

## Additional files

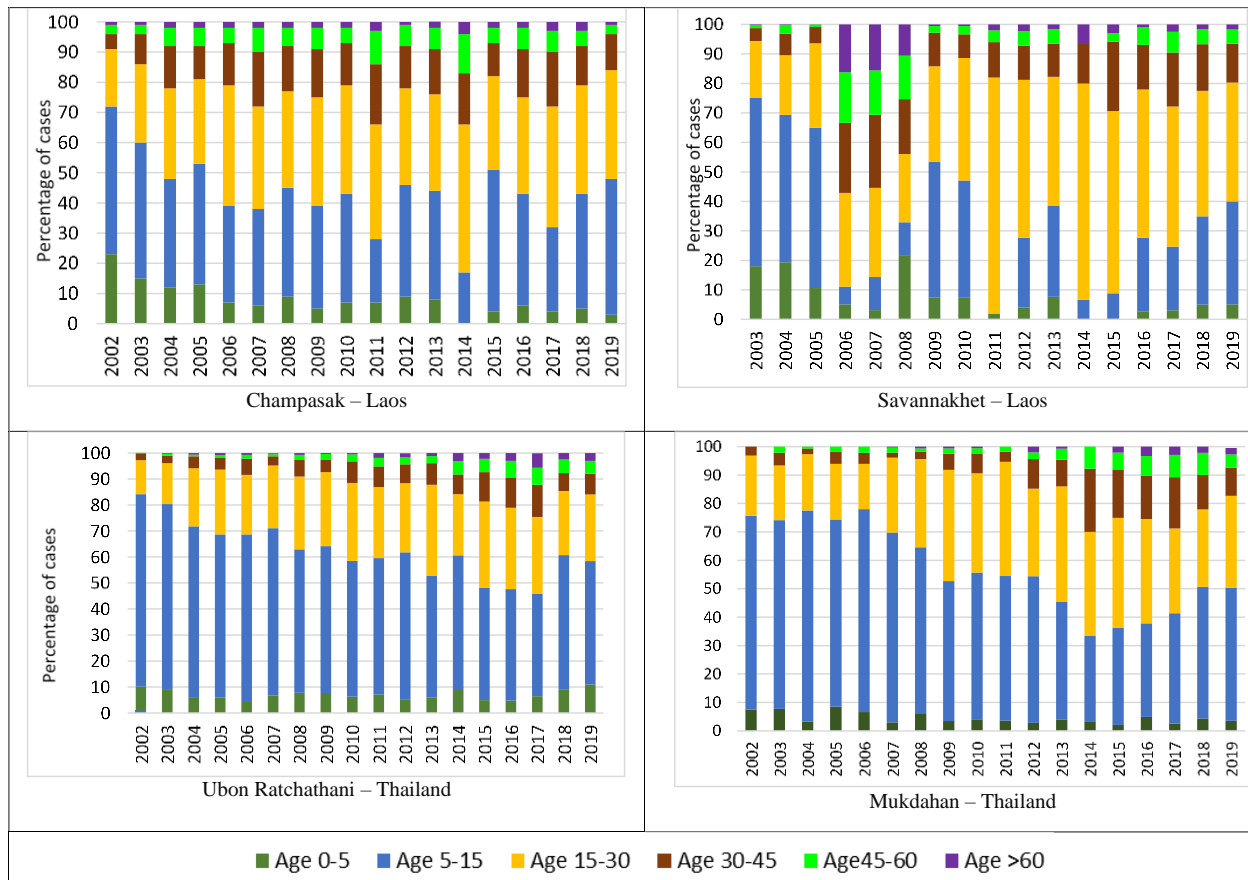


Figure S1. Age group distribution of reported dengue cases (DF, DHF, and DSS) in Savannakhet and Champasak provinces in Laos and Mukdahan and Ubon Ratchathani provinces in Thailand between 2002 and 2019.

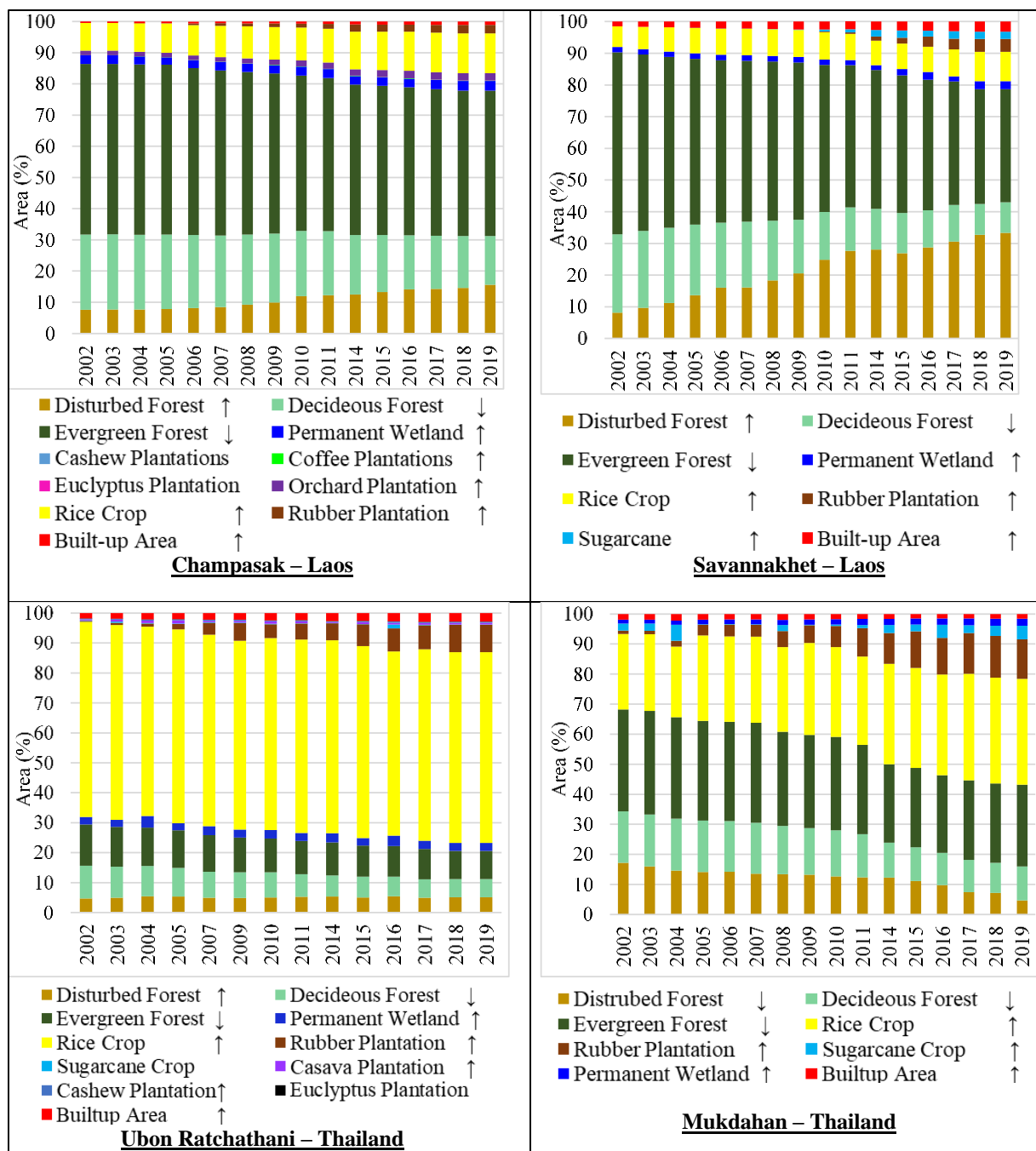


Figure S2. Landuse and landcover change in Champasak and Savannakhet provinces in Laos and Mukdahan and Ubon Ratchathani provinces in Thailand between 2002 and 2019.

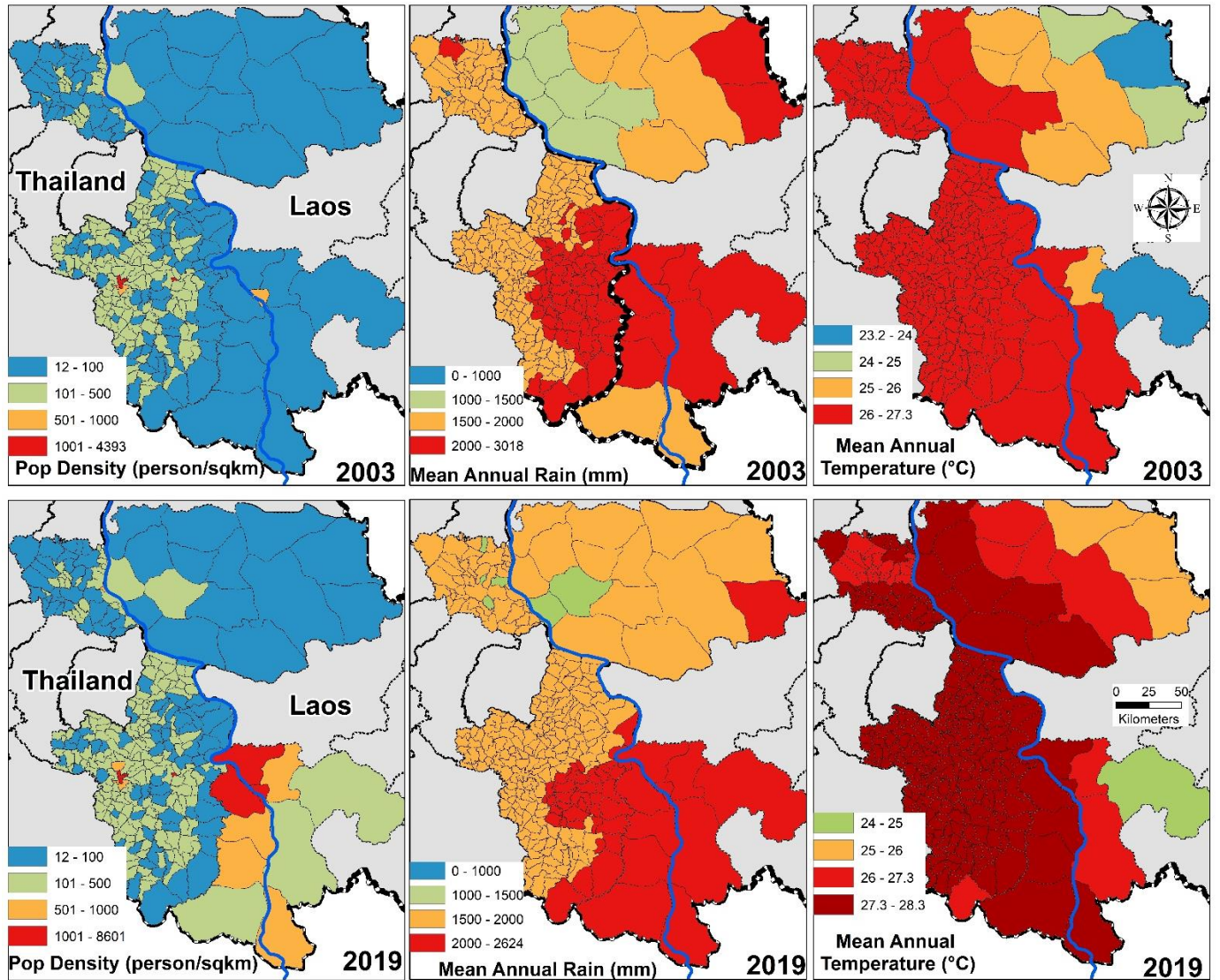


Figure S3: Change in three of the four exposure indicators; population density, mean annual rainfall, and mean annual temperature in selected provinces in Laos and Thailand between 2003 and 2019. The fourth exposure indicator, land environment change is shown in Figure 2 in the manuscript.

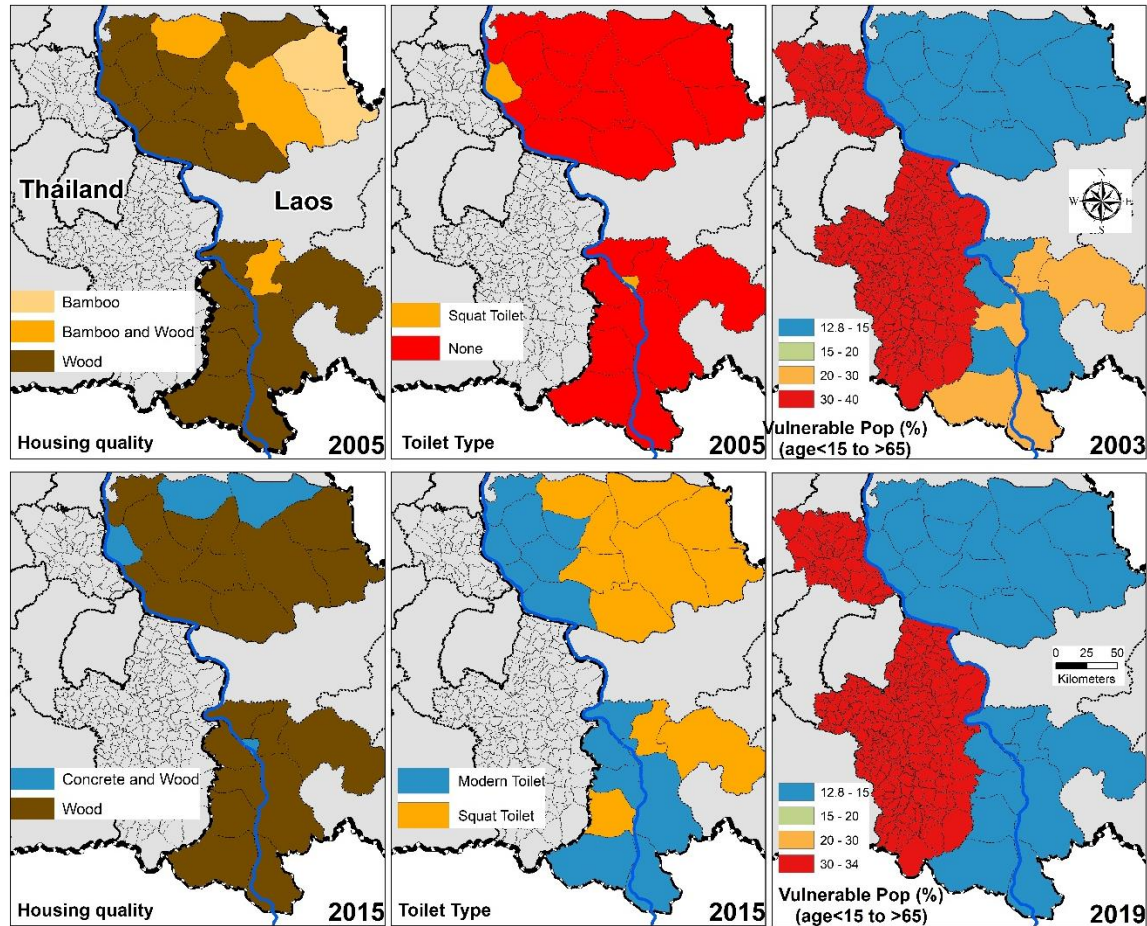


Figure S4: Change in the three susceptibility indicators, housing quality (left panels), toilet type (middle panels) and vulnerable populations (right panels) in Savannakhet and Champasak provinces in Laos in 2003 and in Mukdahan and Ubon Ratchathani provinces in Thailand in 2019 (Lao Statistics Bureau 2019; National Statistical Office of Thailand 2019).

- Housing quality for 2015 was assessed by categorizing districts into either having 25 - 50 % of village houses made of wood and concrete (blue) or 50 - 75% of village houses made wood (dark brown).
- Toilet type was assessed by categorizing districts into either having >50% of village houses with a squat toilet (yellow), >50% of village houses with a modern toilet (blue) or >50% of village houses with neither (red). Neither category likely consisted of open defecation.
- Vulnerable populations were assessed by % of the combined proportion of people <15 years and >60 years of age
- In Laos, 2005 census data were only available at the district level and here we presented these aggregated values.



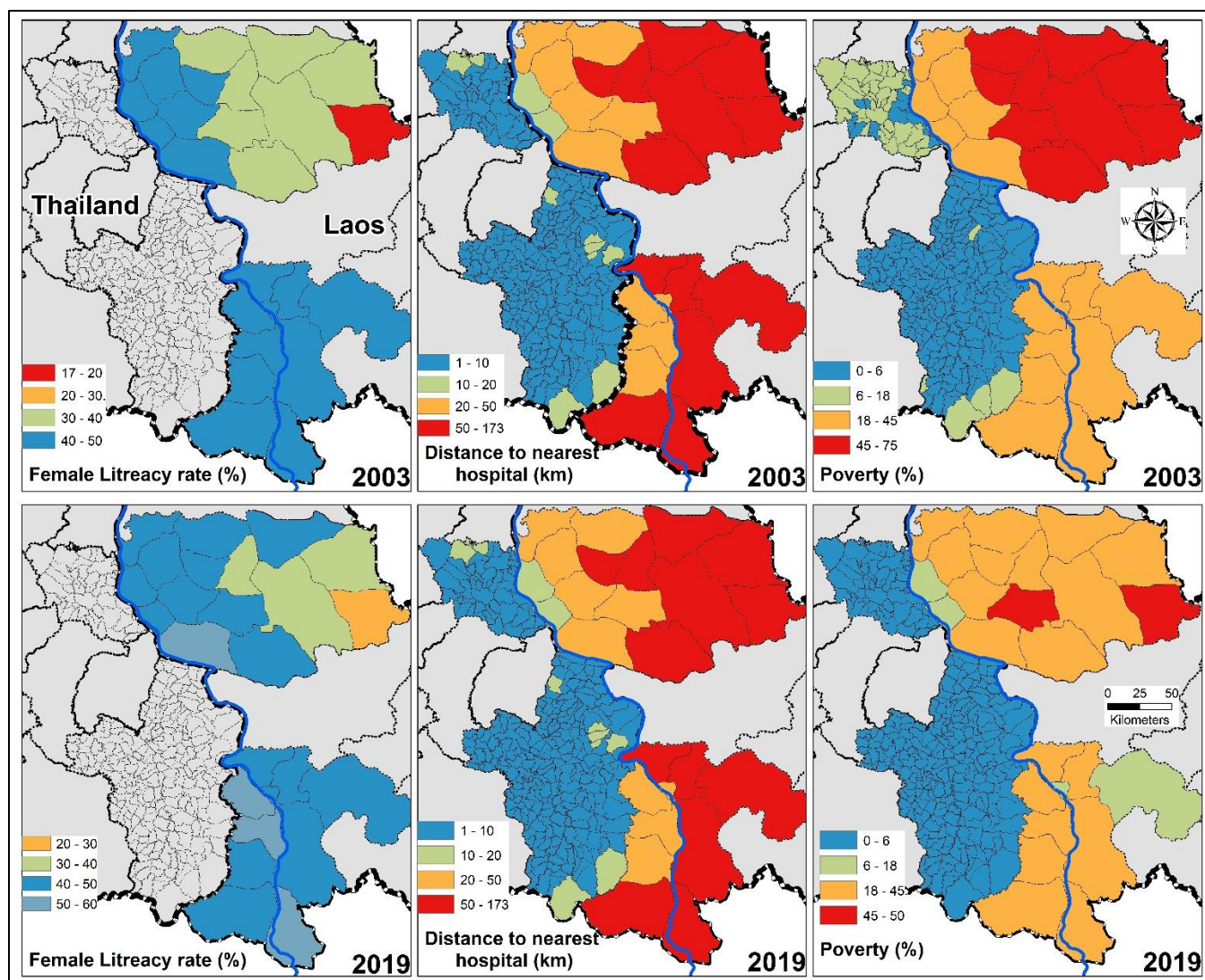


Figure S5: Change in indicators of adaptive capacity in selected provinces in Laos and Thailand between 2003 and 2019. Female literacy rate was not available for Thailand at subdistrict level. (Lao Statistics Bureau 2019; National Statistical Office of Thailand 2019).

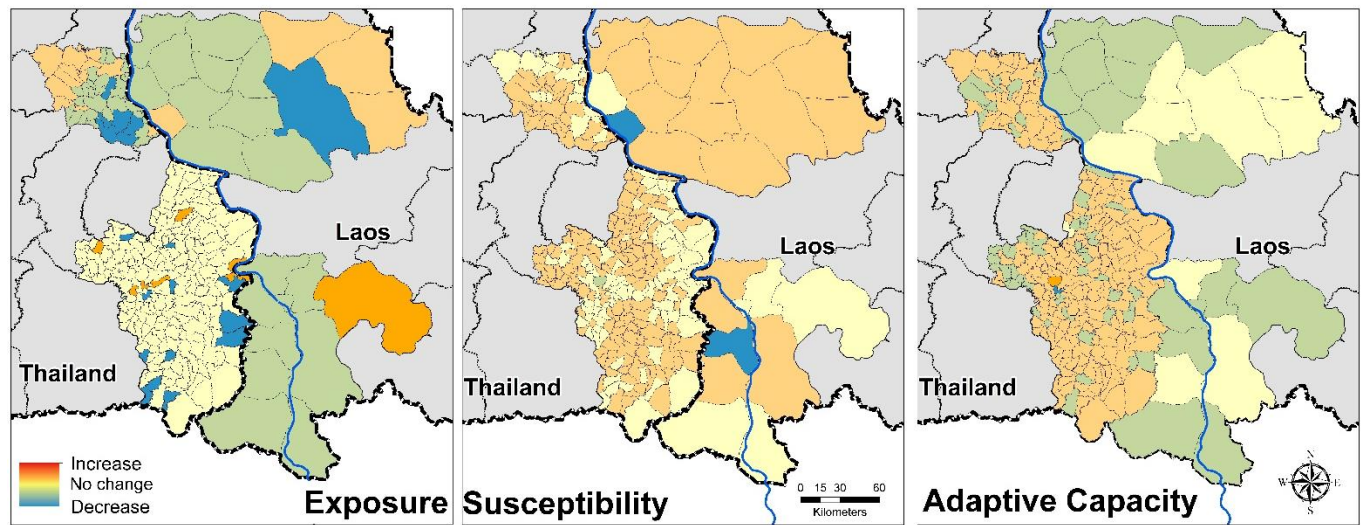


Figure S6: Change in exposure (left panel), susceptibility (middle panel) and adaptive capacity (right panel) based on the Water Associated Disease Index ( $DVI_{WADI}$ ) in Savannakhet and Champasak provinces in Laos and Mukdahan and Ubon Ratchathani provinces in Thailand between 2003 and 2019.

Table S1: Indicator weight calculation using Shannon's Entropy (SE) for Laos

Determinants	Indicators (i)	Sub classes (j)	Observed dengue cases (DP <sub>i</sub> )	Average population in subclass ij (TP <sub>ij</sub> )	d <sub>ij</sub>	P <sub>ij</sub>	Σp <sub>ij</sub>	H <sub>j</sub>	1-H <sub>j</sub>	W <sub>ij</sub>
Exposure	Cumulative rainfall in mm (1 month lag)	0–300	48906	82978	0.59	0.91	–0.31	0.12	0.88	0.08
		300–1000	4806	81068	0.06	0.09				
		>1000	70	144906	0.00	0.00				
	Mean temperature °C (1 month lag)	<20	880	60760	0.01	0.11	–0.76	0.29	0.71	0.06
		>20 – <34	11325	122363	0.09	0.73				
		>34	1490	77844	0.02	0.15				
	Forest area (%)	0–10	0			0.00	0.00	0.00	1.00	0.09
		10–60	33550	99515	0.34	0.52				
		>60	20232	64742	0.31	0.48				
	Disturbed forest area (%)	0–10	17927	67674	0.26	0.39	–0.67	0.25	0.75	0.07
		10–60	35855	86938	0.41	0.61				
		>60	0	0	0	0.00				
	Plantation area (%)	0–20	52433	80141	0.65	0.98	0.00	0.00	1.00	0.09
		20–40	1349	133184	0.01	0.02				
		>40	0			0.00				
	Rice and sugarcane crop area (%)	0–20	34655	69565	0.50	0.74	–0.59	0.22	0.78	0.07
		20–40	18214	107949	0.17	0.25				
		>40	913	333819	0.00	0.00				
	Built-up area (%)	0–10	46204	78205	0.59	0.92	–0.29	0.11	0.89	0.08
		10–30	7578	142427	0.05	0.08				
		>30				0.00				

Determinants	Indicators (i)	Sub classes (j)	Observed dengue cases (DP <sub>i</sub> )	Average population in subclass ij (TP <sub>i</sub> )	d <sub>ij</sub>	P <sub>ij</sub>	Σp <sub>ij</sub>	H <sub>j</sub>	1-H <sub>j</sub>	W <sub>ij</sub>
Exposure	Population density (person/sqkm)	0–200	44890	66576	0.67	0.95	–0.20	0.08	0.92	0.08
		200–400	7656	227317	0.03	0.05				
		>1000	1236	1135248	0.00	0.00				
		Normal	29568	62455	0.47	0.65				
		none	14979	60808	0.25	0.34				
Susceptibility	Age (%)	<15 and >60	32008	101692	0.31	0.54	–0.69	0.26	0.74	0.06
		>15 and <60	18741	71160	0.26	0.46				
	Living conditions/ housing quality (%)	Houses made of concrete	1404	107183	0.01	0.07	–0.89	0.34	0.66	0.06
		Houses made of concrete and wood	5400	80952	0.07	0.37				
		Houses made of wood	3888	39315	0.10	0.55				
	Toilet type (%)	Modern	6202	919721	0.01	0.01	–0.69	0.26	0.74	0.06
		Normal	29568	62455	0.47	0.65				
		none	14979	60808	0.25	0.34				
Adaptive Capacity	Female literacy rate (%)	0–50	51052	87570	0.58	0.90	–0.32	0.12	0.88	0.08
		50–100	2730	42792	0.06	0.10				
	Mean distance to hospital (km)	0–10	0	0	0	0.00	–0.69	0.26	0.74	0.06
		10–20	26379	87068	0.30	0.47				
		>20	27403	78920	0.35	0.53				
	Poverty incidence (%)	0–20	7271	81208	0.09	0.14	–0.76	0.29	0.71	0.06
		20–40	39517	81208	0.49	0.73				
		>40	6994	81209	0.09	0.13				
		50–100	2730	42792	0.06	0.10				



Table S2: Indicators weight calculation using Shannon's Entropy (SE) for Thailand

Determinants	Indicators (i)	Sub classes (j)	Observed dengue cases (DP <sub>i</sub> )	Average population in subclass (TP <sub>i</sub> )	d <sub>ij</sub>	P <sub>ij</sub>	Σp <sub>ij</sub>	H <sub>i</sub>	1-H <sub>i</sub>	W <sub>ij</sub>
Exposure	Cumulative rainfall in mm (1 month lag)	0-300	24398	7837	3.11	0.59	-0.68	0.26	0.74	0.09
		300-1000	17609	8233	2.14	0.41				
		>1000								
	Mean temperature (°C)	0 - 24	562	7367	0.08	0.01	-0.76	0.29	0.71	0.09
		24 - 28	21009	7904	2.66	0.51				
		>28	20436	8156	2.51	0.48				
	Forest area (%)	0-10	648	5853	0.11	0.12	-0.93	0.35	0.65	0.08
		10-60	3651	6562	0.56	0.58				
		>60	1890	6422	0.29	0.31				
	Disturbed forest area (%)	0-10	37990	435045900	0.00	0.25	-1.08	0.41	0.59	0.08
		10-60	3480	27171252	0.00	0.36				
		>60	537	3943728	0.00	0.39				
	Plantation area (%)	0-20	41447	7985	5.19	0.98	-0.09	0.04	0.96	0.12
		20-40	531	5355	0.10	0.02				
		>40	29	3565						
	Rice and sugarcane crop area (%)	0-20	12463	7948	1.57	0.30	-1.09	0.41	0.59	0.07
		20-40	10755	6799	1.58	0.30				
		>40	18789	8805	2.13	0.40				
	Built-up area (%)	0-10	40388	7669	5.27	0.99	-0.04	0.01	0.99	0.13
		10-30	1619	49551	0.03	0.01				
		>30								

Determinants	Indicators (i)	Sub classes (j)	Observed dengue cases (DP <sub>i</sub> )	Average population in subclass (TP <sub>i</sub> )	d <sub>ij</sub>	P <sub>ij</sub>	Σp <sub>ij</sub>	Hi	1-Hi	Wij
Exposure	Population density (person/sqkm)	0–200 person per sqkm	30768	6931	4.44	0.86	-0.47	0.18	0.82	0.10
		200–400	7750	11989	0.65	0.12				
		>1000	3489	33900	0.10	0.02				
Susceptibility	Age (%)	<15 and >60	33167	12742	2.60	0.80	-0.50	0.19	0.81	0.10
		>15 and <60	8833	13398	0.66	0.20				
Adaptive Capacity	Mean distance to hospital (km)	0–10	30374	8158	3.72	0.70	-0.72	0.27	0.73	0.09
		10–20	9864	7239	1.36	0.26				
		>20	1769	8948	0.20	0.04				
	Poverty incidence (%)	0–20	41965	7937	5.29	1.00	0.00	0.00	1.00	0.13
		20–40	4	5398	0.00	0.00				
		>40	38	5173	0.01	0.00				

Table S3: Pearson's correlation coefficients between each of three vulnerability indices and monthly dengue incidence per 100,000 persons per year in Laos and Thailand during 2003-2019. The DVI<sub>BWM</sub> for Thailand was not calculated because of lack of data at the subdistrict level. Coefficients in bold indicate significant correlations. DVI<sub>WADI</sub>: Dengue Vulnerability Index – Water Associated Disease Index. DVI<sub>BWM</sub>: Dengue Vulnerability Index - Best Worst Method. DVI<sub>SE</sub>: Dengue Vulnerability Index - Shannon's Entropy.

Year	Laos			Thailand	
	DVI <sub>WADI</sub>	DVI <sub>BWM</sub>	DVI <sub>SE</sub>	DVI <sub>WADI</sub>	DVI <sub>SE</sub>
2003	0.17	0.09	<b>0.73</b>	<b>0.54</b>	0.17
2004	0.44	<b>0.75</b>	-0.34	<b>0.81</b>	-0.25
2005	0.33	0.31	0.15	<b>0.79</b>	0.28
2006	0.37	<b>0.80</b>	-0.39	<b>0.86</b>	0.40
2007	0.49	0.35	-0.08	<b>0.82</b>	-0.67
2008	0.44	0.47	<b>0.75</b>	<b>0.92</b>	-0.34
2009	0.47	0.43	<b>0.58</b>	<b>0.86</b>	-0.17
2010	<b>0.53</b>	<b>0.54</b>	-0.27	<b>0.90</b>	<b>0.79</b>
2011	<b>0.80</b>	<b>0.76</b>	-0.16	<b>0.78</b>	-0.55
2012	<b>0.57</b>	<b>0.59</b>	-0.40	<b>0.67</b>	-0.22
2013	0.06	0.03	<b>0.65</b>	<b>0.61</b>	<b>0.94</b>
2014	0.03	-0.02	<b>0.56</b>	<b>0.82</b>	-0.38
2015	-0.21	-0.32	0.22	<b>0.89</b>	0.32
2016	0.10	-0.08	0.11	<b>0.77</b>	<b>0.71</b>
2017	<b>0.63</b>	<b>0.51</b>	0.15	<b>0.92</b>	0.40
2018	<b>0.64</b>	<b>0.55</b>	-0.39	<b>0.86</b>	<b>0.72</b>
2019	0.12	0.02	<b>0.77</b>	0.45	0.40

Table S4: Number of districts and percentage of with significant correlation coefficients (p-value < 0.05) and respective percentages out of the 25 districts of Savannakhet and Champasak in Laos and the 272 sub-districts of Mukdahan and Ubon Ratchathani in Thailand during 2003-2019. DVI<sub>WADI</sub>: Dengue Vulnerability Index – Water Associated Disease Index. DVI<sub>BWM</sub>: Dengue Vulnerability Index - Best Worst Method. DVI<sub>SE</sub>: Dengue Vulnerability Index - Shannon's Entropy.

	Laos						Thailand			
Year	DVI <sub>WADI</sub>		DVI <sub>BWM</sub>		DVI <sub>SE</sub>		DVI <sub>WADI</sub>		DVI <sub>SE</sub>	
	Districts									
	No	%	No	%	No	%	No	%	No	%
2003	4	16	3	12	6	24	59	22	53	19
2004	3	12	1	4	6	24	50	18	17	6
2005	4	16	3	12	8	32	46	17	23	8
2006	5	20	5	20	10	40	51	19	15	6
2007	5	20	5	20	7	28	79	29	23	8
2008	6	24	6	24	4	16	44	16	9	3
2009	2	8	1	4	5	20	50	18	13	5
2010	4	16	1	4	4	16	99	36	38	14
2011	10	40	5	20	6	24	61	22	25	9
2012	7	28	6	24	6	24	41	15	19	7
2013	2	8	1	4	5	20	94	35	96	35
2014	2	8	0	0	4	16	51	19	8	3
2015	0	0	0	0	6	24	144	53	45	17
2016	8	32	7	28	5	20	77	28	32	12
2017	9	36	4	16	3	12	80	29	33	12
2018	8	32	7	28	4	16	124	46	44	16
2019	1	4	1	4	5	20	87	32	103	38
Average of the districts with >0.5 correlation	5	19	3	14	6	22	73	27	35	13
Outbreak year: Average of the districts with >0.5 correlation	4	14	3	10	5	21	98	36	53	19



Table S5. The extent of inundated areas for annual flooding events in Savannakhet and Champasak provinces in Laos and Mukdahan and Ubon Ratchathani provinces in Thailand between 2002 and 2019. using Landsat (United States Geological Survey, 2020) and Sentinel-1 satellite images (European Space Agency, 2019). Overflowing of local rivers causes floods almost every year. Normalized difference water index (NDWI) was applied to extract the extent of water outside the riverbanks. The NDWI values range from -1 to +1. The NDWI values greater than 0 represent water/flooded areas (McFeeters, 1996). Flood extent from Sentinel-1 images was mapped using the focal median filter and applying a backscatter threshold value of -10 to -16 (Liu, 2016). A dash (-) represents no flooding in that particular year or province.

a. Laos

Year	Savannakhet			Champasak		
	Start date	End date	Area Inundated (SqKm)	Start date	End date	Area Inundated (SqKm)
2002	10-Jul	2-Aug	1412	10-Jul	2-Aug	5862
2003	-	-	-	-	-	-
2004	-	-	-	-	-	-
2005	27-Jul	19-Oct	1145	27-Jul	19-Oct	3576.6
2006	-	-	-	-	-	-
2007	10-Oct	30-Oct	806	-	-	-
2008	No satellite image					
2009	10-Jul	30-Oct	4168	13-July	14 October	8794
2010	1-Oct	7-Oct	1006	-	-	-
2011	23-Jul	1-Aug	485	30-Jul	27-Sep	2643
2012	-	-	-	-	-	-
2013	7-Jul	19-Jul	404.5	-	-	
2014	27-Jul	17-Sep	No satellite image	27-Jul	17-Sep	No satellite image
2015	15-Jul	30-Aug	2187	-	-	-
2016	-	-	-	15 Jul	24 Aug	5722
2017	1-Jul	30-Sep	6489	-	-	-
2018	28-Jul	27-Aug	3400	28-Jul	27-Aug	3727.4
2019	31-Aug	13-Oct	2704	31-Aug	1-Oct	1960

b. Thailand

Year	Ubon Ratchathani			Mukdahan		
	Start date	End date	Area Inundated (SqKm)	Start date	End date	Area Inundated (SqKm)
2002	10-Jul	2-aug	4104	-	-	-
2003	-	-	-	-	-	-
2004	8-Aug	10 Oct	3128	-	-	-
2005	27-Jul	19-oct	448.5	-	-	-
2006	3-Oct	19-Nov	1937	-	-	-
2007	10-Oct	30-oct	277	-	-	-
2008	5-Oct	26-Nov	473	-	-	-
2009	10-Jul	30-oct	1292	-	-	-
2010	1-Oct	7-oct	543	-	-	-
2011	23-Jul	15-nov	1024	23 -Jul	1-Aug	98.2
2012	-	-	-	-	-	-
2013	7-Jul	19-jul	643	23 - Sep	29 Sep	1.11
2014	27-Jul	17-sep	807	-	-	-
2015	15-Jul	30-aug	20	-	-	-
2016	01-Sep	30-sep	35	-	-	-
2017	1-Jul	30-sep	406	1-Jul	30-Sep	8.7
2018	25-Aug	06-sep	56	25-Aug	06-Sep	8.8
2019	31-Aug	05-oct	1309	31-Aug	1-Oct	54