33.3868	390	-	proposed
Kirthai II	India	75.1994	33.3868	930	-	proposed
Pakal Dul	India	75.8136	33.4572	1000	0.1	proposed
Kwar	India	75.8280	33.3623	540	-	proposed
Kiru	India	75.8898	33.3518	624	-	proposed
Bursar	India	75.6956	33.3903	800	0.6	proposed
Ujh	India	75.5156	32.5590	212	-	proposed

Table S2. Additional planned hydropower projects included in the NEST implementation of the IRB. Locations, capacities and dates are approximate and estimated by the authors based on reported technical data.



Basin boundary from HydroBASINS (Lehner, 2013). Country borders from the Geospatial Data Abstraction Library (GDAL)

Figure S2. Existing (a), (b) and planned (c), (d) power plant capacity in the NEST implementation of the IRB. Sources: World Electric Power Plant (WEPP) Database, Raptis et al. (2016); van Vliet et al. (2016)

S3 Costs and Capacity Factor assumptions

Tables S3 and S4 show costs and capacity factor values for a number of technologies in the model. Technologies like transmission lines or water canals are not included, as costs are dependent on the length and the region. The tables only include a subset of energy technologies with different cooling systems. Costs for gas plant in combined cycle (cc), single turbine (gt) and steam turbine (st) configurations are reported for all cooling systems, air cooling (ac), closed loop (cl) and once through cooling (oc). Although we model these different cooling systems also for oil, coal, geothermal and nuclear power plants, we only show costs for closed loop in Tables S3 and S4.

Solar and wind power plants are divided in three groups having same cost assumptions but different levels of capacity factor, attached in the Supplementary Information *Variable_capacity_factor.xlsx*.

Technology	I_{cost} [unit]	F_{cost} [unit]	Var_{cost} [unit]	CF [-]
Crops	[$/ha]	[$/ha]	[$/(ha month)]	
wheat	341	36	72	1
rice	716	15	22	1
cotton	416	9	13	1
fodder	130	3	4	1
sugarcane	849.6	17	25.5	1
pulses	1320	26.4	39.6	1
maize	1000	20	30	1
fruit	545.5	11.5	16.5	1
vegetables	1362.5	27.5	41	1
Energy Technolgies	[$/kW]	[$/kW]	[$/kWh]	
coal st cl	6860	24	0.048611	0.9
electricity distribution industry	1120	36	0.034722	0.9
electricity distribution irrigation	1120	36	0.034722	0.9
electricity distribution rural	1120	36	0.034722	0.9
electricity distribution urban	1120	36	0.034722	0.9
electricity short strg	3000	16	0.020833	0.9
gas cc ac	1105	17	0.037264	0.9
gas cc cl	1064	16	0.036875	0.9
gas cc ot	1023	15	0.036111	0.9
gas gt	676	7	0.122222	0.9
gas st cl	1205	17	0.048611	0.9
geothermal cl	6343	135	0.025	0.9
hydro old	5000	15	0	0.95
igcc cl	4131	32	0.079167	0.9
nuclear cl	5751	97	0.029167	0.9
oil cc cl	1064	16	0.036875	0.9
oil gt	676	7	0.122222	0.9
solar pv 1	3873	15	0.004167	variable
solar pv 2	3873	15	0.004167	variable
solar pv 3	3873	15	0.004167	variable
wind 1	7000	8	0	variable
wind 2	7000	8	0	variable
wind 3	7000	8	0	variable

Table S3. Investment, fixed and variable costs and capacity factor values for model technologies. Sources: Parkinson et al. (2016); Fricko et al. (2016); Kahil et al. (2018) and local data

Technology	I_{cost} [unit]	F_{cost} [unit]	Var_{cost} [unit]	CF [-]
Irrigation technologies	[$/ha]	[$/ha]	[$/(ha month)]	
drip	2600	52	78	0.9
flood	460	10	14	0.9
sprinkler	1625	33	49	0.9
canal lining flood	3110	62	94	0.9
smart	2825	57	85	0.9
drip smart	3100	62	93	0.9
sprinkler smart	2125	43	64	0.9
Water diversion/treatment technologies	[$/(mq /day)]	[$/(mq /day)]		
industry gw diversion	20	8.5	0	0.9
industry sw diversion	57	3	0	0.9
industry wastewater recycling	1350	99	0	0.9
industry wastewater treatment	431	37	0	0.9
irrigation gw diversion	8.5	1	0	0.9
irrigation sw diversion	57	3	0	0.9
rural gw diversion	8.5	1	0	0.9
rural piped distribution	326	18	0	0.9
rural sw diversion	57	3	0	0.9
rural wastewater recycling	1350	99	0	0.9
rural wastewater treatment	759	77	0	0.9
smart irrigation sw diversion	62.7	3.3	0	0.9
urban gw diversion	20	8.5	0	0.9
urban piped distribution	1013	252	0	0.9
urban sw diversion	57	3	0	0.9
urban wastewater collection	785	251	0	0.9
urban wastewater irrigation	1350	99	0	0.9
urban wastewater recycling	1350	99	0	0.9
urban wastewater treatment	431	37	0	0.9

Table S4. Investment, fixed and variable costs and capacity factor values for model technologies. Sources: Parkinson et al. (2016); Fricko et al. (2016); Kahil et al. (2018) and local data.

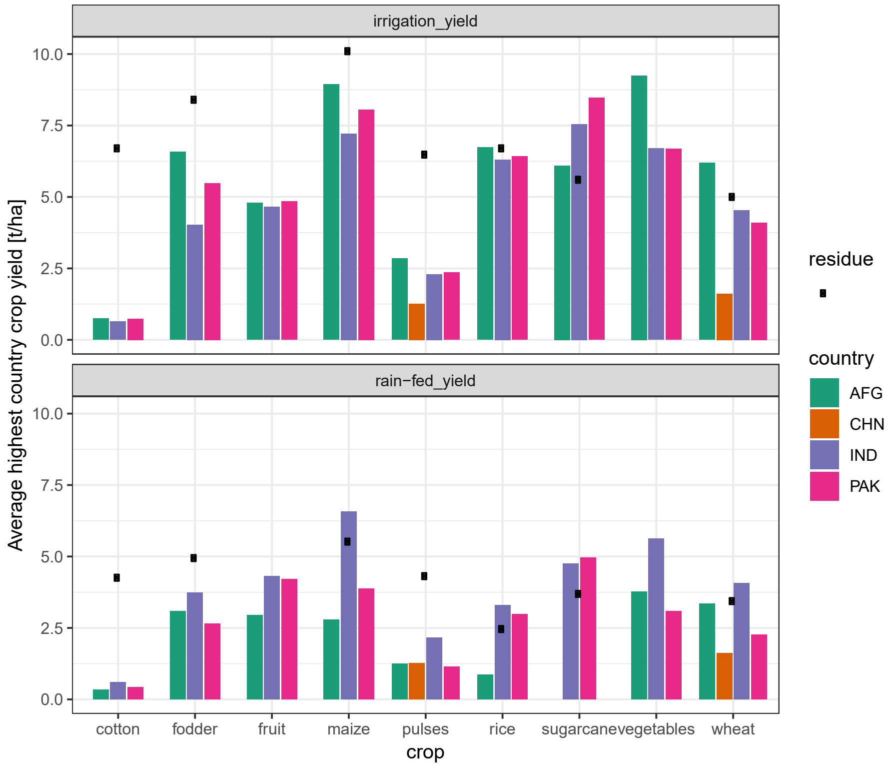


Figure S3. Average highest irrigated and non-irrigated yield for each crop-country pairing in the NEST implementation of the IRB as well as the corresponding rates of residue generation. Sources: GAE

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GAEZ: Global Agro-Ecological Zones, http://www.fao.org/nr/gaez/en/.

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