Supplementary materials

Table S1. NBS potential water related indicators

Water-related indicator	Description	Applicable to	Data collection method
W1: Local flood mitigation (rivers, lakes)	Flood mitigation through water storage or velocity reduction (at a cross-section near the NBS)	Wetlands, floodplains, ponds, high-water channels	Hydrodynamic modelling
W2: Downstream flood mitigation (rivers, lakes)	Flood level reduction through water storage or velocity decrease (at a cross-section downstream of NBS)	Wetlands, floodplains, ponds, high-water channels	Hydrodynamic modelling
W3: Historical flood mitigation	Reduction in flooded area using NBS	Wetlands, floodplains, ponds, high-water channels	Flood maps
W4: Flood mitigation (coastal)	Reduction in flooded coastal areas using NBS	Wetlands, floodplains, ponds, high-water channels, mangroves	Hydrodynamic modelling
W5: Water reuse	Volume of water from NBS available for reuse	Green roofs, rainwater harvesting, floodplains, ponds, high-water channel	Interviews with NBS users or maintenance staff
W6: Resilience to drought	How NBS minimizes the effects of drought	Floodplains, ponds, high-water channel	Interviews and records
W7: Resilience to flood	How NBS minimizes the effects of flooding	Green roofs, green walls, rain gardens, vegetated bioswales, porous pavement, tree filter, planter boxes, rainwater harvesting, urban tree canopy, riparian buffer strip, wetlands, mangroves, floodplains, ponds, high-water channel, reforestation	Interviews and records
W8: Irrigation cost	The cost for all sources of irrigation (surface and groundwater) for water storing NBS	Ponds, high-water channel, rainwater harvesting	Interviews and records
W9: Connectivity	Connection of land and waterways, species, nutrient and sediment transport between water bodies; can also be for connectivity of vegetated land areas	Vegetated bioswales, wetlands, floodplains, ponds, high-water channel	Google Earth and maps

Table S2. NBS potential nature related indicators

Nature-related indicator	Description	Applicable to	Data collection method
N1: Infiltration	Ability to infiltrate water within the NBS	Rain gardens, vegetated bioswales, porous pavements, tree filter, planter boxes, riparian buffer strips, wetlands, floodplains, ponds, high-water channel, reforestation	The measurements may be taken using an infiltration ring; measured values may be compared to the optimal value found in literature
N2: Groundwater recharge	Groundwater level increase due to NBS	Rain gardens, vegetated bioswales, porous pavements, tree filter, planter boxes, riparian buffer strips, wetlands, floodplains, ponds, high-water channel, reforestation	Modelling, monitoring well data, Water Table Fluctuation method (WTF), estimated literature rates
N3: Biodiversity	Increase in number of plant and animal species due to NBS	Green roofs, green walls, rain gardens, vegetated bioswales, tree filter, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, floodplains, ponds, high-water channel, reforestation	Interviews, site surveys, remote sensing
N4: Air quality	Carbon sequestration by vegetation	Green roofs, green walls, rain gardens, vegetated bioswales, tree filter, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, reforestation	Site surveys, Google Earth, maps
	Emissions (NO_2, CO, CO_2, etc.)	Green roofs, green walls, rain gardens, vegetated bioswales, tree filter, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, reforestation	Remote sensing databases, site monitors
N5: Water quality	Sediment and nutrients removal from water	Green roofs, green walls, rain gardens, vegetated bioswales, porous pavement, tree filter, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, floodplains,	Site water testing

Nature-related indicator	Description	Applicable to	Data collection method
		ponds, high-water channel, reforestation	
N6: Habitat provision	Increase in habitat for land and water species due to NBS	Green roofs, green walls, rain gardens, vegetated bioswales, tree filters, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, floodplains, ponds, high-water channel, reforestation	Aerial images, remote sensing
N7: Climate control	Temperature decreases through shade, evapotranspiration, reduction of concrete and asphalt areas	Green roofs, green walls, rain gardens, vegetated bioswales, tree filters, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, floodplains, ponds, high-water channel, reforestation	Site measurements, maps
N8: Landslide risk reduction	Slope stability due to NBS	Urban tree canopy, riparian buffer strips, mangroves, floodplains, reforestation	Landslide risk maps, site surveys
N9: Carbon storage	Storage capacity of biomass of NBS	Green roofs, green walls, rain gardens, vegetated bioswales, tree filters, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, floodplains, reforestation	Literature sequestration values
N10: Ground-water quality	Improvement of groundwater quality due to NBS	Rain gardens, vegetated bioswales, porous pavements, tree filter, riparian buffer strips, wetlands, floodplains, ponds, high-water channel, reforestation	Groundwater testing
N11: Noise quality	Reduction through vegetation and alternative surfaces of NBS	Green roofs, green walls, rain gardens, vegetated bioswales, tree filters, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, reforestation	Site measurements

Table S3. NBS potential people related indicators

People-related indicator	Description	Applicable to	Data collection method
P1: Recreational	Number of recreation events due to NBS	Ponds, high-water channel, urban tree canopy, wetlands, mangroves, reforestation	Interviews
P2: Education and research	Number of educational events due to NBS	Green roofs, green walls, rain gardens, vegetated bioswales, porous pavements, tree filters, planter boxes, urban tree canopy, riparian buffer strips, wetlands, mangroves, floodplains, ponds, high-water channel, reforestation	Interviews
P3: Cultural and spiritual	Number of cultural and spiritual events due to NBS	Urban tree canopy, wetlands, mangroves, floodplains, ponds, reforestation	Interviews
P4: Community interaction	Number of interactions within and between communities; stakeholder participation due to NBS	Green roofs, green walls, rain gardens, vegetated bioswales, tree filters, planter boxes, rainwater harvesting, urban tree canopy, riparian buffer strips, wetlands, mangroves, floodplains, ponds, high-water channel, reforestation	Interviews
P5: Quality of life	Improve health and happiness, increased physical activity due to NBS	Green roofs, green walls, rain gardens, vegetated bioswales, tree filters, planter boxes, rainwater harvesting, urban tree canopy, riparian buffer strips, wetlands, mangroves, floodplains, ponds, high-water channel, reforestation	Interviews
P6: Aesthetics / property value	Area beauty improvement; increased property value due to NBS	Green roofs, green walls, rain gardens, vegetated bioswales, tree filters, planter boxes, rainwater harvesting, urban tree canopy, riparian buffer strips, wetlands, mangroves, ponds, reforestation	Municipal records

People-related indicator	Description	Applicable to	Data collection method
P7: Agriculture	Productivity increase due to NBS	Rainwater harvesting, ponds, high-water channel	Interviews
P8: Economic	Income increase due to NBS	Rainwater harvesting, ponds, high-water channel	Interviews
P9: Green jobs	New businesses and job creation due to NBS	Green roofs, green walls, rain gardens, vegetated bioswales, porous pavements, tree filters, planter boxes, rainwater harvesting, urban tree canopy, riparian buffer strips, wetlands, mangroves, ponds, high-water channel, reforestation	Employment records
P10: Social safety	Safe neighbourhoods, parks, playgrounds	Urban tree canopy, riparian buffer strips, ponds, reforestation	

Table S4. Water related indicators and equations

Indicator	Equation	Parameters
Local flood mitigation	**W1** = $100\ [1-(D-H_{st}) \div D]$	D = Height (m) at which maximum flood damage occurs (on flood damage-depth graph for case study). H_{st} = Difference in flood height level (m) in river near storage location before and after storage is added.
Down-stream flood mitigation	**W2** = $100\ [1-(D-H_{st}) \div D]$	D = Height (m) at which maximum flood damage occurs (on flood damage-depth graph for case study) H_{st} = Difference in flood height level (m) in river downstream of storage location before and after storage is added.
Historical flood mitigation	**W3** = $100\ [(B - A) \div B]$	B = Flooded comparison area without NBS (%) A = Flooded study case area with NBS (%)
Flood mitigation (coastal)	**W4** = $100\ [(B - A) \div B]$	B = Flooded comparison area without NBS (%) A = Flooded study case area with NBS (%)
Water storage and reuse	**W5** = 100 W	W = Time duration that all irrigation needs were met by the NBS (# days / 365)
Resilience to drought	**W6** = $100\ [(I_B - I_A) \div I_B]$	I_B = (1-[Y/X]): Area B income (% loss between years) I_A = (1-[Y/X]): Area A income (% loss between years) Y = Drought year

		X = Non-drought year; X and Y are consecutive
Resilience to flood	**W7** = 100 [(I_B – I_A) ÷ I_B]	I_B = (1-[Y/X]): Area B income (% loss between years) I_A = (1 – [Y/X]): Area A income (% loss between years) Y = Flood year X = Non-flood year; X and Y are consecutive
Irrigation cost	**W8** = 100 [(I_B – I_A) ÷ I_B]	I_B = Irrigation costs of Area B ($ / year / km^2) I_A = Irrigation costs of Area A ($ / year / km^2) Costs: electricity, equipment, fuel, labor, etc.
Connectivity	**W9** = 100 [(C_A – C_B) ÷ C_A]	C_A = Length of water channels in Area A (km / km^2) C_B = Length of water channels in Area B (km / km^2)

Table S5. Nature related indicators and equations

Indicator	Equation	Parameters
Infiltration	**N1** = 100 [1 – {(F_L – F_A) ÷ F_L}]	F_L = Optimal infiltration rate (mm / h) F_A = Infiltration rate in Area A (mm / h)
Ground water recharge	**N2** = 100 [(R_A – R_B) ÷ R_A]	R_A = Average recharge in Area A (meters / year R_B = Average recharge in Area B (meters / year) Using Water Table Fluctuation method (WTF) for unconfined aquifers
Biodiversity	**N3** = 100 [(B_A – B_B) ÷ B_A]	B_A = Number of plants and animals in Area A (# / km^2) B_B = Number of plants and animals in Area B (# / km^2)
Air quality	**N4** = 100 [(P_B – P_A) ÷ P_B]	P_B = Pollutant concentration in Area B (ppm) P_A = Pollutant concentration in Area A (ppm) Pollutant: NO_2, CO, CO_2, etc.
Water quality	**N5** = average [($W_{i,R}$ - $W_{i,A}$) ÷ $W_{i,R}$] 100	W = Water quality pollutant concentration (units vary) $_i$ = Individual pollutant $_R$ = Runoff $_A$ = Area A Pollutants: Total suspended solids (TSS), total dissolved solids (TDS), turbidity, etc.
Habitat provision	**N6** = 100 [(H_A - H_B) ÷ H_A]	H_A = Habitat in Area A (# / km^2) H_B = Habitat in Area B (# / km^2)
Climate control	**N7** = 100 [(X_B - X_A) ÷ X_B]	T_B = Average X in Area B (x / year) T_A = Average X in Area A (x / year)

		X = temperature, wind velocity, humidity, evapotranspiration, etc.
Landslide risk reduction	**N8** = 100 $[(L_B - L_A) \div L_B]$	L_B = Landslide risk in Area B (m^2 / km^2) L_A = Landslide risk in Area A (m^2 / km^2)
Carbon storage	**N9** = 100 $[(C_A - C_B) \div C_A]$	C_A = Carbon sequestration of Area A vegetation (C /m^2/y^1) C_B = Carbon sequestration of Area B vegetation (C /m^2/y^1)
Ground water quality	**N10** = 100 x average $[(Q_{i,B} - Q_{i,A}) \div Q_{i,B}]$	Q = Water quality pollutant concentration (varies) $_i$ = Individual pollutant Pollutants: heavy metals, sewage, gasoline, fertilizers, etc.
Noise quality	**N11** = 100 $[(N_B - N_A) \div N_B]$	N_B = Noise level of Area B (dB) N_A = Noise level of Area A (dB)

Table S6. People related indicators and equations

Indicator	Equation	Parameters
Recreational	**P1** = 100 $[1 - \{(X - R_A) \div X\}]$	R_A = Number of events in Area A (# events / year) Benchmark X: Average # visits to local parks
Education and research	**P2** = E / 10	E = Number of events in Area A (# events / year) Benchmark if E = 800, C2 = 80 (high score) Malmo green infrastructure project attracts over 800 visitors per year [37]
Cultural and spiritual	**P3** = 100 $(C_A - C_B) \div C_A$	C_A = Number of events in Area A (# events / km^2 / year) C_B = Number of events in Area B (# events / km^2 / year)
Community interaction & development	**P4** = 100 $(M_A - M_B) \div M_A$	M_A = Number of events in Area A (# events / km^2 / year) M_B = Number of events in Area B (# events / km^2 / year)
Quality of life	**P5** = Q	Q = Scale: 1 is no difference, 10 is major difference
Aesthetics / property value	**P6** = 100 $(P_A - P_B) \div P_A$	P_A = Average property values in Area A ($ / m^2) P_B = Average property values in Area B ($ / m^2)

Agriculture	**P7** = $100 (A_A - A_B) \div A_A$	A_A = Average productivity in Area A [(\$ / km^2) ÷ (\$ / km^2)] A_B = Average productivity in Area B [(\$ / km^2) ÷ (\$ / km^2)] Productivity = income (output) ÷ expenses (input) Output: sale of crops Inputs: cost of seeds, pesticides, fertilizers, packaging, tools, equipment, gas and oil, labor
Economic	**P8** = $100 (E_A - E_B) \div E_A$	E_A = Average income in Area A (\$ / km^2) E_B = Average income in Area B (\$ / km^2)
Green jobs	**P9** = $100 (G_A - G_B) \div G_A$	G_A = Green jobs in Area A (# / km^2) G_B = Green jobs in Area B (# / km^2)
Social safety	**P10** = S	S = Scale: 1 is no difference, 10 is major difference

1. QUESTIONS

AREA A: NONG SUEA (district) – Noppharat (sub-district) Farmers. DATE:

Name:

Email:

Phone Number:

Address:

1. History of farm

2. Estimate the percentage of irrigation water is from furrows (vs. canals):

3. What are annual irrigation costs (equipment, pumping, fuel, etc.)?

4. What was the decrease in annual income in 2015 due to drought? (from 2017)

5. List of crops, animals, insects, birds etc.

6. Type of fertilizer:

    amount used: $kg/km^2/year$:

    cost (Baht/year):

    where is it used:

7. Farmer income: (Baht/year.)

8. Size of farm:

9. Productivity: outputs/inputs (Baht/Baht) (expenses: fuel, equipment, seeds, labour, fertilizer etc):

AREA B: NONG KHAE (district) Nong Rong (sub-district) Farmers. DATE:

Name:

Email:

Phone Number:

Address:

1. History of farm:

2. What are annual irrigation costs (equipment, pumping, fuel, etc.)?

3. What was the decrease in annual income in 2015 due to drought? (from 2017)

4. List of crops, animals, insects, birds etc.

5. Type of fertilizer:

amount used: kg/km^2/year:

cost (Baht/year):

where is it used:

6. Farmer income: (Baht/year.):

7. Size of farm:

8. Productivity: outputs/inputs (Baht/Baht) (expenses: fuel, equipment, seeds, labour, fertilizer etc)

2. FARMER ANSWERS

Interviews were conducted in Farms A-3 and A-4 and in B-1, B-2, B-3, and B-4.

Farm A-3 (Noppharat) with furrows

Farm A-3 is 18 Rai (2.88 ha – approximately 1/3 furrows and 2/3 land) in size and owned by a Thai family for 26 years; the following is a brief history:

- 1993 – 1994: rice paddies
- 1994 – 2007: converted to orange crop with furrows
- 2007 – 2010: rented out to a horse owner (orange disease destroyed most of crop)
- 2010 – 2016: orange and lime crops

- 2016 – present: in the process of establishing a tourism farm making use of the furrows with fishing (7 types of fish), boating, flower and mulberry gardens (for site decoration and selling) and sleeping huts

Furrow water is used to water the crops; sediment from the furrows is placed on the cropland once or twice per year using a loader. Furrows are approximately 2.5 – 3.0 m wide and have a maximum depth of 2.0 m. Presently, water is pumped approximately 45 meters once per week from Khlong 12 to fill the furrows. Irrigation costs (pumping, maintenance, equipment, etc.) are 350 Baht/week.

During the drought in 2015 (orange and lime) this farm maintained water in the furrows; although the water level became low, there was enough to irrigate crops; as a result, there was no reduction in income.

The farm income during 2010 (orange and lime) was 450,000 Baht and the expenses were 600,000 Baht; as a result, the farmers decided to change crops to flowers (Fueng Fah). 2016 income 500,000 Baht, expenses 30,000 Baht.

The type of crop at present (flowers and mulberries) do not require fertilizer except a minimal amount when they are being planted to help root establishment; for the remainder of the crops lifespan there is no fertilizer applied. A nominal value of 5000 Baht/year was allocated for fertilizer.

During the past 2 years the farmers have been converting the farm to grow flowers; they plan to make it a tourist vacation area with overnight huts, fishing and boating in the furrows and enjoying the flowers.

Farm A-4 (Noppharat) with furrows

Farm A-4 is 18 Rai (2.88 ha – approximately 1/3 furrows and 2/3 land) in size and owned by a Thai man & his parents for 30 years; the following is a brief history:

- 1989: rice paddies
- 1990 – 2008: converted to orange crop with furrows
- 2008 – present: rotating crops of banana and corn (orange disease destroyed most of crop), also minor crops of peanut and melon

Furrow water is used to water the crops; sediment from the furrows is placed on the cropland only during the initial planting of the banana crop; approximately once per year using a rented mire suction boat. Furrows are approximately 2.5 – 3.0 m wide and have a maximum depth of 2.0 m. Presently, water is pumped approximately 25 meters twice per week from Khlong 12 to fill the furrows. Irrigation costs (pumping, maintenance, equipment, etc.) are 1500 - 2000 Baht/month. The furrows also contain fish whose main purpose is to eat the weeds in the furrow, but periodically they are caught and sold.

During the drought in 2015 (banana crop) this farm experienced low water levels in the furrows, resulting in reduced irrigation volumes and consequently a decrease in income of 30%.

The farm income during 2016 (banana crop) was 500,000 Baht and the expenses were 100,000.

This farmer uses mixtures of 16:16:16 and 24:24:24 fertilizer. Fertilizer costs 30,000 Baht per year; at 20 Baht for 1 kg; the farmer uses approximately 1,500 kg of fertilizer per year.

Farm B-1 (Nong Rong) no furrows

Farm B-1 is 36 Rai in size and has been rented by a Thai family for 80 years; during this time, it has been used for growing rice; typically, two crops per year. Currently it is run by a Thai husband & wife.

Irrigation water is pumped approximately 30 meters from Klong 26 several times during the rice cycle: once to flood land prior to planting, then flood again once rice is established, then as required to maintain the water level. When irrigating the crop land, it takes two days to fill the 36 Rai. Groundwater wells have not been used, even in drought conditions. Irrigation costs approximately 333 Baht/year/Rai. This farm has no furrows.

During the drought in 2015, there was not enough water for the second crop of rice, as a result, there was a decrease in income of 50%. This farm was unaffected by the 2011 and 2016 flood; the farmer said it was due to the dikes along Khlong 26.

The farm income during 2018 (two crops total) was 147,200 Baht (20 tons of rice at 7000 Baht/tons plus additional income of 7,200 Baht was made by selling the post-harvest plants as livestock feed) and the expenses were 144,000 (140,000 Baht for rice and 4000 Baht for post-harvest plants). Since 2013, burning of the rice plants after harvest has been banned; now many farmers have the plants baled and sells it for extra income.

This farmer uses insecticides and fertilizer. Fertilizer costs 28,800 Baht/year; at 20 Baht for 1 kg; this farmer uses approximately 1440 kg fertilizer per year.

Farm B-2 (Nong Rong) no furrows

Farm B-2 is 9 Rai in size and has been owned by a Thai family for 100 years; during this time, it has been used for growing rice; typically, two crops per year. Currently this farm is run by a Thai man.

Irrigation water is pumped approximately 40 meters from Klong 26. Groundwater wells have not been used, even in drought conditions. Irrigation costs approximately 1,333 Baht / year / Rai (2018).

During the drought in 2015, water supply was low but farmers were able to rent a large pump to meet the irrigation requirements, so they produced two crops, but the costs increased by 20%. During the 2011 flood, the farmer had just harvested the crop four days before the flood, so there was minimal effect on productivity. This farm has no furrows.

The farm income during 2018 (two crops total) was 110,000 Baht and the expenses were 40,000.

This farmer uses insecticides and fertilizer. One year of fertilizer costs 13,400 Baht; at 20 Baht for 1 kg; this farmer uses approximately 670 kg of fertilizer per year (2018).

Farm B-3 (Nong Rong) no furrows

Farm B-3 is 36 Rai in size and has been rented by a Thai family (Elderly couple and their son and his wife) for 70 years; during this time, it has been used for growing rice; typically, two crops per year.

Irrigation water is pumped approximately 30 meters from Klong 26. Groundwater wells have not been used, even in drought conditions. Irrigation costs were approximately 670 Baht / year / Rai (2018).

During the drought in 2015, water supply was low but farmers were able to rent a large pump to meet the irrigation requirements, so they produced two crops, but the costs increased by 20%. During the 2011 flood, the farmer had just harvested the crop four days before the flood, so there was minimal effect on productivity. This farm has no furrows.

The farm income during 2018 (two crops total) was 240,000 Baht and the expenses were 100,000 Baht.

This farmer uses insecticides and fertilizer. One year of insecticide and fertilizer costs 32,000 Baht; at 20 Baht for 1 kg; this farmer uses approximately 1,600 kg of fertilizer per year (2018).

Farm B-4 (Nong Rong) no furrows

Farm B-4 is made up of a cooperative of 60 farms, with a total size of 500 Rai; an average of 8.3 Rai for each farm. The farmer interviewed had been growing grass since 2003; his family has owned the farm for 100 years. Due to low rice prices and disease, this farmer decided to switch to Pongola grass, which is used for livestock feed. The change required no alterations to the land, but the first couple years the costs were high due to equipment needs. The government saw the potential in the grass crop so a cooperative was started in the community where the expenses, equipment, labour and incomes would be shared amongst the sixty farmers.

Irrigation water is pumped from klong 26. Groundwater wells have not been used, even in drought conditions. Irrigation costs approximately 5% of income or 150 Baht / year / Rai (2016).

In a typical year, there will be three crop cycles, each one is approximately 60 days. During monsoon season the grass is not harvested because it needs dry weather for the bales to dry. The drought in 2015 was beneficial for the grass farmers because they could harvest more often and the result was five crop cycles. The grass crop requires less water than many crops, so even in a drought, there is enough water. However, during the 2011 and 2016 floods, only two crop cycles were harvested per year because they could not dry the grass. These farms have no furrows.

The farm income during 2018 (three crops total) was 3000 Baht / Rai and the expenses were 1,400 Baht / Rai. The fertilizer typically costs 20 Baht per kilogram.

The farmers typically use manure and chemical fertilizers; approximately 15kg / Rai / cycle, so for three cycles, or one year, the cost will be 900 Baht / Rai. Manure, urea and chemical fertilizers are used.

When asked why the farmer did not convert his land to furrows instead of grass, the farmer had the following reasons:

- the transition from rice to grass is much easier
- grass does not need large amounts of water
- equipment for rice can be used for grass, but not suitable for furrows
- high investment for furrows

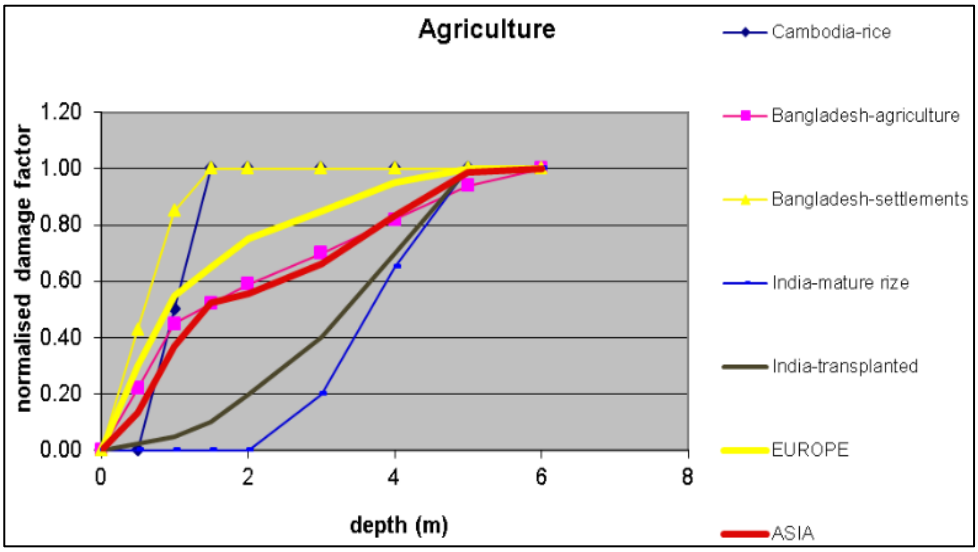

Figure S1. Agriculture flood depth-damage curve [26]

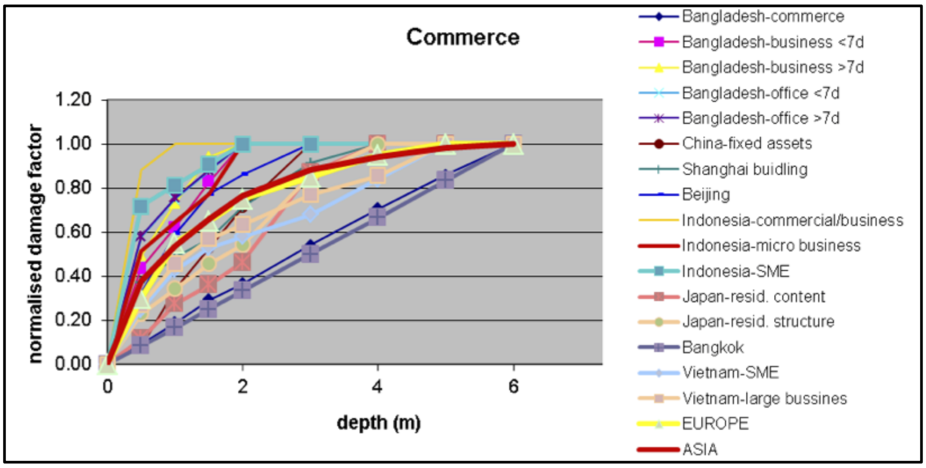

Figure S2. Commerce flood depth-damage curve [26]

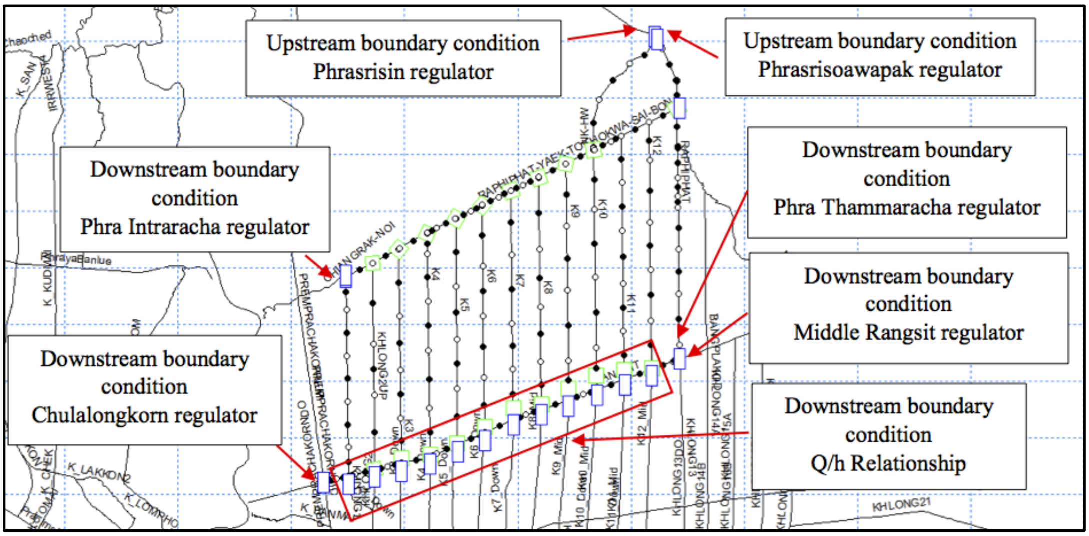

Figure S3. Model domain and boundary conditions [22]

Table S7. E1: Green Ampt infiltration parameters [32]

Parameter	Unit	Symbol	Soil type: silty clay
Porosity	-	η	0.479
Effective porosity	-	$\boldsymbol{\theta}$	0.423
Wetting front suction head	cm	ψ	29.22
Hydraulic conductivity	cm / hour	K	0.05
Time since infiltration began	hour	t	1
Cumulative infiltration	cm	F(t)	1.1448
Cumulative formula:	$F(t) = Kt + \psi\Delta\boldsymbol{\theta}\ln(1 + F(t)/\psi\Delta\boldsymbol{\theta})$		1.1448 cm
Infiltration formula:	$f(t) = K(\psi\Delta\boldsymbol{\theta}/ F(t)) + 1$		10.2 mm/hour