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Water footprint of rice

Quantifying the rainbow of virtual water fluxes related to rice trade

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RE-THINKING PARADIGMS: WATER AND FOOD SECURITY
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Backdrop

- It is a popular belief that rice is one of the most water guzzling crops.
- reinforced by the reflection of what we see in rice fields/thousands of pictures of rice fields covered with a thick layer of standing water.
- large irrigation projects, often constructed to meet the water demand in rice production.
- the largest grain category feeding the world population, mostly in South Asia and Africa, → consuming rice is very water intensive.

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Questions….

- Is consuming rice more water expensive, or is this a perception merely based on the fact that rice is mostly produced in wet-land systems with standing water all over the time?

- How does the global consumption of rice relate to the use of different kinds of water at production regions?

- What is the role of the blue (surface and ground) and green water in rice production?

- What is the volume of water polluted (grey) in the local water resources as a result of fertilizers use in the rice fields?.

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Questions….

- How does the temporal and spatial variations in rice production relate to the water footprint of rice consumption globally?
- What are the external water footprints of nations related to rice consumption?
- A thought, do we really want to increase irrigation efficiency in rice fields (reduced percolation)?
- Do we have better mechanism to allocate water saved as a result of less percolation from rice fields?

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Rice production statistics

- Systems of rice production:
  - wet-land system (85% of area)
  - upland system (15%)
- About 75% of the rice productions are obtained from irrigated wetland rice.
- In Asia, rice fields are prepared by tillage followed by puddling. The soil layer is saturated and there is standing water during the entire growth period of the crop.
- In US, Australia, parts of Europe and some Asian countries, rice land is prepared dry and flooded later.

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Rice production statistics

- Produced in115 countries (FAOSTAT)
- Production = 592 million metric tons/yr, yield = 4.49 t/ha (FAOSTAT)
- 13 countries account for >90% of the global rice production, and >82% of the total export of rice-equivalent globally (PC-TAS).
- Only 6-7% of world rice production is traded internationally (FAOSTAT).

[All data from FAOSTAT, period 2000-04]

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Rice production statistics

Countries	Average production (t/yr)[1]	Global share (%)[1]	Average area harvested (ha/yr)[1]	Average yield (t/ha)[1]
China	177,657,605	30.0%	28,670,030	6.19
India	126,503,280	21.4%	43,057,460	2.93
Indonesia	52,014,913	8.8%	11,642,899	4.47
Bangladesh	37,217,379	6.3%	10,641,271	3.50
Viet Nam	33,960,560	5.7%	7,512,160	4.52
Thailand	26,800,046	4.5%	10,038,180	2.67
Myanmar	22,581,828	3.8%	6,431,364	3.51
Philippines	13,322,327	2.3%	4,056,577	3.28
Brazil	11,068,502	1.9%	3,371,562	3.28
Japan	10,989,200	1.9%	1,706,000	6.44
USA	9,520,015	1.6%	1,285,671	7.40
Pakistan	6,910,650	1.2%	2,339,200	2.95
Korea, Rep.	6,808,450	1.2%	1,045,173	6.51
Sub total	535,354,755	90.5%	131,797,547	-
Global total	591,751,209	-	150,666,851	4.49

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Calculation data and assumptions

- The volume of water used in land preparation is assumed to be 200 mm.
- This demand is assumed to be spread over one month period.
- There is a layer of standing water, ~100 mm, gradually maintained in one month.
- There is a constant percolation as long as there is standing water in the field.
- The field is let dry in the last month of harvesting.

[All data from FAOSTAT, period 2000-04]

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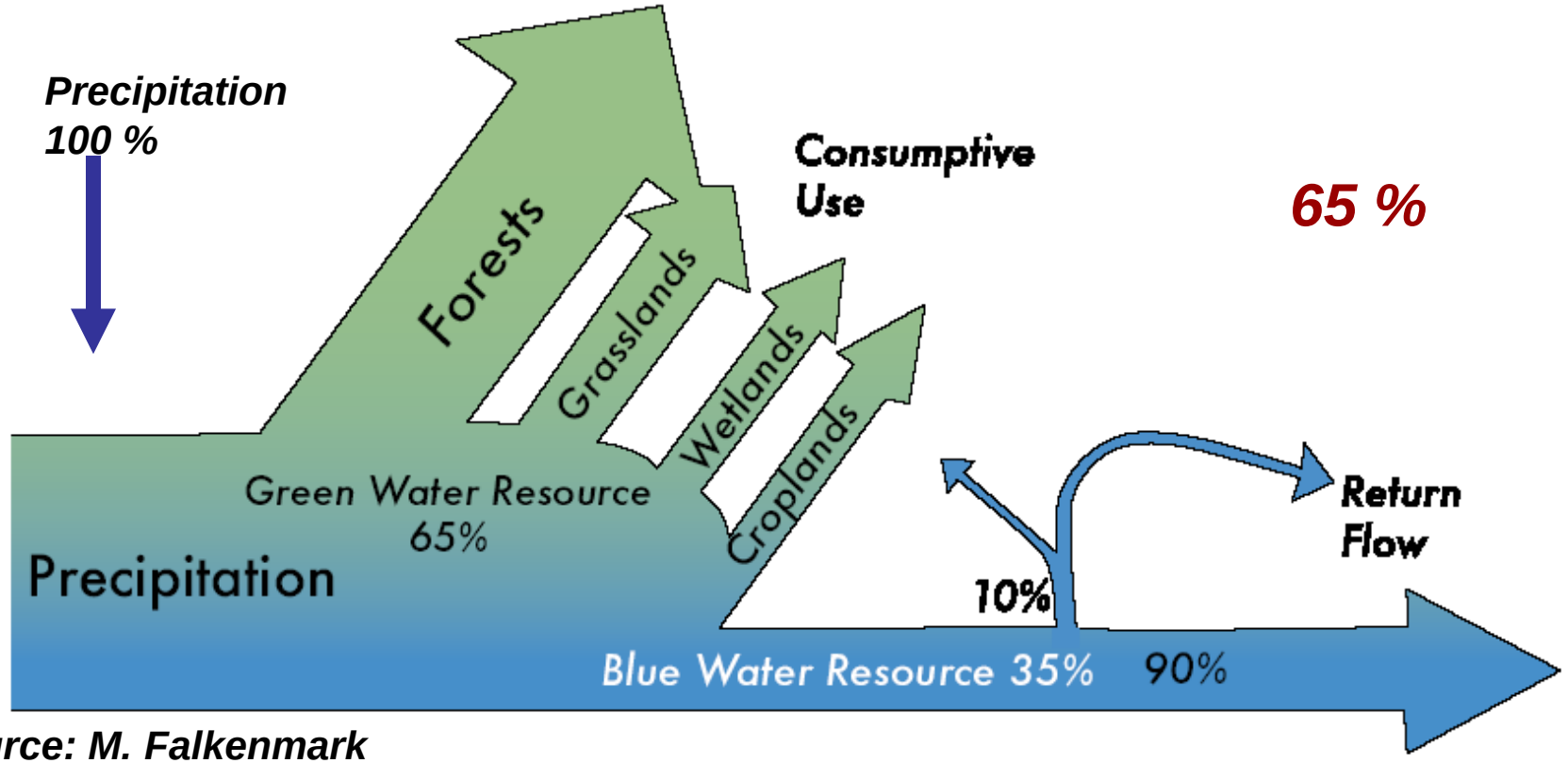
Globally available water



Source: M. Falkenmark

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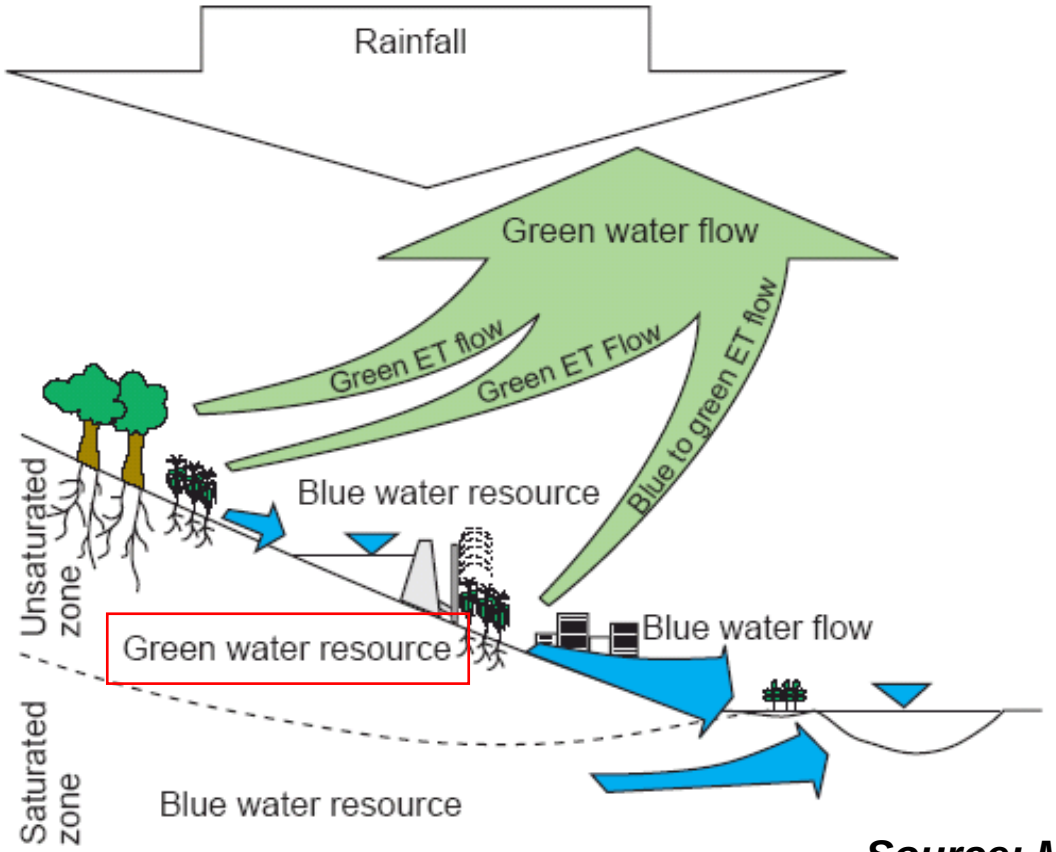

Source: M. Falkenmark






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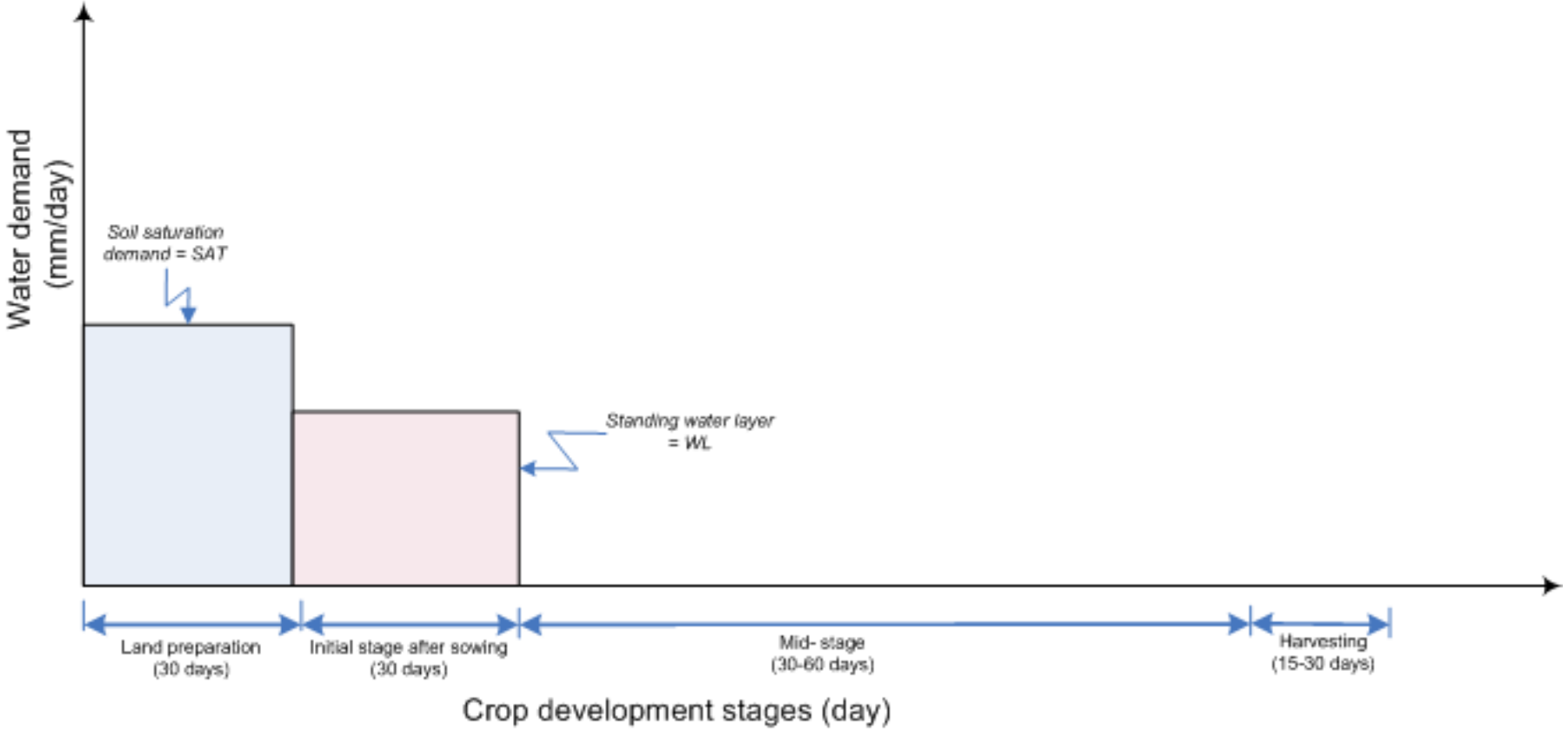
Water demand at different stages





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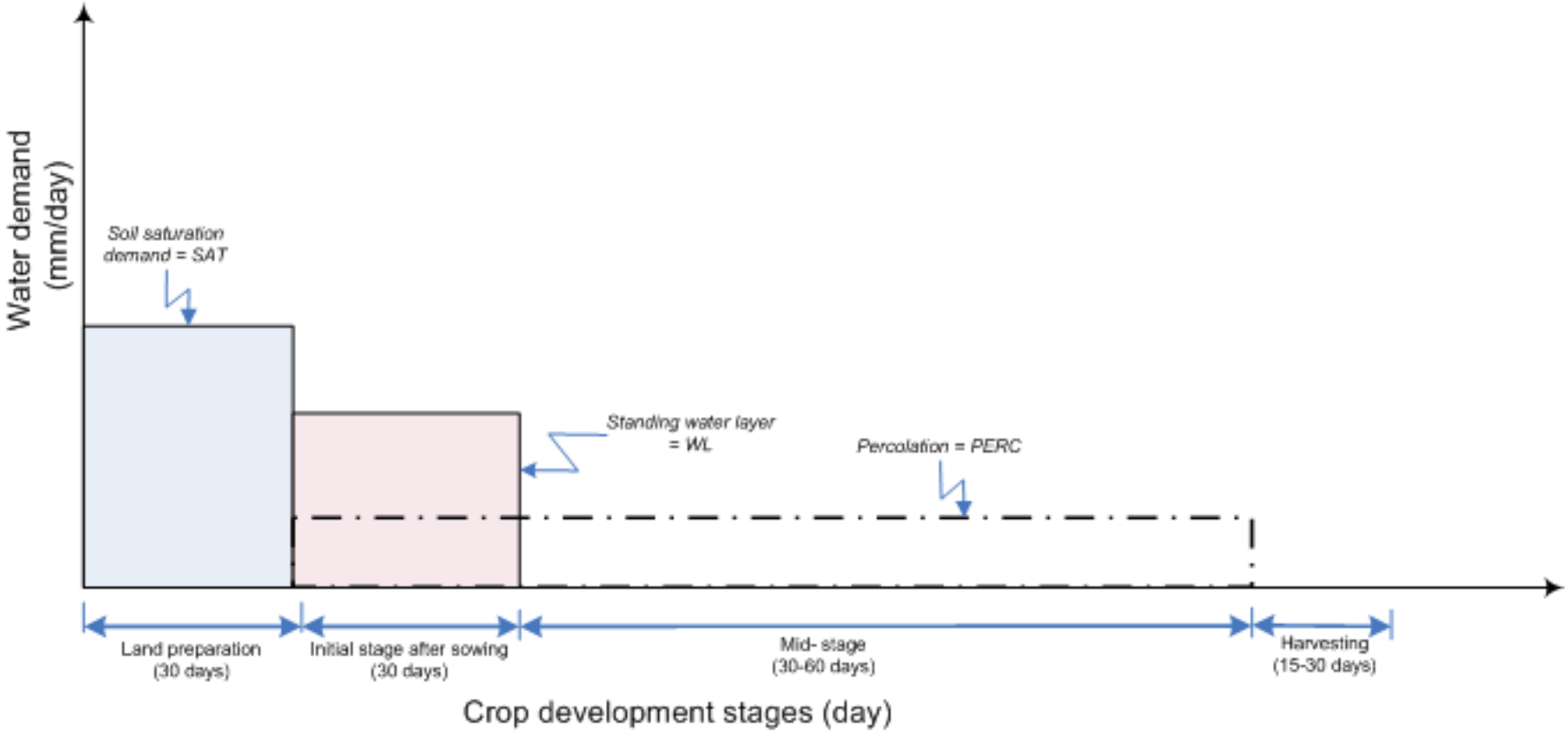
Water demand at different stages





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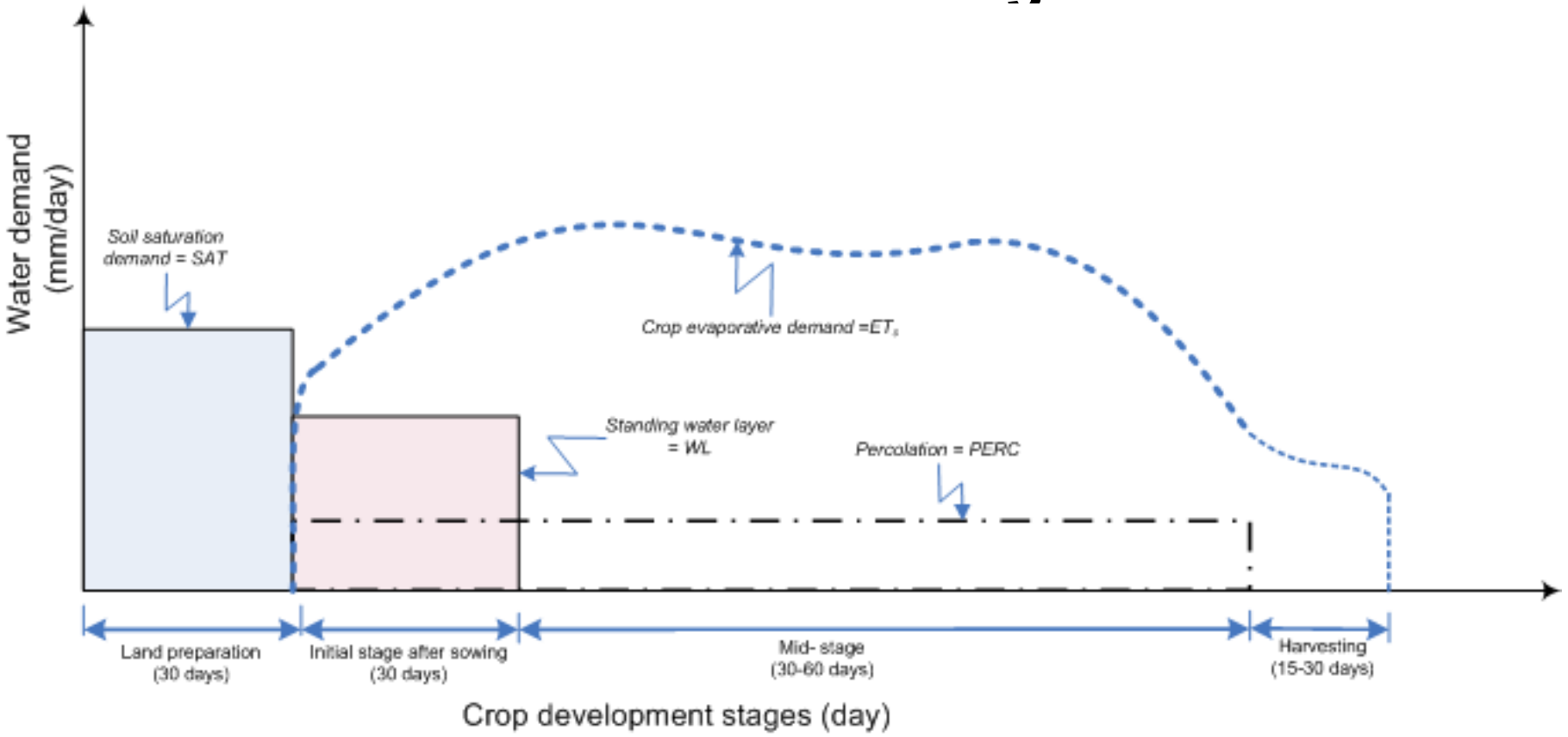
Water demand at different stages





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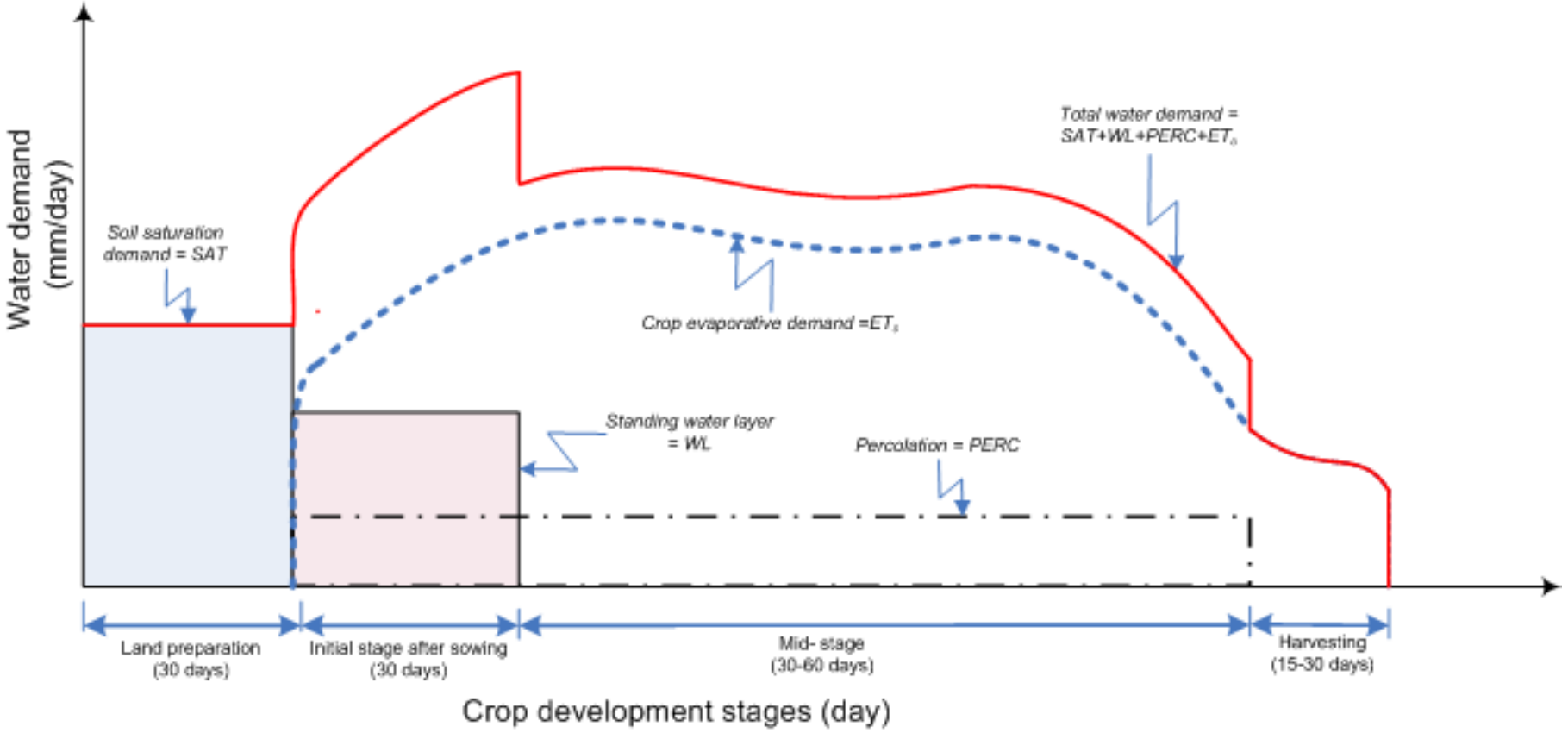
Water demand at different stages





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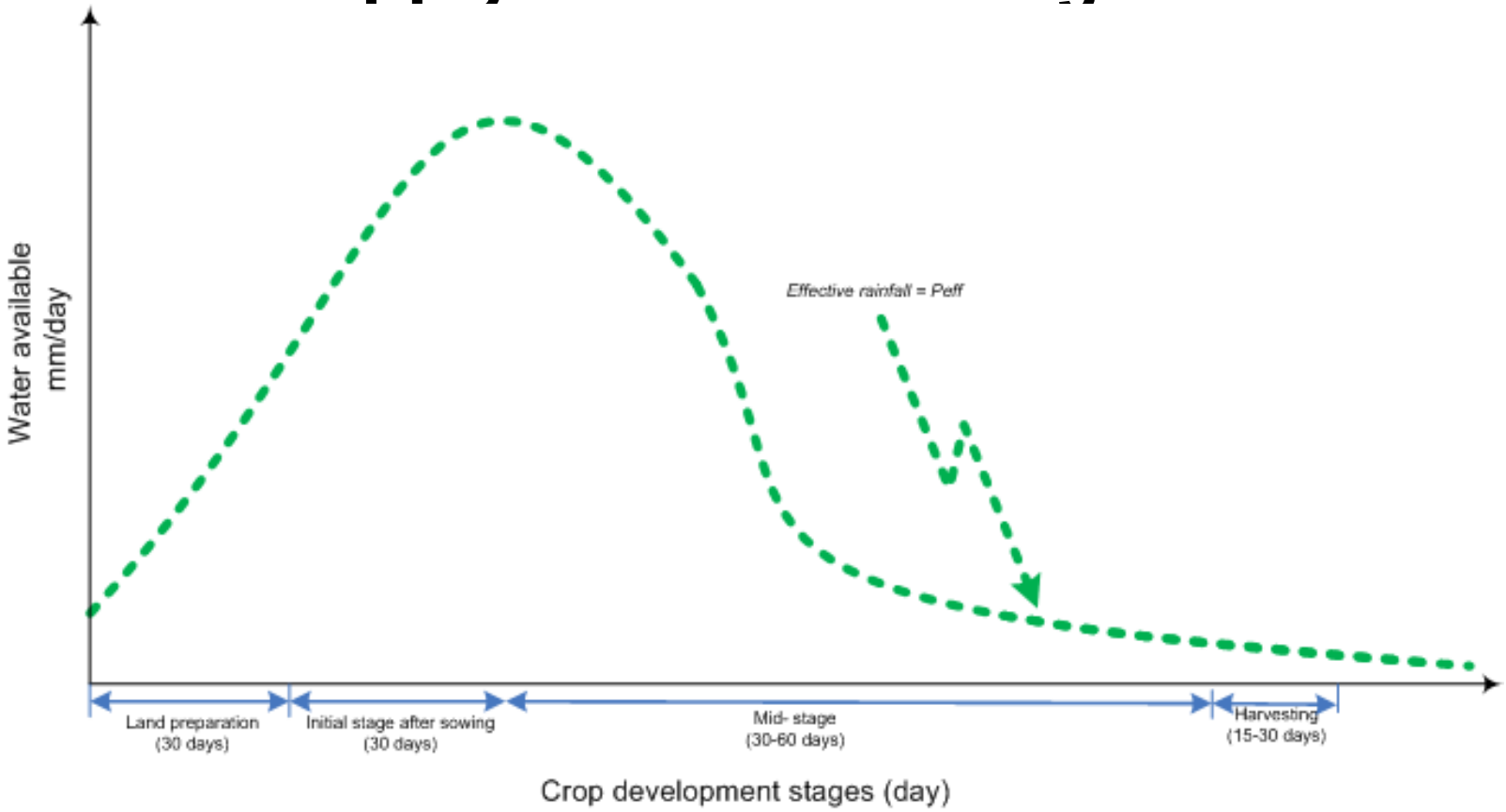
Water supply at different stages





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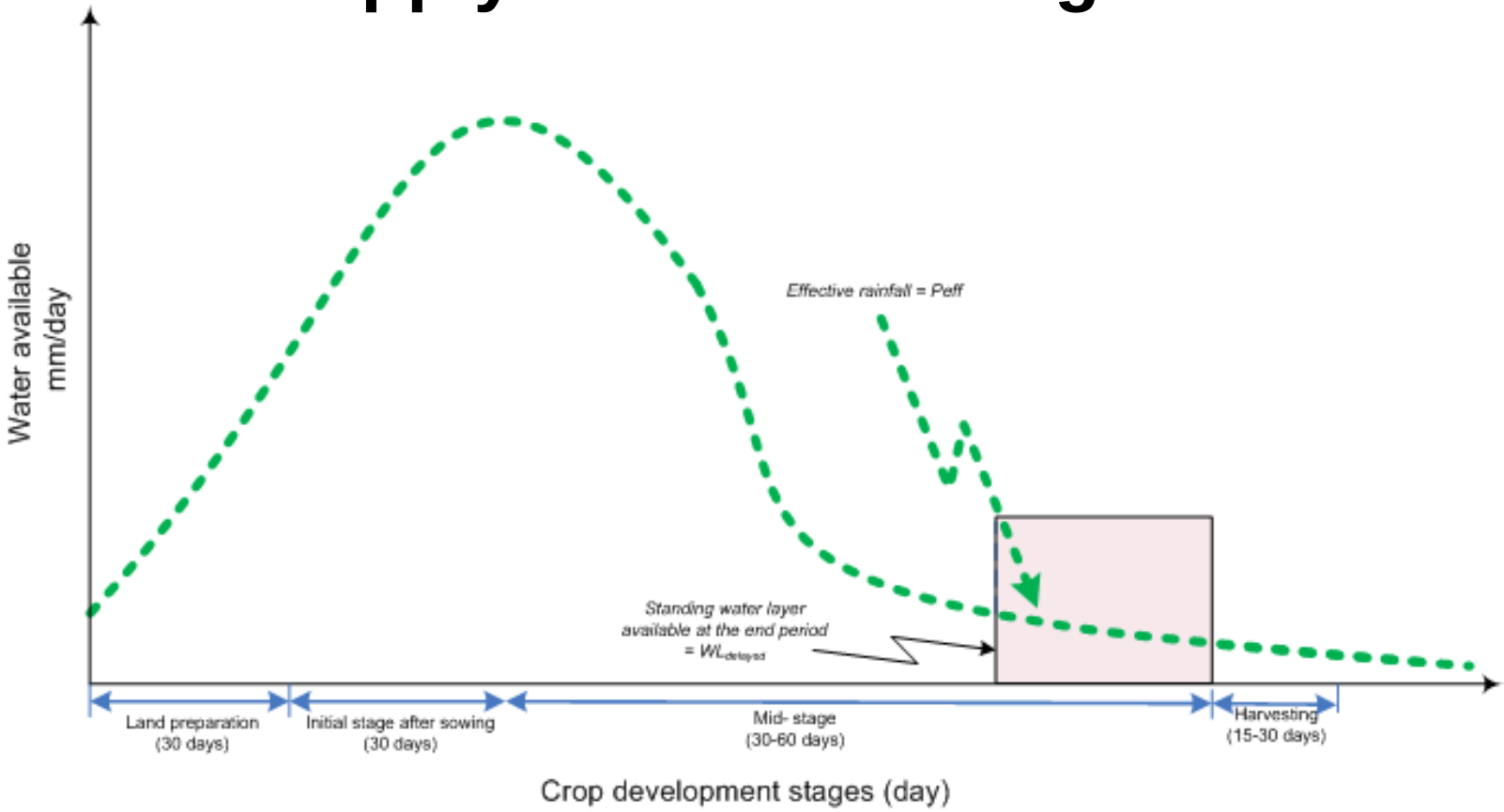
Water supply at different stages





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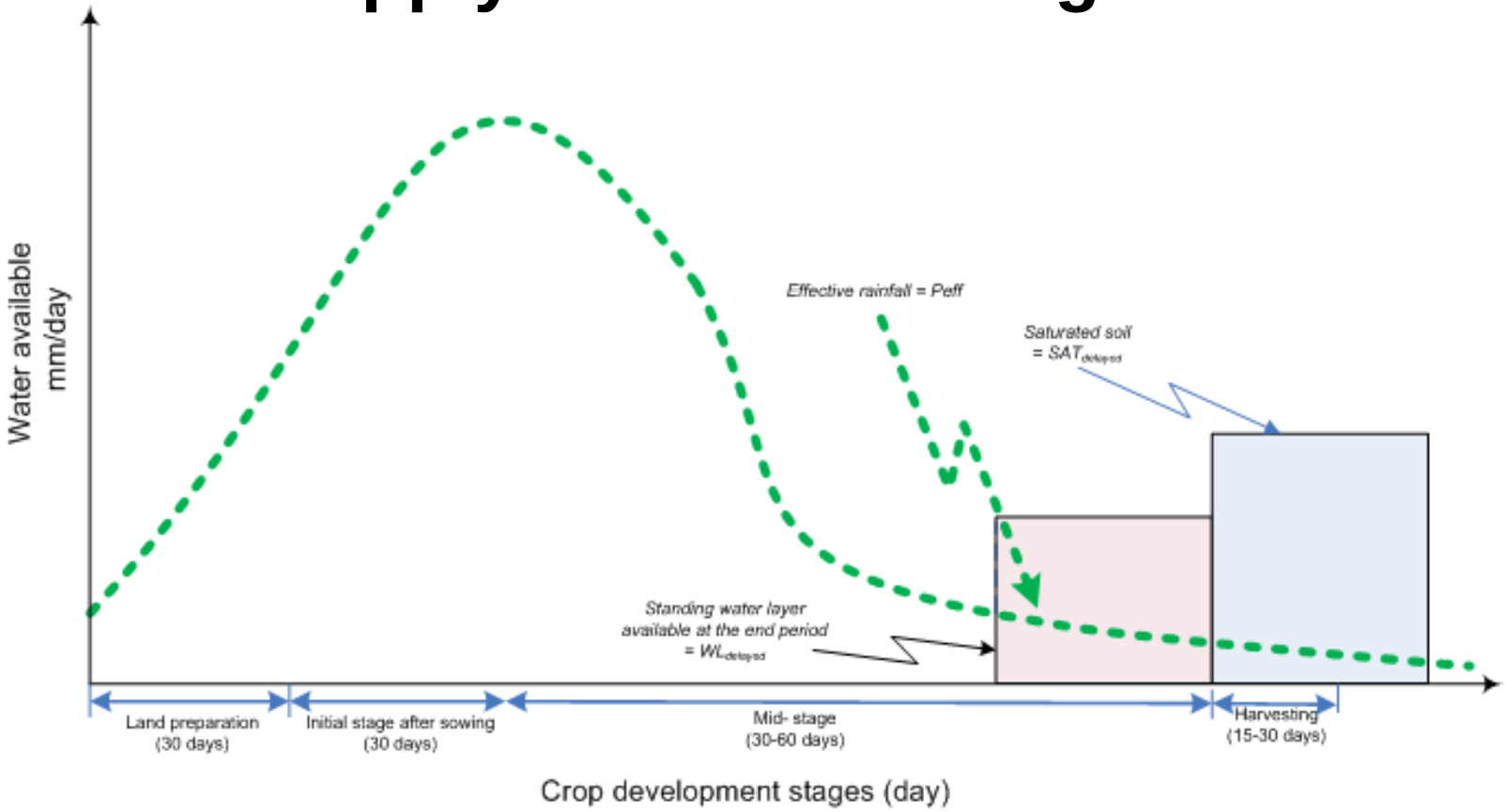
Water supply at different stages





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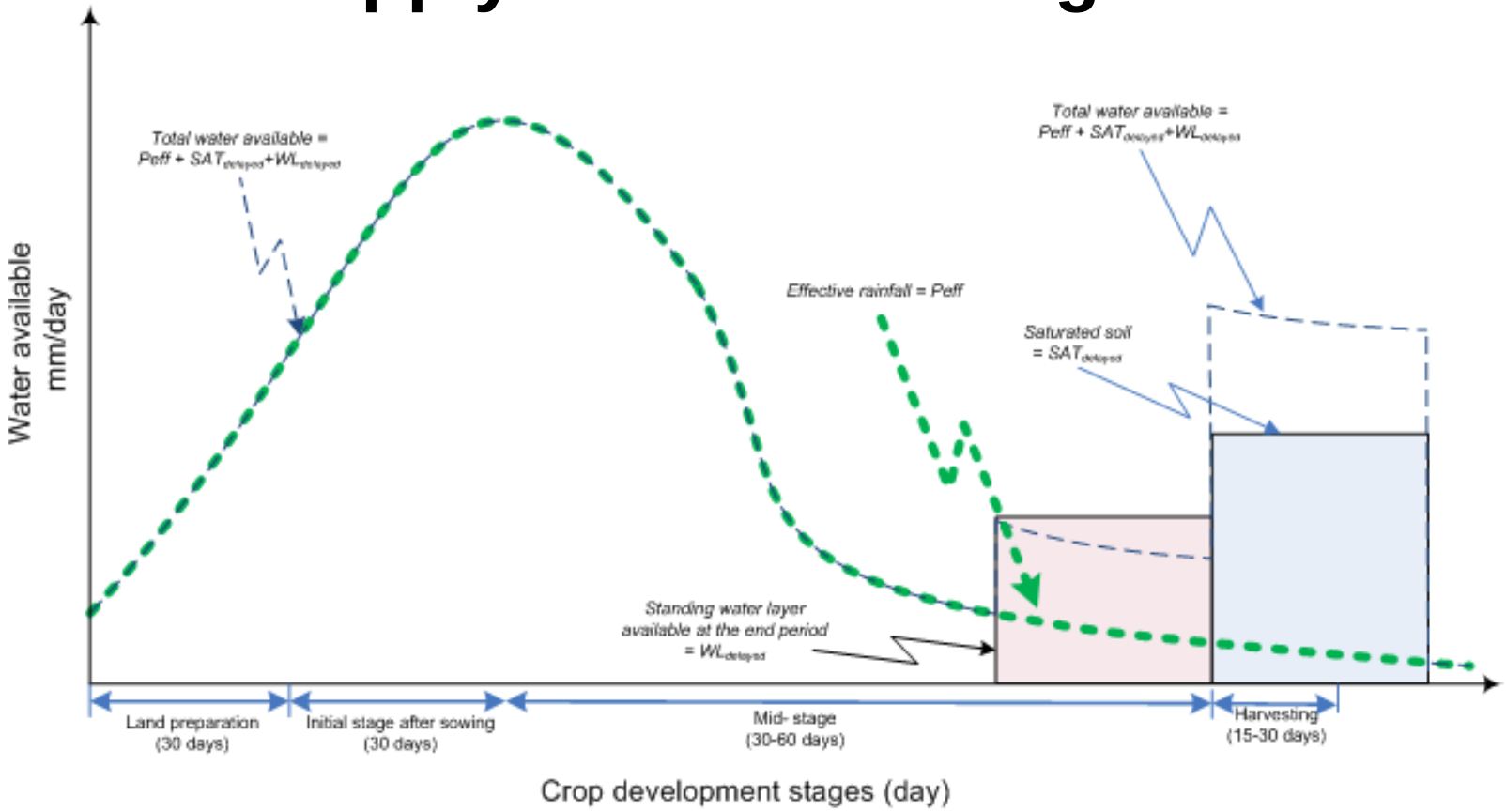
Water supply at different stages





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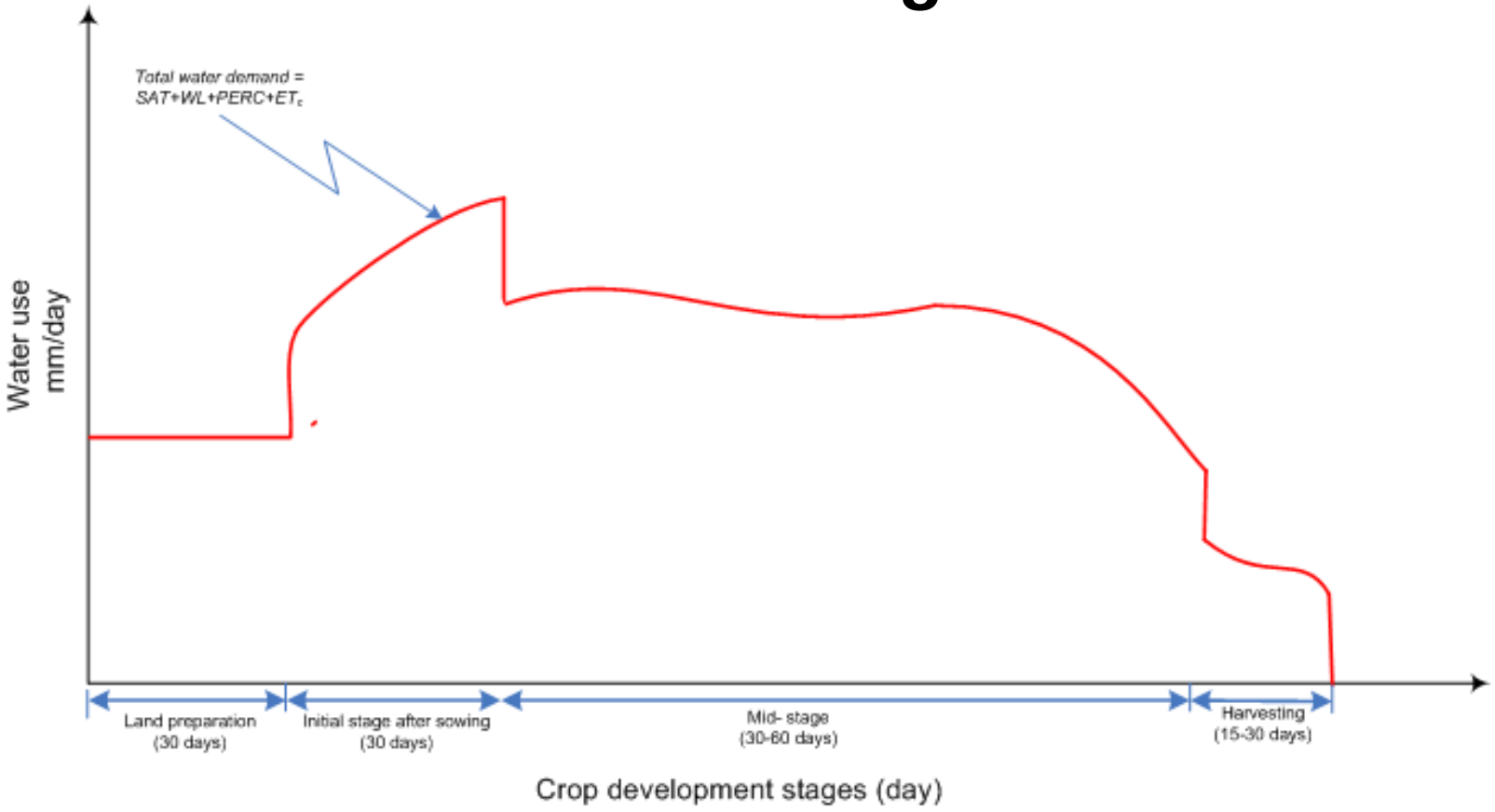
Water use at different stages





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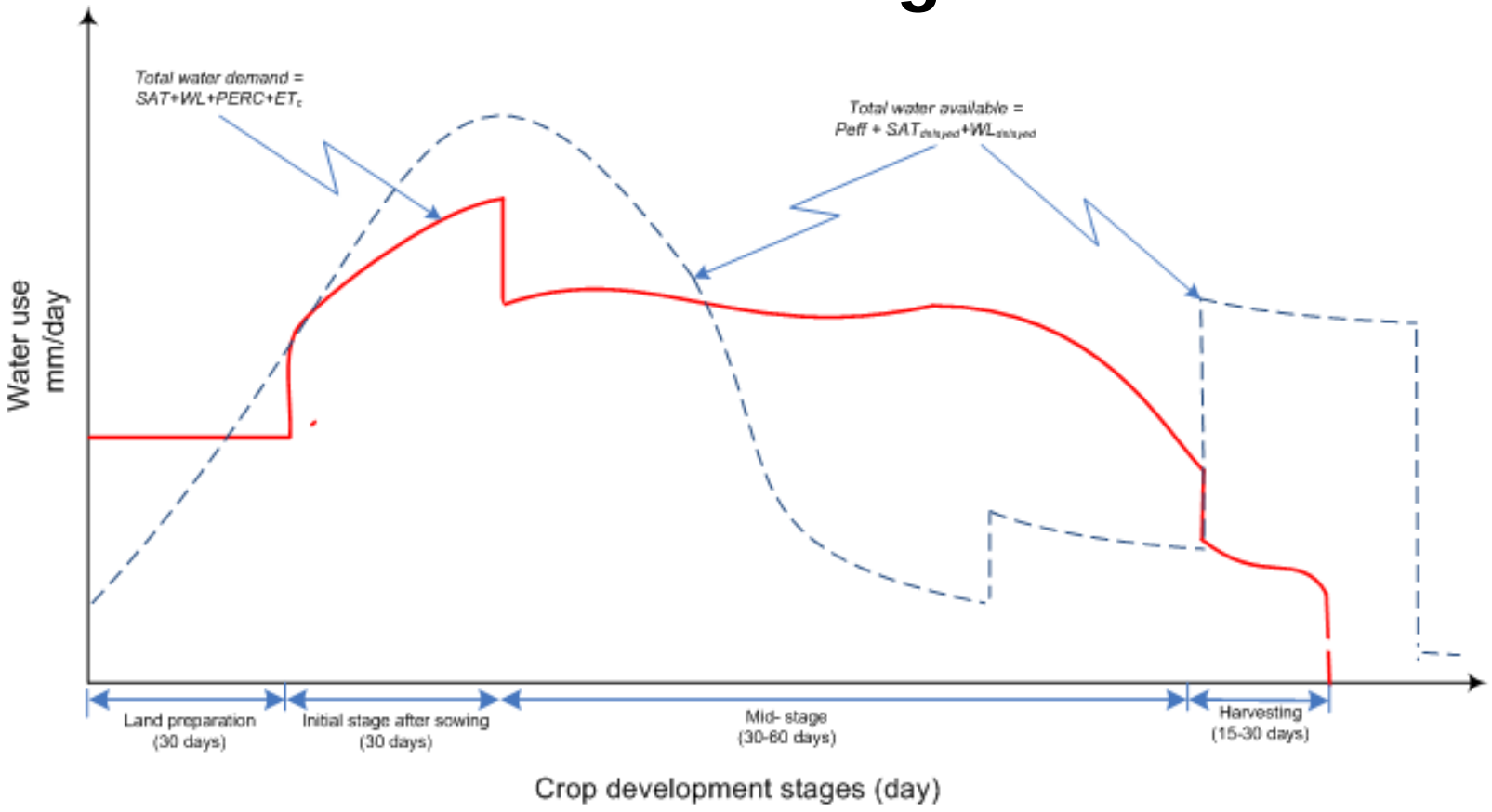
Water use at different stages





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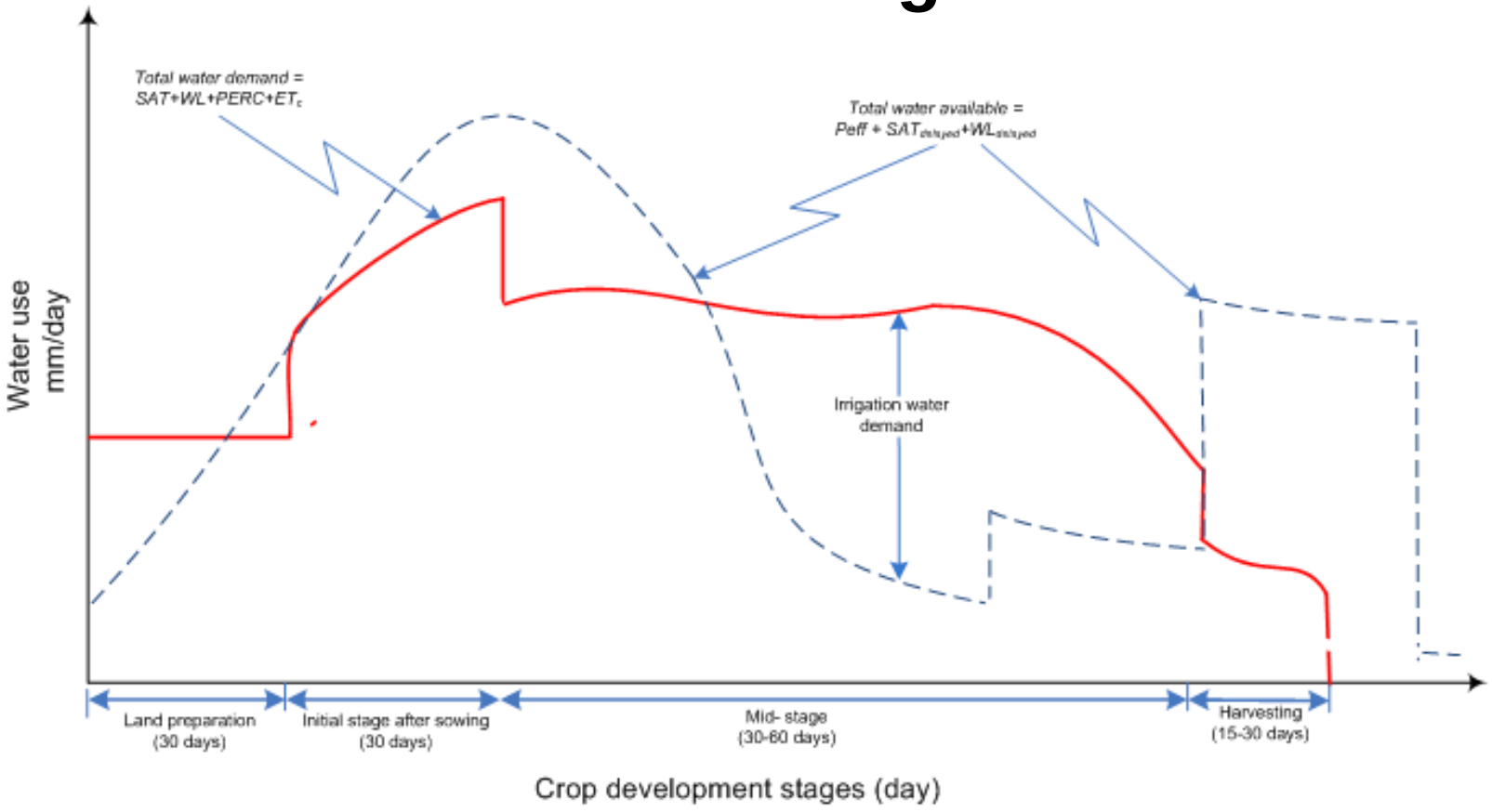
Water use at different stages





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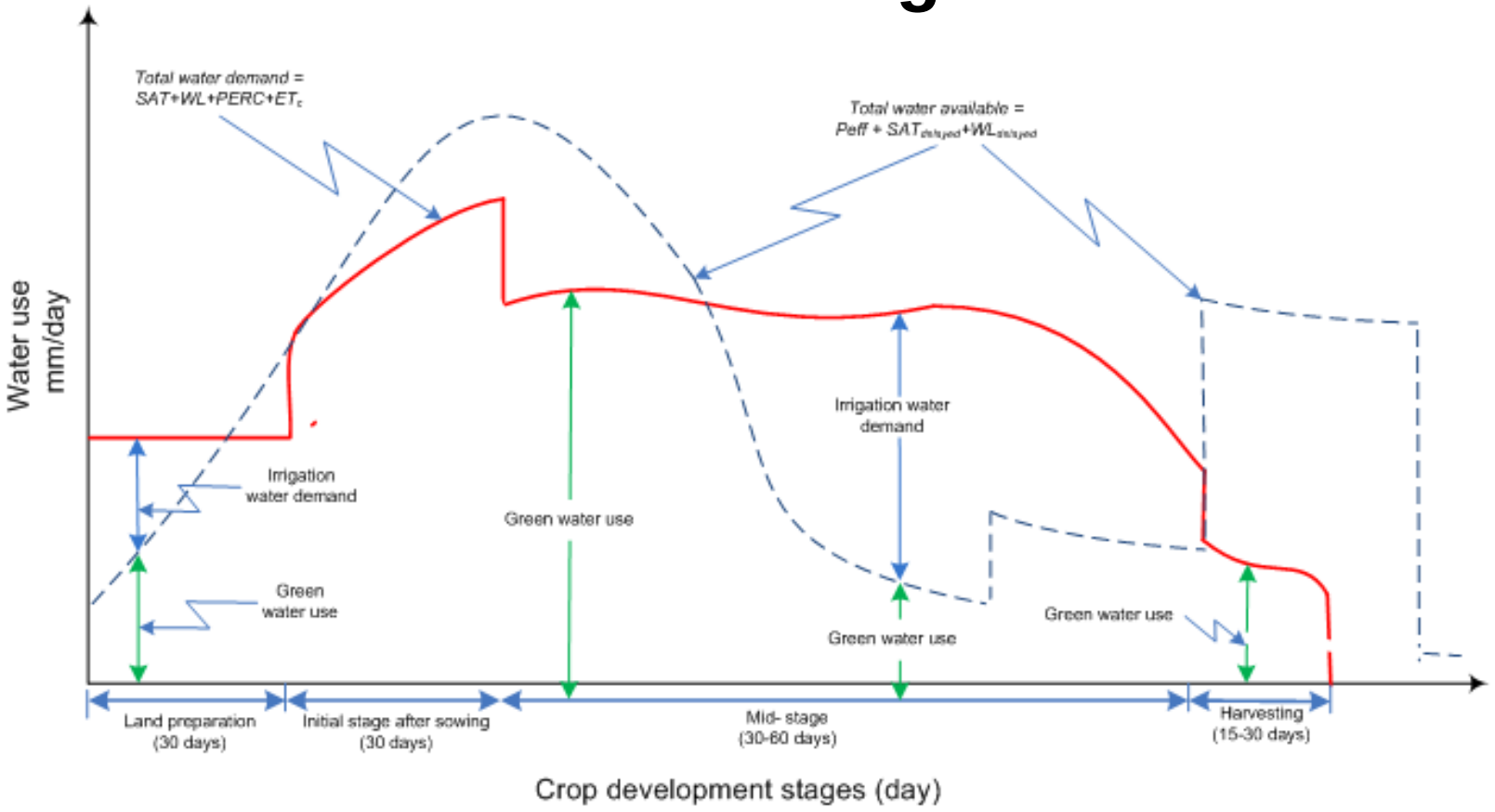
Water use at different stages





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Calculation of water use

- For each of the 13 countries;
  - green water use
  - irrigation demand
  - blue water use
- Estimate is made based on whether
  - wetland system
  - upland system
- For each variety grown in each season
- For each major regions of production

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Calculation of water use

- National average water uses are calculated based on the regional share of production to the total national value.

- The planting and harvesting period is chosen based on the major crop season in each region.

- Local climate data is used for each production regions

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Unit water use (mm/yr)

	Water use by source type (mm/yr)			Water use by event type (mm/yr)		
	Green water use	Blue water use	Total	Evaporation	Losses	Total
China	345	591	936	529	407	937
India	485	434	919	544	375	919
Indonesia	407	433	840	465	375	840
Bangladesh	317	417	734	386	348	734
Viet Nam	318	225	543	222	321	543
Thailand	374	281	654	379	275	654
Myanmar	511	246	757	414	343	757
Japan	381	556	938	478	460	938
Philippines	461	276	737	406	331	737
Brazil	325	511	836	467	369	836
USA	218	991	1209	787	422	1209
Korea, Rep.	355	487	842	477	365	842
Pakistan	176	1047	1223	823	400	1223






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Total water use (km^3/yr)

	Evaporation (km^3/yr)			Losses (km^3/yr)			Total crop water use (Evaporation + losses) (km^3/yr)		
	Green	Blue	Total	Green	Blue	Total	Green	Blue	Total
China	55.9	95.8	151.7	43.1	73.7	116.8	98.9	169.4	268.3
India	124.6	111.3	236.0	86.0	76.8	162.8	210.6	188.1	398.7
Indonesia	26.2	27.9	54.2	21.2	22.5	43.7	47.4	50.5	97.9
Bangladesh	17.7	23.3	41.0	16.0	21.0	37.1	33.7	44.4	78.1
Viet Nam	9.8	6.9	16.6	14.1	10.0	24.1	23.9	16.9	40.8
Thailand	21.7	16.3	38.1	15.8	11.8	27.6	37.5	28.2	65.7
Myanmar	18.0	8.7	26.7	14.9	7.2	22.1	32.9	15.8	48.7
Japan	3.3	4.8	8.2	3.2	4.7	7.8	6.5	9.5	16.0
Philippines	10.3	6.2	16.5	8.4	5.0	13.4	18.7	11.2	29.9
Brazil	6.1	9.6	15.7	4.8	7.6	12.4	11.0	17.2	28.2
USA	1.8	8.3	10.1	1.0	4.5	5.4	2.8	12.7	15.5
Korea, Rep.	2.1	2.9	5.0	1.6	2.2	3.8	3.7	5.1	8.8
Pakistan	2.8	16.5	19.2	1.3	8.0	9.4	4.1	24.5	28.6






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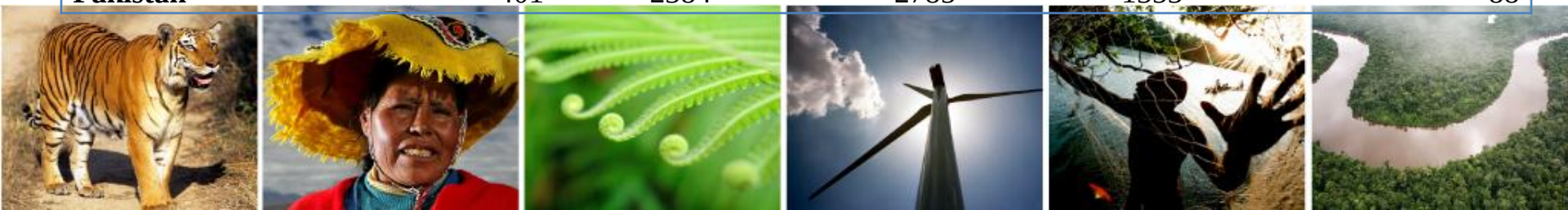
Virtual water content of paddy (m^3/t)

	Evaporative (m^3/t)			Non-evaporative (m^3/t)	Pollution (m^3/t)
	Green	Blue	Evaporative total	losses	Grey
China	315	539	854	658	117
India	985	880	1865	1287	113
Indonesia	504	537	1041	840	118
Bangladesh	476	626	1103	996	103
Viet Nam	287	203	490	711	127
Thailand	811	609	1421	1030	116
Myanmar	796	384	1180	977	50
Japan	302	440	742	714	61
Philippines	773	463	1236	1008	78
Brazil	554	869	1422	1124	61
USA	191	871	1062	570	101
Korea, Rep.	309	424	732	560	84
Pakistan	401	2384	2785	1353	88



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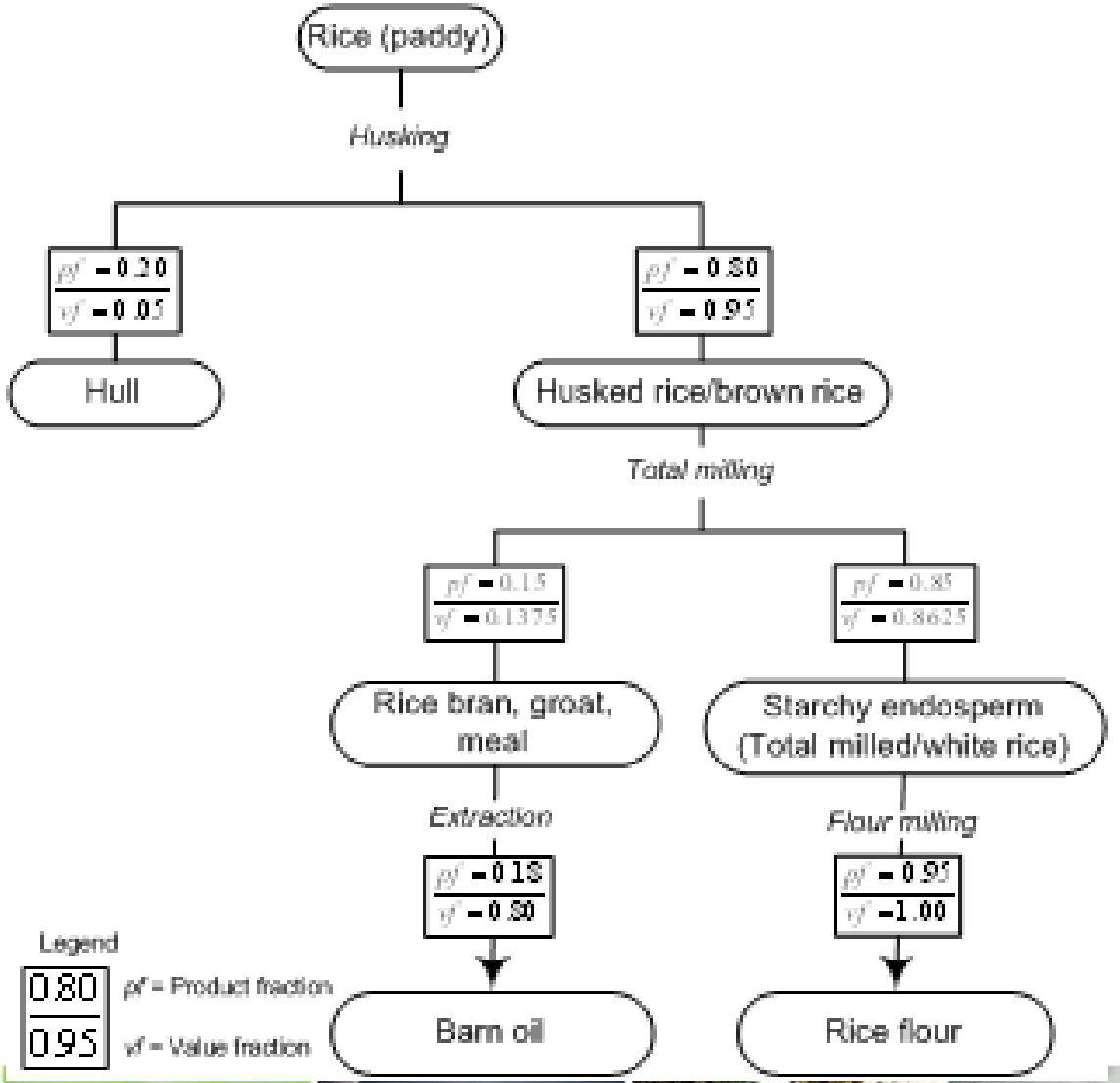
Product tree





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Virtual water content of rice products (m^3/t)

PC-TAS code	Product description	Green* (m^3/t)	Blue* (m^3/t)	Grey (m^3/t)
100610	Rice in the husk (paddy or rough)	564	634	109
100620	Rice, husked (brown)	670	753	129
110314	Rice groats and meal	614	690	118
100630	Rice, semi-milled, milled, whether or not polished or glazed	680	764	131
100640	Rice, broken	680	764	131
110230	Rice flour	715	804	138






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Virtual water flows (Mm^3/yr)

Largest gross-exporters (Mm^3/yr)					Largest top gross-importers (Mm^3/yr)				
	Green	Blue	Grey	Total		Green	Blue	Grey	Total
Thailand	4,830	3,627	691	9,149	**Nigeria**	1,359	1,299	209	2,867
India	2,529	2,260	290	5,078	**Indonesia**	709	733	151	1,592
USA	572	2,600	302	3,474	**Iran**	597	770	98	1,466
Pakistan	408	2,426	90	2,923	**Saudi Arabia**	592	731	80	1,403
China	420	720	156	1,296	**South Africa**	637	571	92	1,300
Viet Nam	555	393	246	1,194	**Senegal**	660	521	106	1,287
Italy	446	501	86	1,033	**Brazil**	402	512	84	997
Uruguay	383	430	74	886	**Japan**	313	573	87	973
Egypt	274	308	53	635	**Philippines**	440	407	103	949
Australia	255	287	49	591	**UK**	352	508	65	924
World total	12,463	15,504	2,366	30,333					






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Water footprint of rice

- The global WF of rice production is 1308 Mm^3/yr,
  - out of which 707 Mm^3/yr is evaporated
    - 332Mm^3/yr is green water use
    - 374 Mm^3/yr is blue water use
  - 64 Mm^3/yr is pollution
  - 538 Mm^3/yr is lost (percolation+ residual soil moisture after the harvest)






	Evaporative water footprint			Pollution water footprint	Water losses	Water footprint including losses
	Green	Blue	Total	Grey	(Green+Blue)	Total
India	122,093	109,078	231,171	13,982	159,475	404,628
China	55,875	95,295	151,170	20,680	116,382	288,232
Indonesia	26,936	28,662	55,599	6,261	44,823	106,683
Bangladesh	17,860	23,429	41,288	3,846	37,229	82,364
Thailand	16,916	12,703	29,618	2,421	21,471	53,510
Myanmar	17,867	8,614	26,481	1,118	21,926	49,525
Philippines	10,738	6,569	17,307	1,137	14,177	32,621
Brazil	6,516	10,108	16,624	756	13,090	30,470
Pakistan	2,363	14,053	16,415	521	7,974	24,910
Viet Nam	9,197	6,504	15,701	4,074	22,767	42,542
Japan	3,609	5,382	8,991	748	8,382	18,121
USA	1,636	6,036	7,672	719	4,247	12,638
Egypt	3,095	3,478	6,573	595	4,999	12,167
Nigeria	3,099	3,255	6,353	544	4,729	11,626
Korea Rep.	2,159	2,981	5,140	592	3,922	9,654






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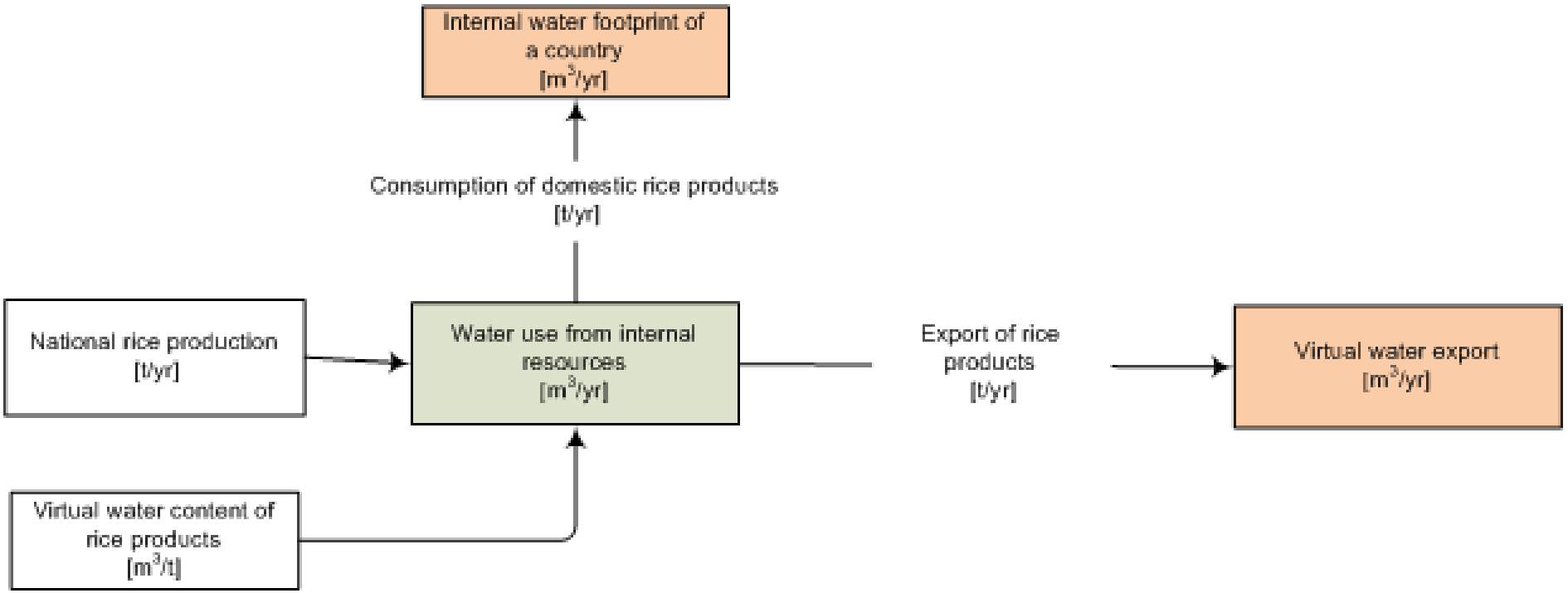
Internal WF





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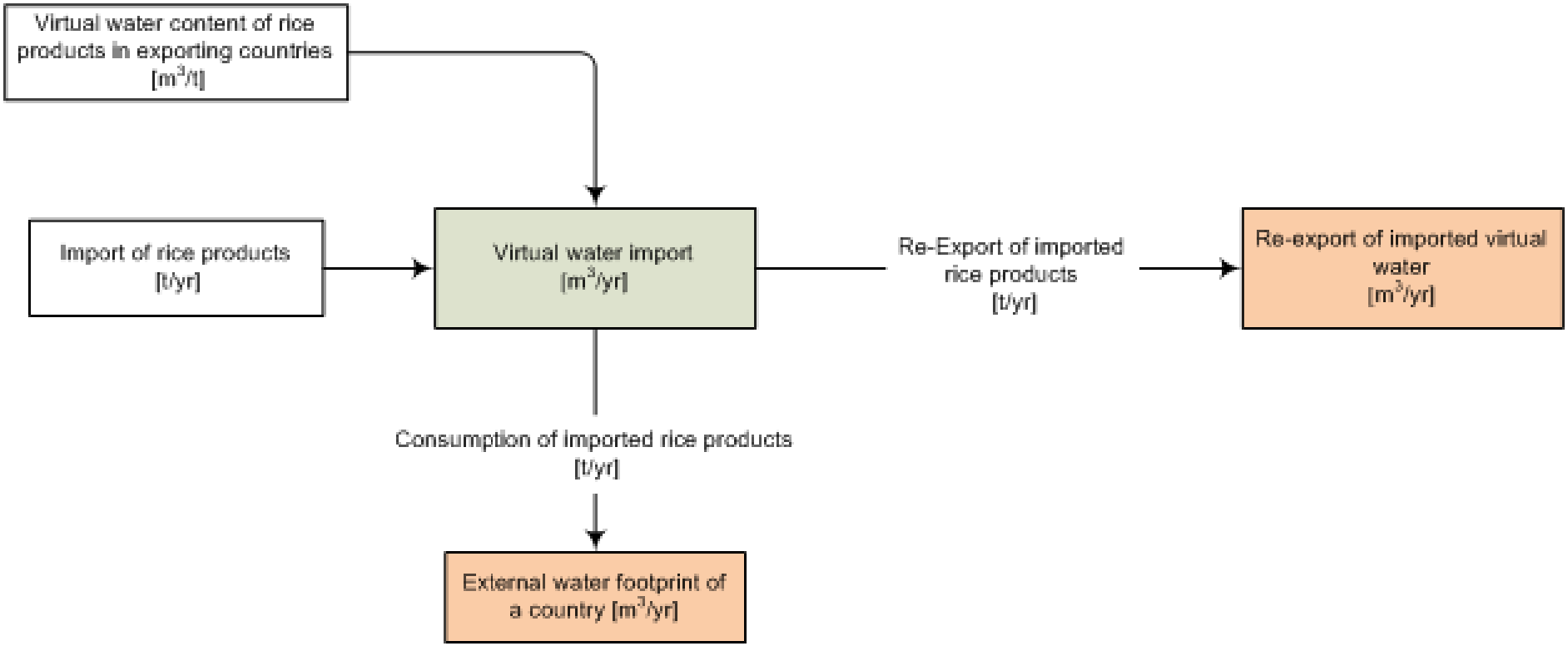
External WF





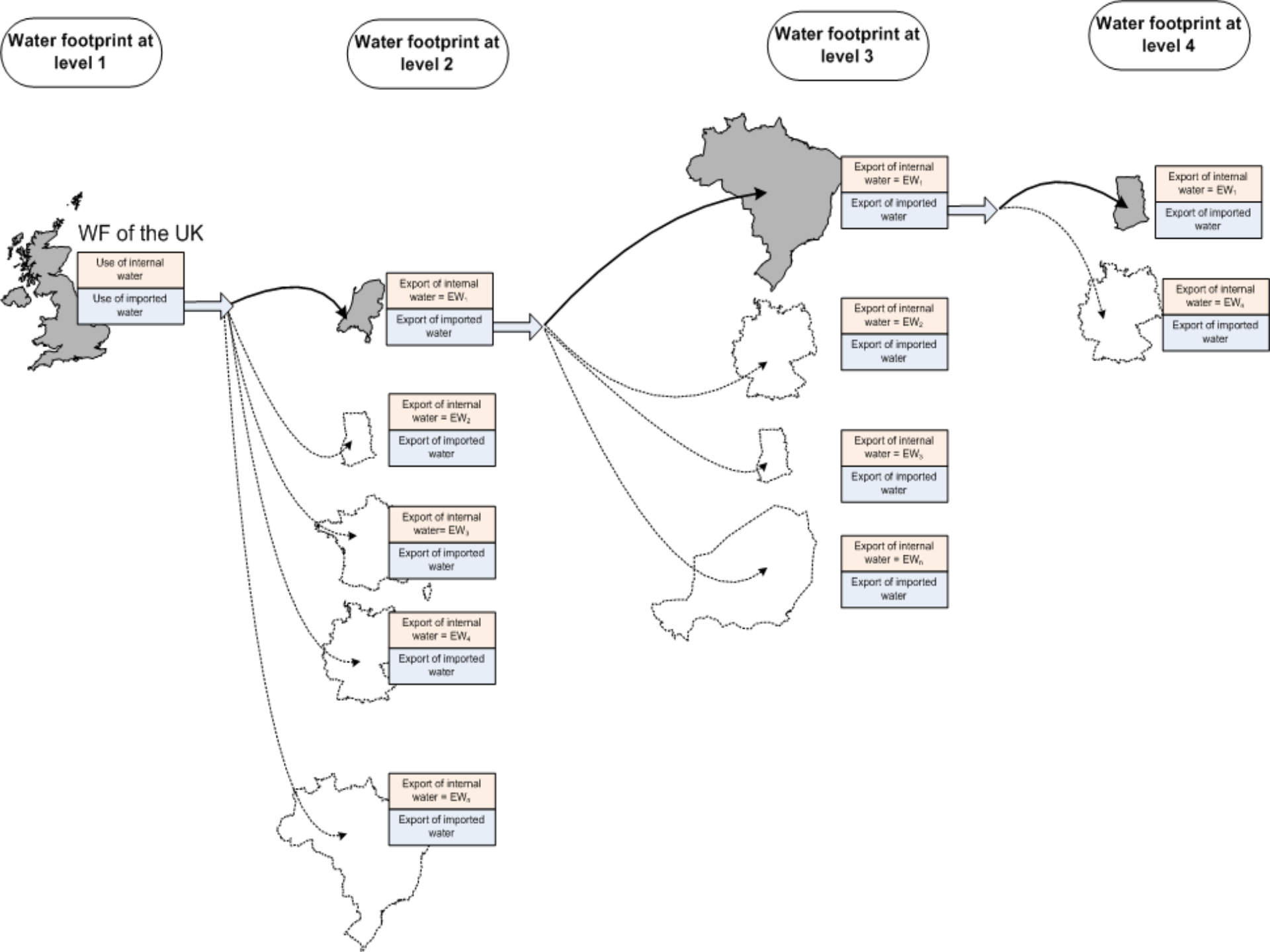



Spatial linkages of water footprint related to rice

	Internal water footprint (Mm3/yr)				External water footprint (Mm3/yr)				Total water footprint*				Total WF**
	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	(including losses)
India	122,091	109,075	13,981	245,148	1	3	0	4	122,093	109,078	13,982	245,153	404,628
China	55,530	95,036	20,630	171,195	345	260	50	655	55,875	95,295	20,680	171,850	288,232
Indonesia	26,228	27,930	6,111	60,269	708	732	151	1,591	26,936	28,662	6,261	61,860	106,683
Bangladesh	17,726	23,310	3,831	44,867	133	119	15	267	17,860	23,429	3,846	45,134	82,364
Thailand	16,915	12,702	2,421	32,038	1	1	0	2	16,916	12,703	2,421	32,039	53,510
Myanmar	17,867	8,614	1,118	27,599	-	-	-	-	17,867	8,614	1,118	27,599	49,525
Viet Nam	9,197	6,504	4,074	19,775	-	-	-	-	9,197	6,504	4,074	19,775	42,542
Philippines	10,299	6,162	1,034	17,495	440	407	103	949	10,738	6,569	1,137	18,444	32,621
Brazil	6,115	9,597	673	16,385	401	511	83	995	6,516	10,108	756	17,380	30,470
Pakistan	2,363	14,053	521	16,936	-	-	-	-	2,363	14,053	521	16,936	24,910
Japan	3,298	4,812	662	8,772	311	570	86	968	3,609	5,382	748	9,739	18,121
USA	1,351	5,794	679	7,823	285	243	40	568	1,636	6,036	719	8,391	12,638
Egypt	**3,095**	**3,478**	**595**	**7,168**	-	-	-	-	**3,095**	**3,478**	**595**	**7,168**	**12,167**
World total	320,244	359,365	61,919	741,528	12,012	14,887	2,282	29,181	332,257	374,252	64,201	770,710	1,308,550







Water footprint at level 1
Water footprint at level 2
Water footprint at level 3
Water footprint at level 4
WF of the UK
Use of internal water
Use of imported water
Export of internal water = EW1
Export of imported water
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Export of imported water

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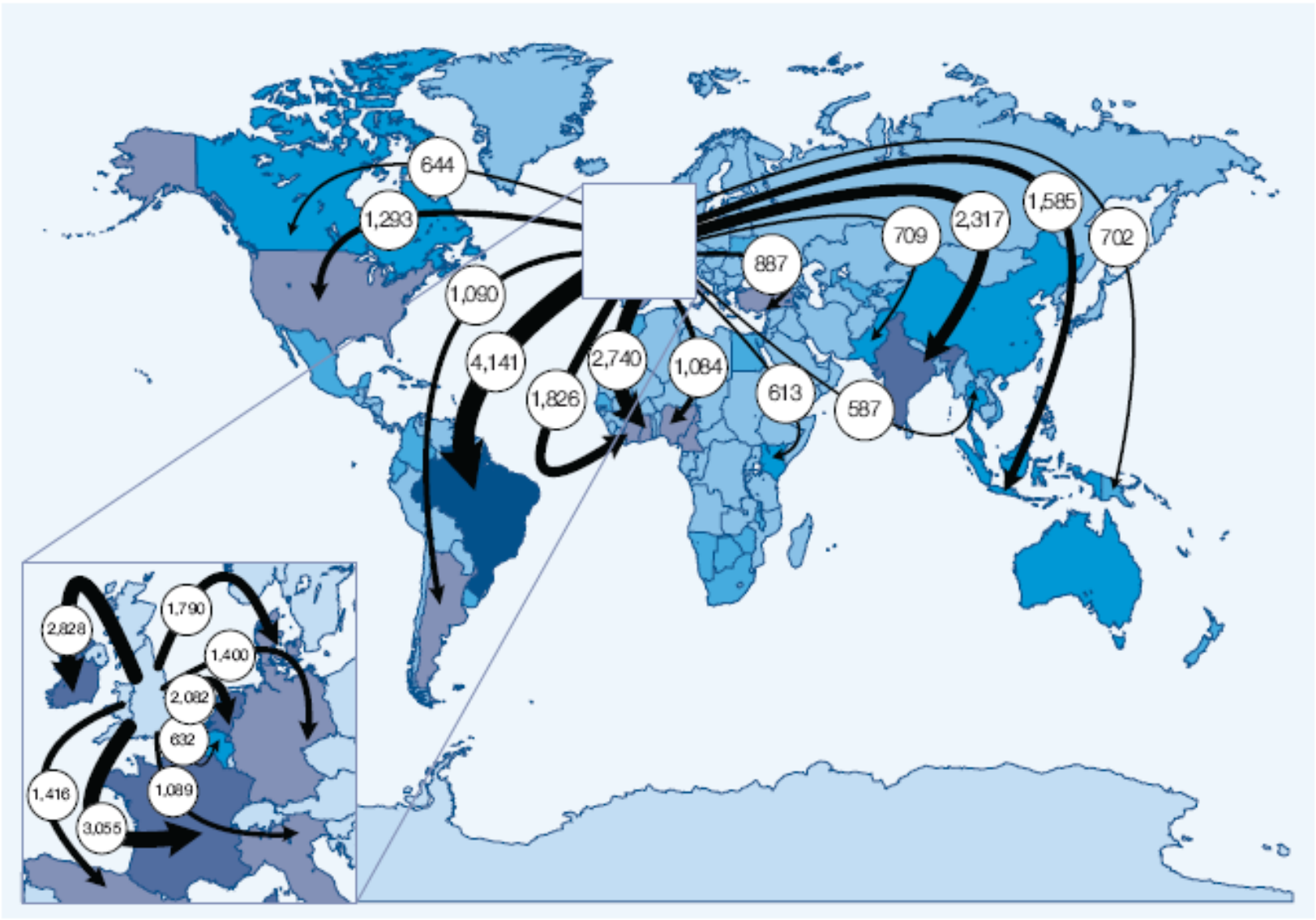
Water footprint of the UK related to agricultural products



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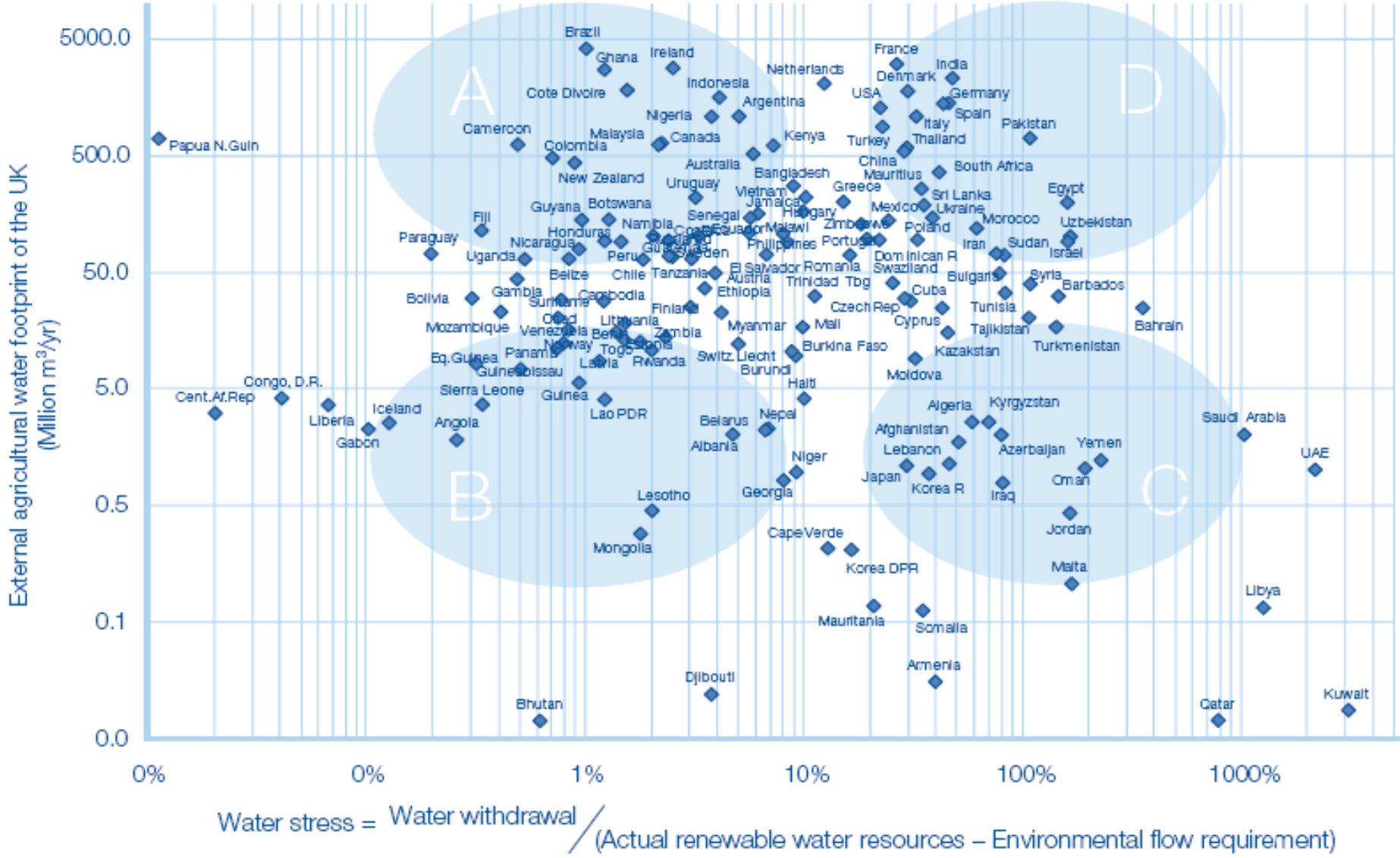

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USA, EU27

- Consumption of rice products in EU27 nations is indirectly connected to the management of water resources in Thailand, India and Pakistan.

- EU27 and USA rice consumption =>
  - total evaporation of 2205 Mm^3 of water
  - polluted return flows of 171 Mm^3 around the globe, mainly in Thailand, Vietnam and India.

- Overlaying with water availability maps show that the water footprint of global rice consumption creates relatively lower stress on the water resources in Thailand compared to that in Pakistan
  - as in the later case rice is extensively irrigated and blue water resource is even more scarcer.

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Summary

- Producing a kilogram of rice **(paddy)** in average
  - evaporates about 1200 litres of water
  - pollutes 110 litres of fresh water.
  - 910 litres of water lost in the field as a result of percolation and unused soil moisture.

- Contribution of green water to the total evaporation is about 47%

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Summary

- Producing a kilogram of milled - rice (white/polished rice) in average
  - evaporates about 1444 litres of water (680 green and 764 blue)
  - pollutes 131 litres of fresh water.
  - 1098 litres of water lost in the field as a result of percolation and unused soil moisture (575litres irrigation + 523 litres augmented water in the field).
  - Total WF of 1 kg of milled rice = 2672 litres

- The share of green virtual water to the total global virtual water ~41% => importance of green water in the context of international trade, rising food security and water scarcity around the world.

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- Farming communities manage about 80 per cent of the water used in our economies - about 70 per cent by volume of this water is green water and 30 per cent is blue water [Tony Allan, 2009]

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Options for 3.8 bln poor

[M. Falkenmark]

- **modernise agriculture/reduce water losses**
- **maximising crop per drop**
  = loss of return flow = increased river depletion

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Water for rice, or rice for water

- Increasing field efficiency in rice fields may further trigger the expansion of agriculture (under suitable conditions)
  - Less water available for already stressed river system

- Best option at production end would be to
  - Efficiency gain is to be targeted towards consumptive (evaporative) use rather than in total use
  - Adopt suitable fertilizer application strategy so that there is almost full recovery in crop
  - Stimulate rice cultivation mainly in rainy season

- Best option at consumption end would be to
  - Reduce the overall consumption
  - Switch to different consumption pattern with equivalent calorie content
  - Understand the impacts of our individual choices, and thus engage with suppliers if possible
  - Import from regions where the impacts are minimal.

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Many thanks