Climatic Change

Regionalisation of population growth projections in coastal exposure analysis

Jan-Ludolf Merkens[a*], Daniel Lincke[b], Jochen Hinkel[b,c], Sally Brown[d,e], Athanasios Thomas Vafeidis[a]

[a] Department of Geography, Kiel University, Ludewig-Meyn-Str. 14, 24118 Kiel, Germany

[b] Global Climate Forum e.V. (GCF), Neue Promenade 6, 10178 Berlin, Germany

[c] Division of Resource Economics, Albrecht Daniel Thaer-Institute and Berlin Workshop in Institutional Analysis of Social-Ecological Systems (WINS), Humboldt-University, Berlin

[d] Faculty of Engineering and the Environment, University of Southampton, University Rd, Southampton SO17 1BJ, UK

[e] Tyndall Centre for Climate Change Research, Southampton, UK

* merkens@geographie.uni-kiel.de; FON +49 431 880-1701; FAX +49 431 880-4658

Supplementary material

Figures

Fig. A. 1: Components of the absolute difference between the coastal and basic approach in population exposed to 1 in 100-year coastal floods under medium SLR in RCP 6.0 (in million).

Fig. A. 2: Share of urbanisation and coastal migration on the relative difference between the coastal and basic approach in population exposed to 1 in 100-year coastal floods under medium SLR in RCP 6.0.

Fig. A. 3: Population exposed to 1 in 100-year coastal floods under different regionalisation approaches and SLR projections.

Fig. A. 4: Absolute Difference (respective approach minus basic approach) in population exposed to 1 in 100-year coastal floods under the lowest and highest SLR variant (in millions). Note the different scales of the y-axis.

Fig. A. 5: Percentage of global population exposed to 1 in 100-year coastal floods for medium SLR projections in RCP 6.0. Constant represents the year 2000 baseline population.

Fig. A. 6: Population exposed to 1 in 100-year coastal floods per continent based on different regionalisation approaches under medium SLR in RCP 6.0.

Fig. A. 7: Absolute difference (respective approach minus basic approach) in population exposed to 1 in 100-year coastal floods per continent under low and high SLR projections.

Fig. A. 8: National population exposed to 1 in 100-year coastal floods based on different regionalisation approaches under medium SLR in RCP 6.0.

Fig. A. 9: Absolute difference (respective approach minus basic approach) in population exposed to 1 in 100-year coastal floods for four countries under low and high SLR projections

Tables

Table A. 1: Relative difference in population exposed to 1 in 100-year coastal floods in 2100 between coastal and basic approach per continent [in %].

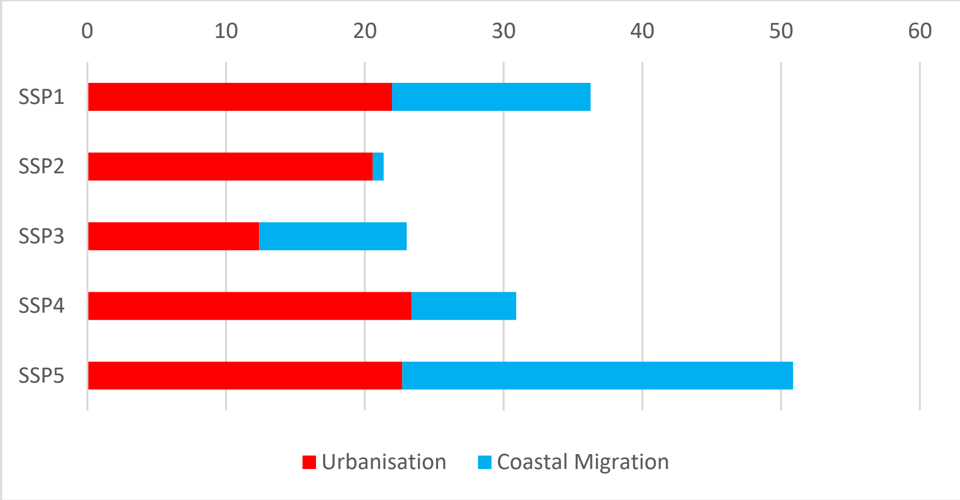

Fig. A. 1: Components of the absolute difference between the coastal and basic approach in population exposed to 1 in 100-year coastal floods under medium SLR in RCP 6.0 (in million).

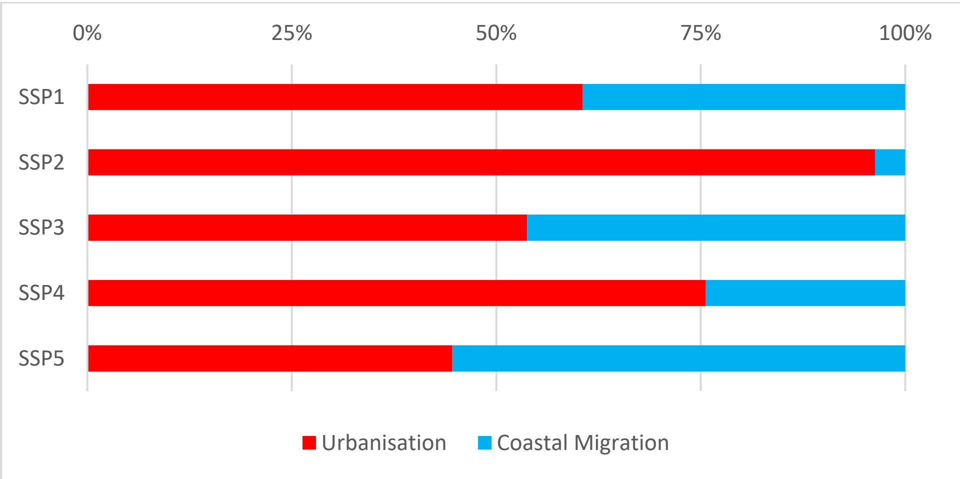

Fig. A. 2: Share of urbanisation and coastal migration on the relative difference between the coastal and basic approach in population exposed to 1 in 100-year coastal floods under medium SLR in RCP 6.0.

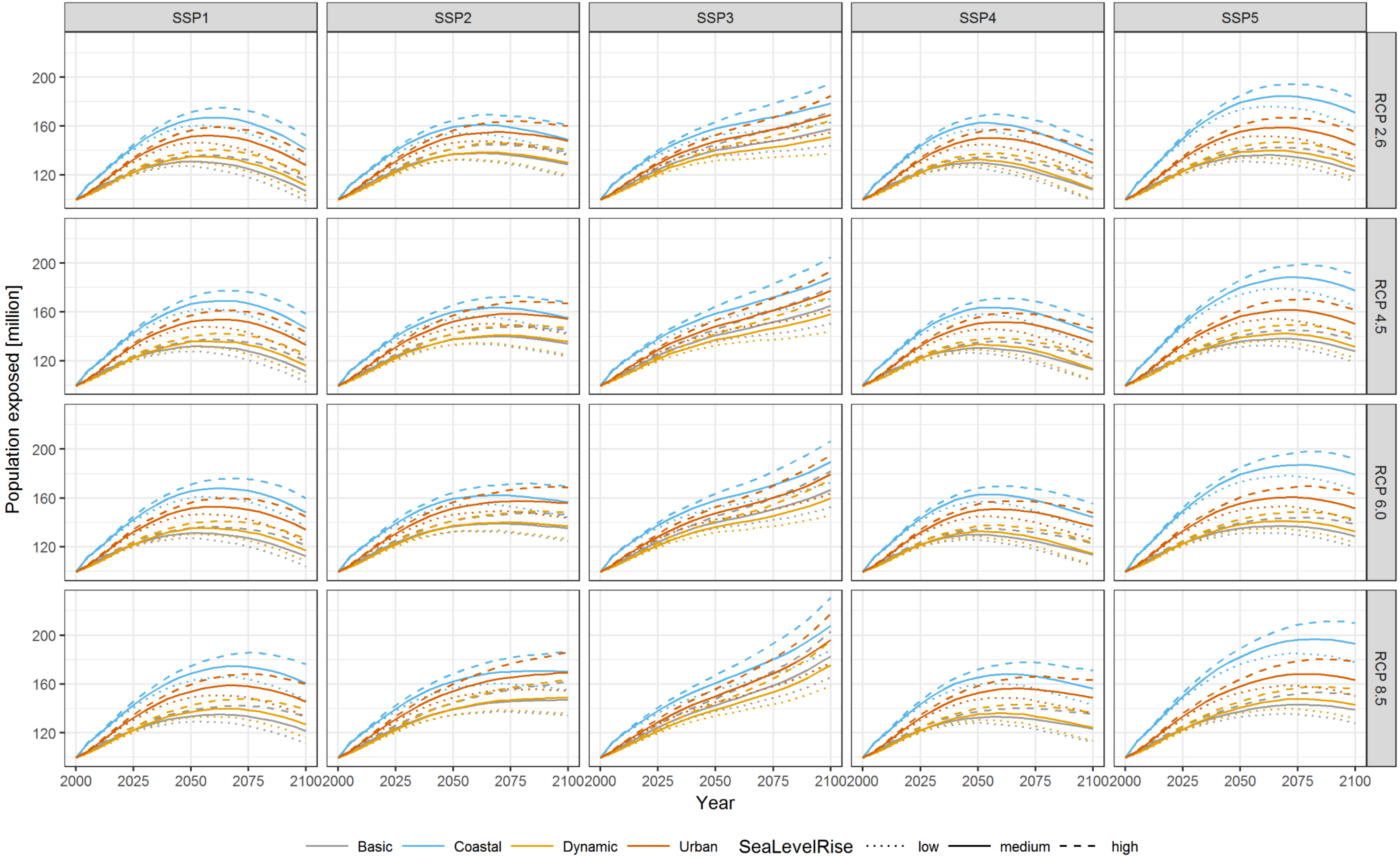

Fig. A. 3: Population exposed to 1 in 100-year coastal floods under different regionalisation approaches and SLR projections.

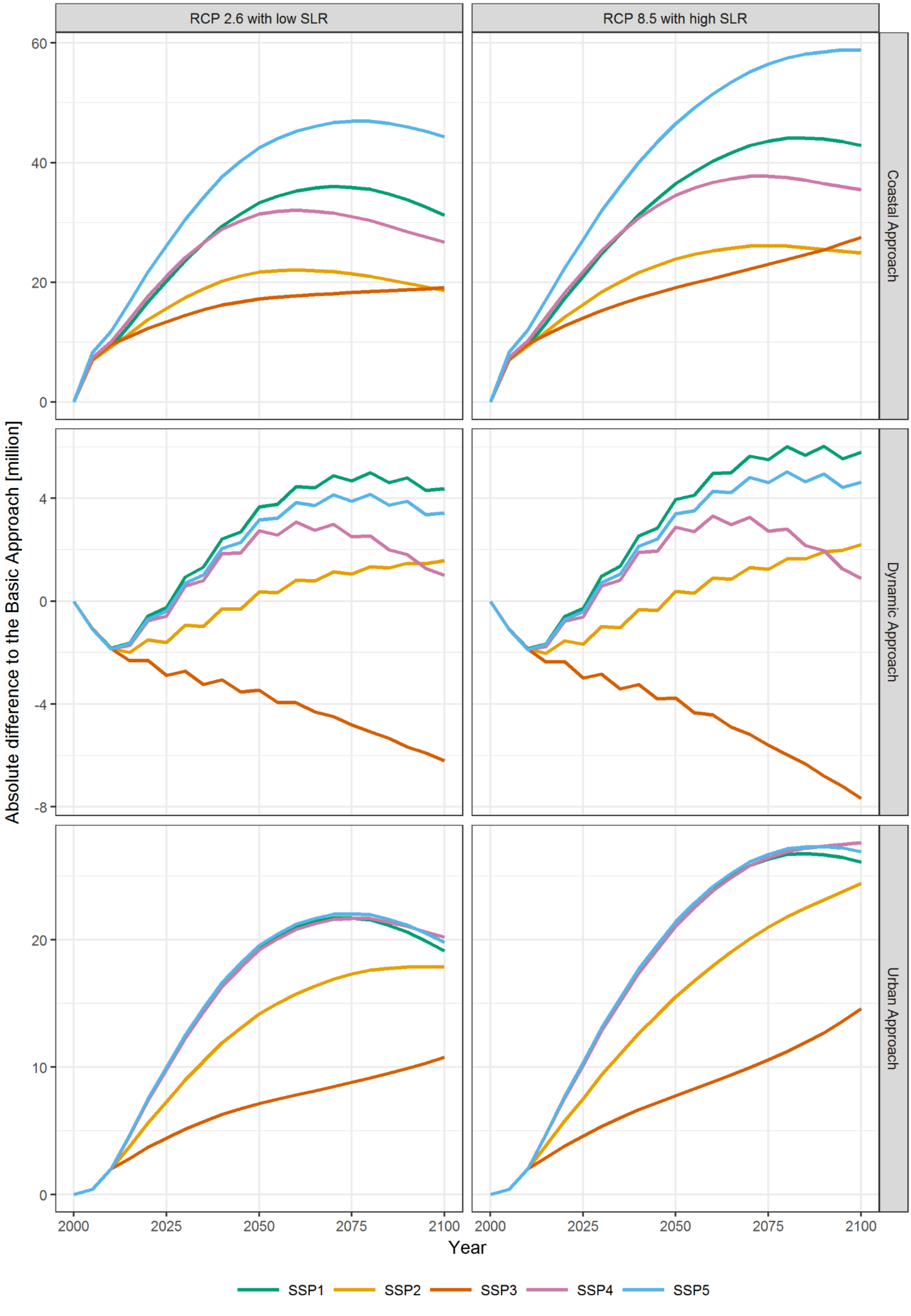

Fig. A. 4: Absolute Difference (respective approach minus basic approach) in population exposed to 1 in 100-year coastal floods under the lowest and highest SLR variant (in millions). Note the different scales of the y-axis.

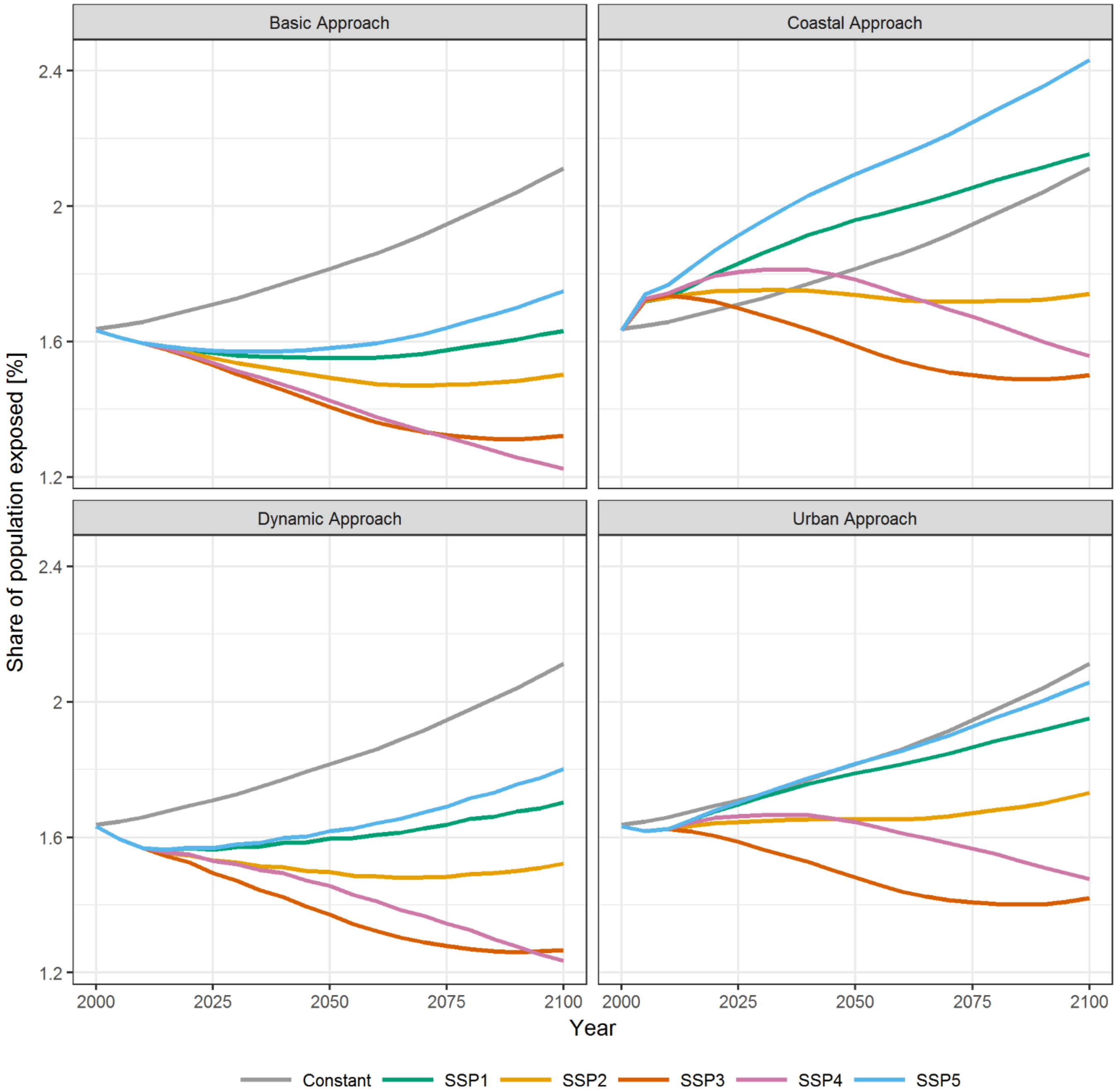

Fig. A. 5: Percentage of global population exposed to 1 in 100-year coastal floods for medium SLR projections in RCP 6.0. Constant represents the year 2000 baseline population.

Fig. A. 5 illustrates the relevance of using socioeconomic scenarios in coastal impact assessments. It shows the share of population exposed to flooding for all SSPs based on the four tested approaches and additionally for a scenario where population remains constant at the year 2000 levels. In this scenario, the share of population exposed to a 1 in 100-year coastal flood under medium SLR in RCP 6.0 increases steadily from ~1.6% in 2000 to ~2.1% in 2100. In the basic approach, the share decreases or remains constant until 2040 in all scenarios, although the absolute exposed population increases (compare with Fig. 2 in the manuscript). In 2100 the share of population exposed ranges from ~1.2% in SSP4 to 1.7% in SSP5. In the coastal approach, the share of exposed population does increase only in SSP1 and SSP5 continuously until 2100 and exceeds the constant scenario. The other SSPs remain at their year 2000 level or decrease. The share of population exposed ranges from 1.5% in SSP3 to 2.4% in SSP5. The general patterns of the dynamic approach follow the ones described for the basic approach but the share of exposed population is ~ 0.05% higher. The general patterns of the urban approach follow the ones described for the coastal approach but are considerable lower for SSPs 1 and 5.Although the population is not changing in the constant scenario at all, the SLR-related increase of the floodplain leads to an increase in exposure to 1 in 100-year coastal floods. This should be kept in mind when interpreting results based on such assessments.

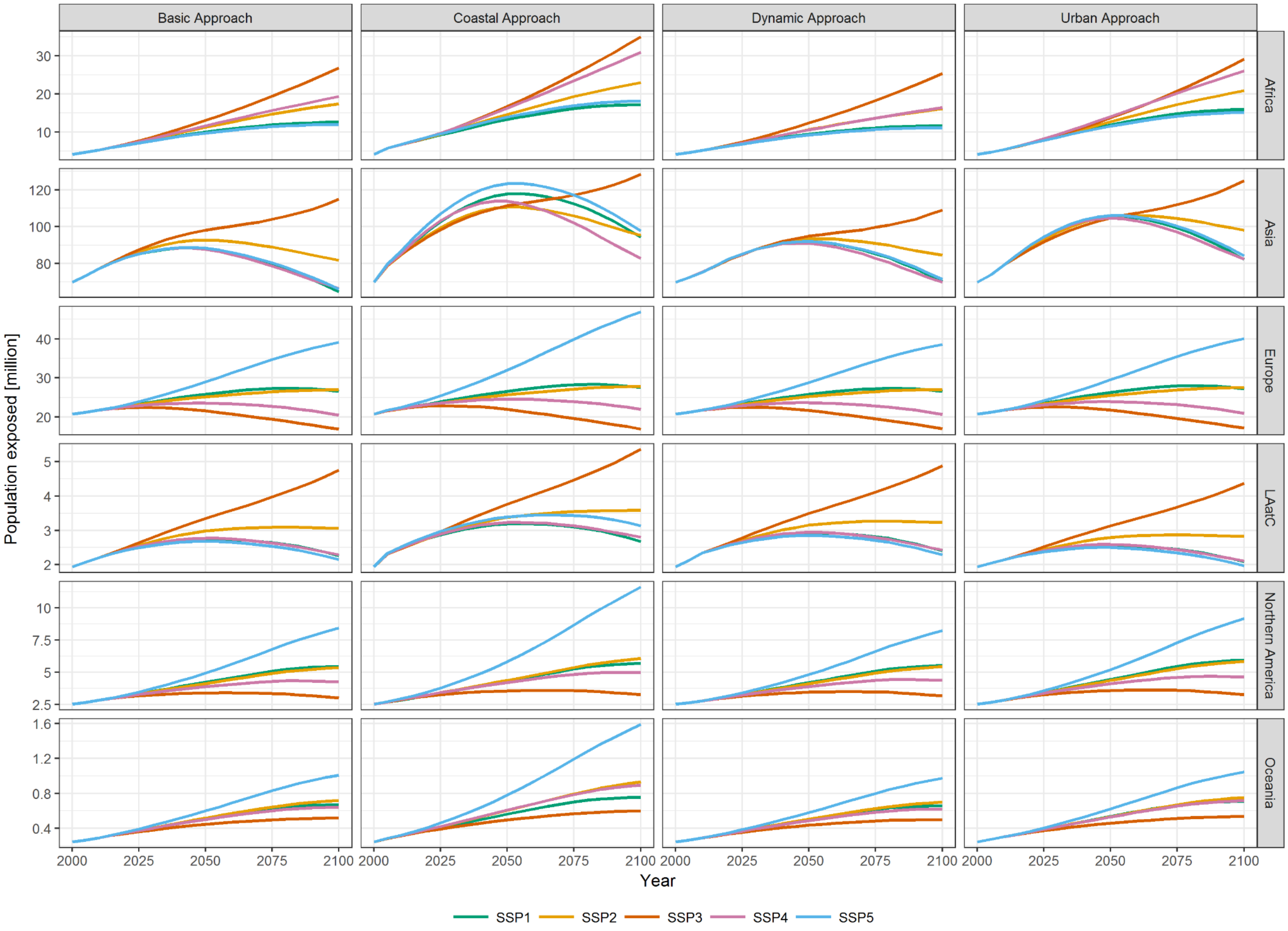

Fig. A. 6: Population exposed to 1 in 100-year coastal floods per continent based on different regionalisation approaches under medium SLR in RCP 6.0.

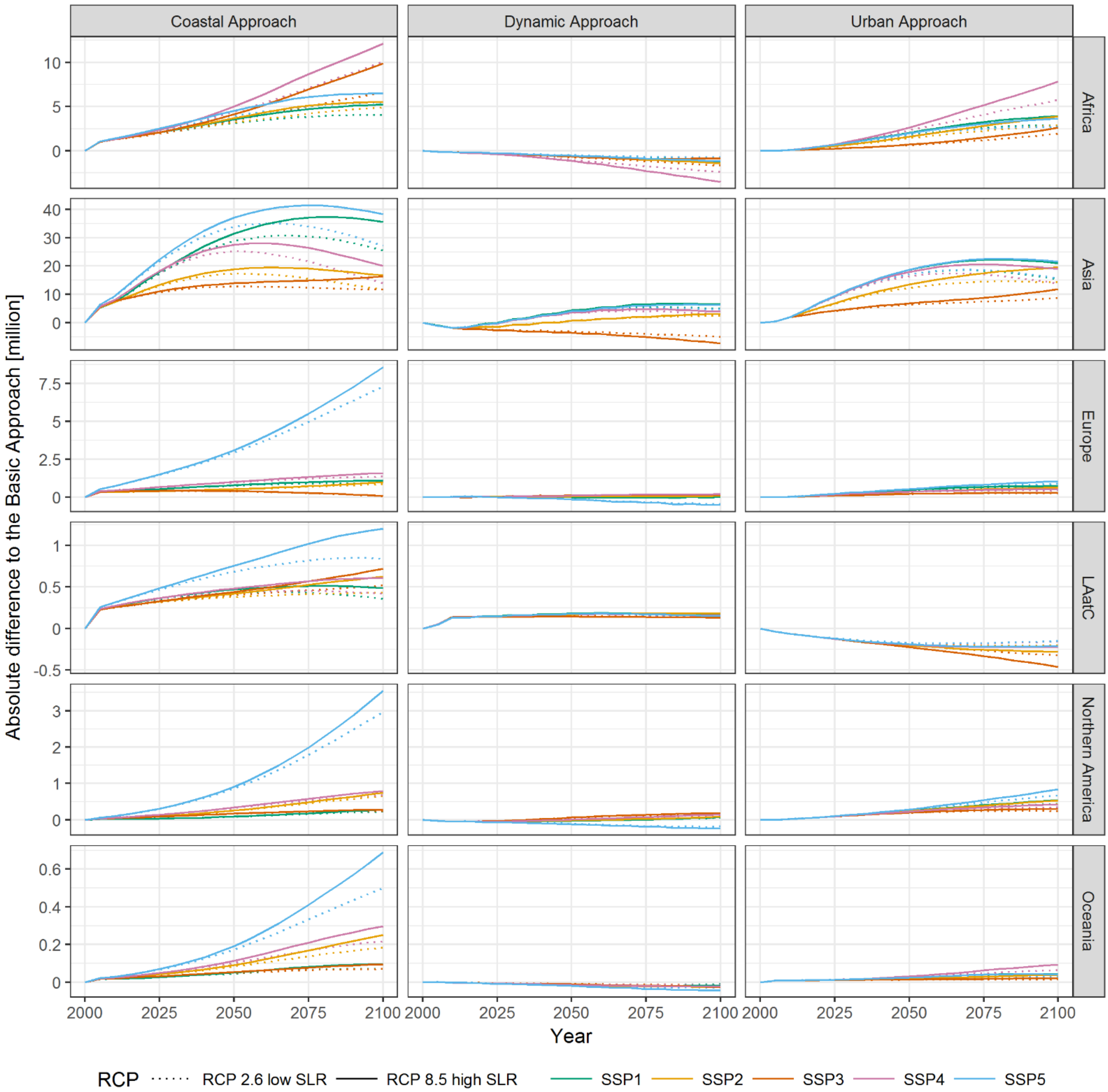

Fig. A. 7: Absolute difference (respective approach minus basic approach) in population exposed to 1 in 100-year coastal floods per continent under low and high SLR projections.

Table A. 1: Relative difference in population exposed to 1 in 100-year coastal floods in 2100 between coastal and basic approach per continent [in %].

		RCP 2.6			**RCP 4.5**			**RCP 6.0**			**RCP 8.5**		
		low	med	hig	low	med	hig	low	med	hig	low	med	hig
Africa	SSP1	40.7	38.3	36.1	39.5	37.2	34.8	39.2	36.9	34.6	37.2	34.4	32.0
	SSP2	35.4	33.2	30.5	34.4	32.0	28.6	34.0	31.7	28.2	32.0	28.0	24.3
	SSP3	31.0	30.6	30.1	30.8	30.4	29.6	30.8	30.4	29.5	30.4	29.4	28.4
	SSP4	64.3	61.9	58.7	63.2	60.6	56.0	62.9	60.2	55.5	60.6	55.2	49.8
	SSP5	57.5	54.1	50.2	55.9	52.3	47.4	55.4	51.8	46.9	52.3	46.7	41.4
Asia	SSP1	45.7	45.7	45.7	45.7	45.7	45.6	45.7	45.7	45.6	45.7	45.6	45.5
	SSP2	16.6	16.7	16.8	16.6	16.7	16.8	16.6	16.7	16.8	16.7	16.8	17.0
	SSP3	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.9
	SSP4	24.4	24.5	24.7	24.5	24.6	24.8	24.5	24.6	24.8	24.6	24.8	25.0
	SSP5	47.7	47.7	47.8	47.7	47.8	47.9	47.7	47.8	47.9	47.8	47.9	48.0
Europe	SSP1	3.6	3.7	3.7	3.6	3.7	3.8	3.6	3.7	3.8	3.7	3.8	3.8
	SSP2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.4
	SSP3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5
	SSP4	7.0	7.0	7.0	7.0	7.0	7.1	7.0	7.0	7.1	7.0	7.1	7.2
	SSP5	19.8	19.9	20.1	19.8	20.0	20.2	19.9	20.0	20.2	20.0	20.2	20.4
Latin America and the Caribbean	SSP1	18.3	18.0	17.7	18.1	17.9	17.6	18.1	17.8	17.6	17.9	17.5	17.2
	SSP2	16.3	16.8	17.1	16.6	17.0	17.2	16.6	17.1	17.2	17.0	17.1	16.6
	SSP3	12.7	12.8	12.8	12.7	12.8	12.7	12.7	12.8	12.7	12.8	12.7	12.2
	SSP4	21.4	21.8	22.1	21.6	22.0	22.1	21.7	22.0	22.0	22.0	22.0	21.3
	SSP5	45.0	45.5	45.9	45.3	45.8	46.0	45.3	45.8	45.9	45.8	45.9	45.2
Northern America	SSP1	4.3	4.3	4.4	4.3	4.4	4.4	4.3	4.4	4.4	4.4	4.4	4.5
	SSP2	12.9	12.6	12.4	12.7	12.5	12.3	12.7	12.5	12.3	12.5	12.3	12.0
	SSP3	8.3	8.3	8.2	8.3	8.2	8.2	8.3	8.2	8.1	8.2	8.1	8.0
	SSP4	17.2	16.9	16.7	17.0	16.8	16.6	17.0	16.8	16.6	16.8	16.5	16.2
	SSP5	37.9	37.6	37.3	37.7	37.5	37.2	37.6	37.4	37.1	37.5	37.1	36.8
Oceania	SSP1	11.3	11.4	11.6	11.3	11.5	11.6	11.4	11.5	11.6	11.5	11.6	11.4
	SSP2	28.2	28.2	28.2	28.3	28.3	28.2	28.3	28.3	28.2	28.3	28.2	28.2
	SSP3	13.6	13.7	13.7	13.7	13.7	13.8	13.7	13.7	13.8	13.7	13.8	13.9
	SSP4	39.0	39.1	39.0	39.1	39.1	39.0	39.1	39.1	39.0	39.1	39.0	38.7
	SSP5	57.0	57.0	57.0	57.0	57.0	56.9	57.0	57.0	56.9	57.0	56.9	56.8

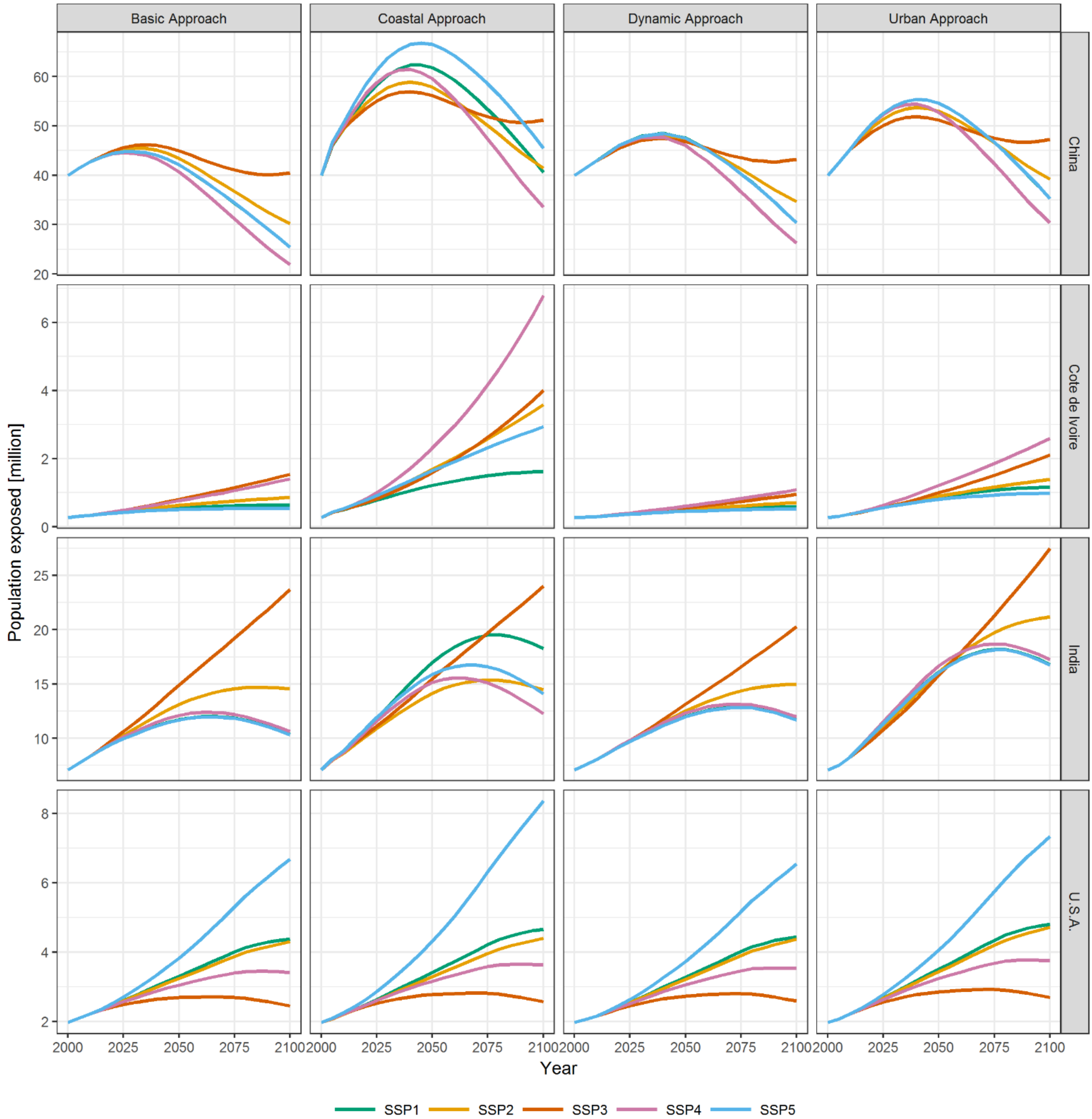

Fig. A. 8: National population exposed to 1 in 100-year coastal floods based on different regionalisation approaches under medium SLR in RCP 6.0.

Urbanisation projections, costal migration and data inconsistencies have a considerable influence on exposure. To demonstrate this, we analyse the difference in exposure between approaches on national level for the U.S.A., India, China and Cote d'Ivoire. The differences in these four countries result from distinct patterns across three continents.

For the U.S.A. the difference between the approaches in SSPs 1-4 is < 350,000 (6.5% relative difference) (see Fig. A. 8 for absolute numbers on exposure and Fig. A. 9 for differences to the basic approach). In SSP5 the absolute difference between the approaches is up to 2 million, which translates into a relative difference of 25%. These high differences in SSP5 result from the assumption in the coastal approach of coastal areas being more attractive than inland areas thus attracting more population (Merkens et al. 2016). The good agreement in exposure between the approaches for the other SSPs results from a high urbanisation level of 80% in the base year (UN 2015) and a low urbanisation gain of 17% until 2100 in all SSPs (Jiang and O'Neill 2017), which also leads to relatively small urban sprawl (difference between dynamic and urban approach).

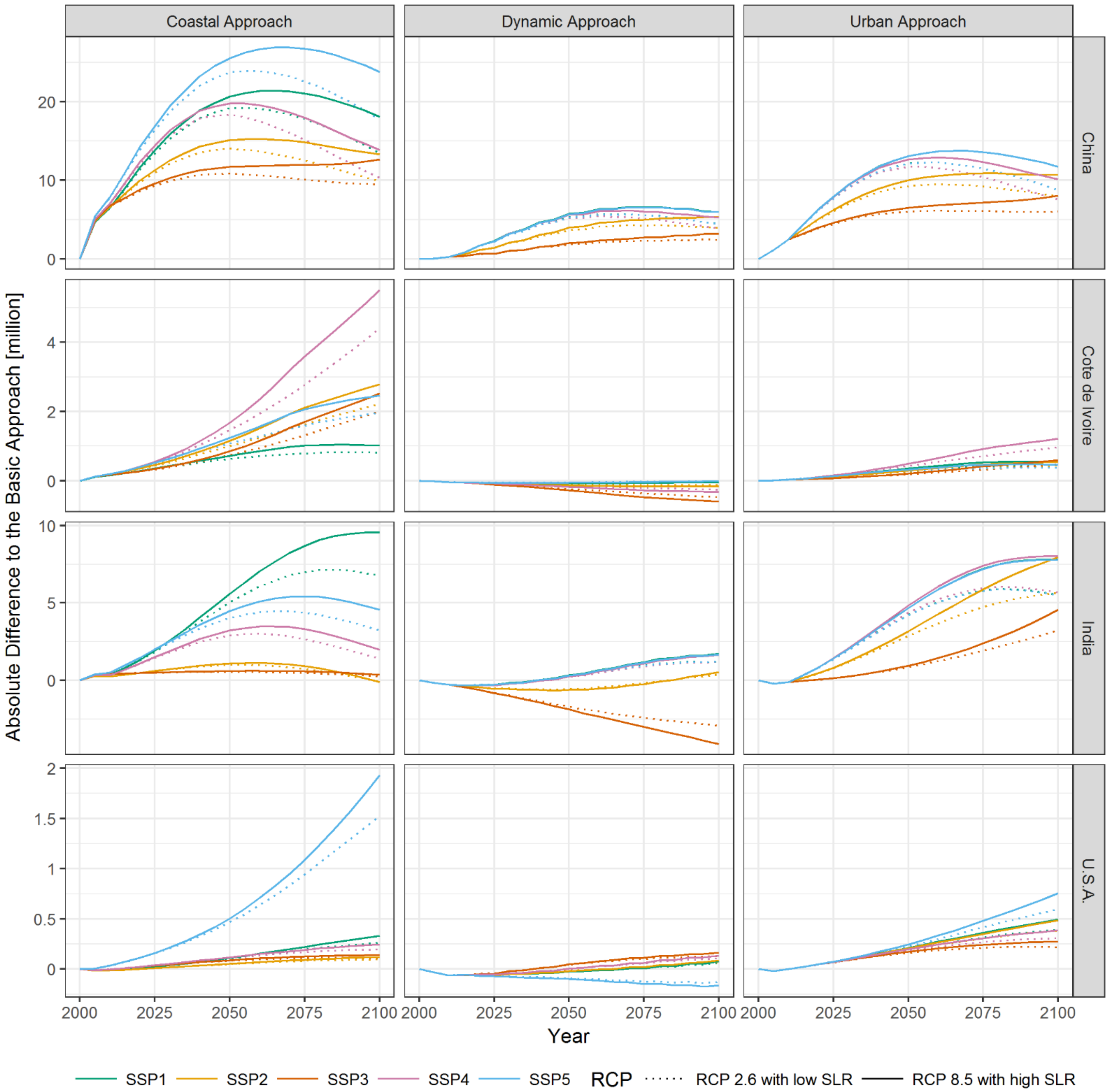

Fig. A. 9: Absolute difference (respective approach minus basic approach) in population exposed to 1 in 100-year coastal floods for four countries under low and high SLR projections

For India, exposure in 2100 is projected to be highest under SSP3 for all approaches with ~20 to 27 million people. Different to the U.S.A., we find the urban approach leading to higher estimates in exposure than the coastal approach. This is due to a negative observed growth difference, which means that for India coastal areas were less attractive than inland areas. In the coastal approach, this observation is assumed to persist. The high difference between the urban and the dynamic approach illustrate that urban sprawl leads to a considerable reduction of exposure compared to the assumption of static urban extents. As both, urban sprawl and migration to the inland lead to a reduction of exposure; we expect all regionalised approaches to overestimate exposure, whereas we assume that the dynamic approach leads to the best estimates in this case.

The opposite applies to Cote d'Ivoire. The exposure in 2100 based on the coastal approach is up to 5.5 time higher than based on the other approaches. We find the highest absolute differences in SSP4 (~ 5 million). This is partly due to the high gain in urbanisation level (increase from 43% in 2000 to 94% in 2100) and a high projected increase of population from 16.5 million in 2000 to 53 million in 2100 (UN 2015; Jiang and O'Neill 2017). We suspect a high positive observed growth difference to be the major driver of the considerably higher exposure in the coastal approach (high difference between coastal and urban approach), which is maintained for SSPs 2-5. In SSP1 the urban growth difference for coastal and inland areas is set to zero, which implies no differences in growth rates for cities and leads to the lowest difference to the other approaches. We consider that in the coastal approach overestimates the exposed population for Cote d'Ivoire. Although other studies project the population of Abidjan (a coastal city) to grow by 4.7 times between 2010 and 2100 (Hoornweg and Pope 2016), the comparison between the dynamic and the urban suggests, that the city will extent to less flood prone areas.

For China, we find the highest differences between the coastal and basic approach in 2100 with ~ 25 million (up to 80% relative difference) under SSP5. This is due to an increase in urbanisation level (35% in the base year to 94% in 2100) and, as already discussed for the U.S.A., the assumption of a high attractiveness of coastal areas in the coastal approach. The difference between the urban and dynamic approach of ~ 8 million suggests that cities expand to less flood prone areas, what leads to a considerable reduction of exposure compared to static urban extents. The difference of ~5 million in exposure for 2005 is due to inconsistencies in the UN (2015) and CIESIN et al. (2011b) data used to determine base year urbanisation in the coastal SSPs. However, even if the absolute differences in exposure for years later than 2010 were reduced by 5 million, the differences between the coastal and the other approaches would still be notable.

References

CIESIN (Center for International Earth Science Information Network - Columbia University), IFPRI (International Food Policy Research Institute), (The World Bank), CIAT (Centro Internacional de Agricultura Tropical) (2011b) Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Urban Extents Grid. NASA Socioeconomic Data and Applications Center (SEDAC), Palisades, NY

Hoornweg D, Pope K (2016) Population predictions for the worlds largest cities in the 21st century. Environment and Urbanization

Jiang L, O'Neill BC (2017) Global urbanization projections for the Shared Socioeconomic Pathways. Global Environmental Change 42:193–199

Merkens J-L, Reimann L, Hinkel J, Vafeidis AT (2016) Gridded population projections for the coastal zone under the Shared Socioeconomic Pathways. Global and Planetary Change 145:57–66

UN (United Nations, Department of Economic and Social Affairs, Population Division) (2015) World urbanization prospects: The 2014 revision. United Nations, New York