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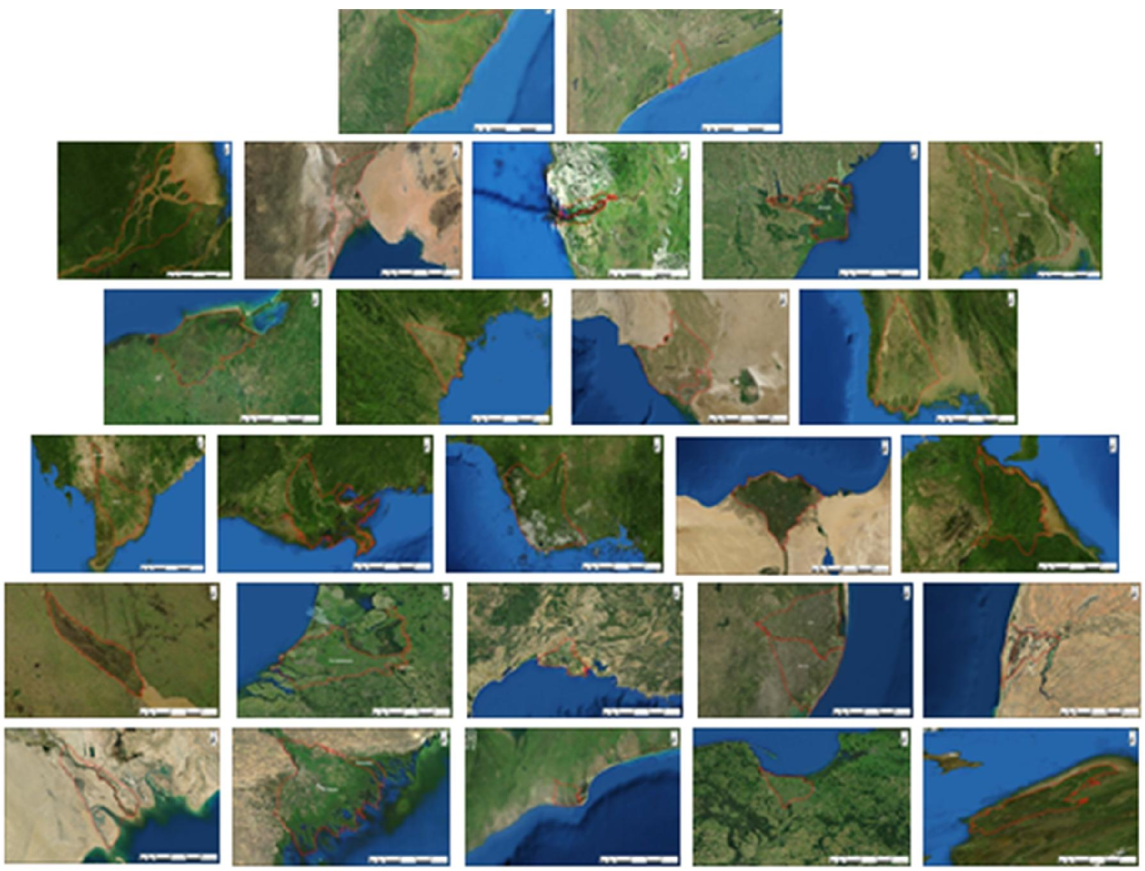
Vulnerability Assessment of Deltas in Transboundary River Basins



TWAP
TRANSBOUNDARY WATERS ASSESSMENT PROGRAMME

gef

UNEP

UNEP-DHI PARTNERSHIP
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UNEP DHI

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Delta Alliance

Delta Alliance is an international knowledge-driven network organization with the mission of improving the resilience of the world's deltas. With increasing pressure from population growth, industrialization and a changing climate, it is more important than ever that these valuable and vulnerable locations increase their resilience to changing conditions. Delta Alliance brings people together who live and work in deltas.

For more information on Delta Alliance and to download this report go to: www.delta-alliance.org

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Contents

1. Introduction

The GEF (Global Environmental Facility) funded Transboundary Water Assessment Programme (TWAP) seeks to develop methodologies for conducting a global assessment of transboundary water systems and to catalyse a partnership and arrangements for conducting such a global assessment. River basins constitute one of the water systems analysed in this programme, and may include deltas, occurring where a river flows into a lake or into the sea. The physical geography of deltas often strongly differs from the neighbouring parts of the river basin, in terms of relief, subsurface characteristics and hydrology. Deltas often host important population numbers, agricultural production areas and economic activities. For these reasons, it was felt that deltas need special attention in the TWAP River Basin assessment.

Delta Alliance, being a knowledge driven network between deltas, was therefore asked by the lead partner of the TWAP River Basins Component, UNEP-DHI, to perform a vulnerability assessment of a limited number of the most important deltas belonging to transboundary river basins.

An evaluation of the delta component in river basins to be analysed in the TWAP requires:

1. definition of deltas;
2. identification and selection of the most relevant deltas;
3. delineation of the selected deltas;
4. importance of the deltas in relation to the river basins, and
5. development of suitable vulnerability indicators and their assessment;

Chapter 2 recapitalises the key results of the assessment. In chapter 3 the results of the first three steps are described. After the definition, identification and the selection, the deltas have been delineated, according to geomorphological criteria. Chapter 4 evaluates the relative importance of the individual deltas in relation to their corresponding basins. The results of the actual vulnerability assessment are given in chapter 5 on the basis of a risk categorisation for four indicators: relative sea level rise, population pressure, wetland ecological threat and governance.

2. Key messages

The vulnerability of deltas differs across the world: The results show a geographical spread of vulnerability depending on the indicator. The Ganges-Brahmaputra-Meghna delta appears to be the most vulnerable, followed by the Niger and Volta deltas. The Amazon, Orinoco and Yukon deltas appear to have low to moderate vulnerability.
Deltas in Asia are most at risk: In general the deltas in Asia seem to have the most serious challenges in terms of human vulnerability caused by a combination of relative sea level rise and population pressures (and sometimes poor delta governance).

The assessment shows a broad geographical spread of results for each of the indicators. Many deltas score relatively high on some indicators and relatively low on others. It also makes clear that many deltas are quite vulnerable and some are highly vulnerable. The Ganges-Brahmaputra-Meghna delta appears to be the most vulnerable with two relative risk scores of 'very high' and one score of 'high'. The Niger and the Volta deltas follow with scores in the 'very high' and 'high' categories for three of the four indicators.

In general the deltas in Asia seem to be faced with the most serious challenges in terms of human vulnerability caused by a combination of a high score for relative sea-level rise combined with a high population pressure (and sometimes poor delta governance).

Of the 26 deltas assessed, 15 have at least two scores in the 'very high' and 'high' categories for two of the indicators. The Amazon, Orinoco and Yukon deltas appear to have relative low vulnerability.

The Relative Sea Level Rise Indicator has the highest number of 'very high' relative risk scores, followed by the Delta Governance Indicator. The Wetland Ecological Threat Indicator has the highest number of 'very low' and 'low' scores. However, this might also be a result of the methodology applied for this indicator.

Knowledge exchange between deltas (including lessons learned) and additional research are needed to address the knowledge gaps regarding the vulnerability of deltas and support the development and implementation of adaptive measures.

More in-depth information about the four indicators and incorporation of additional vulnerability indicators would give greater insight into the problems of deltas and the priorities for action to reduce their vulnerability.

More research is also needed to link the results of the delta assessment to the results of the river basin assessments in order to better understand the interaction between interventions upstream in the basin on the functioning of delta systems and vice versa.

3. Identification, selection and delineation

3.1 Definition of deltas

A sound definition of deltas is needed for identifying and delineating deltas in the TWAP assessment. Various delta definitions exist in the scientific literature taking into account subsurface and submarine characteristics, genesis, and geomorphological characteristics. For practical reasons we utilise a delta definition based on geomorphological criteria that can be applied to remote sensing images. Thereby we exclude offshore submarine and subsurface characteristics. A geomorphological definition of deltas can be based on the existence of multiple active and abandoned distributary river channels on the delta plain. On a natural delta plain the river is not confined by valley slopes and will change its course from time to time, with new distributaries creating new delta lobes on the coastline. In the process of switching, which is called avulsion, multiple active distributaries may coexist for some time, although often delta river discharge is captured by one dominant channel, leaving the earlier channel as a remnant on the delta plain. Because of this typical deltaic process of channel switching, deltas can be defined geomorphologically to include *the radial complex of active and abandoned distributary channels with associated fluvial landforms and the enclosed portions of the coastal plain, which forms where a river meets the sea or a lake.* Defined as such, neighbouring parts of the coastal plain without landforms created by the delta river are excluded from the delta, as well as offshore areas and uplands that are above present river flood levels.

3.2 Identification and selection of deltas

Working from the delta definition given above, we have screened all TWAP river basins for significant deltas. In this process we used the following data sources: (1) Google Earth, (2) the TWAP database of transboundary river basins, (3) the World Delta Database (WDD, Louisiana State University: www.geol.lsu.edu/WDD), (4) the delta overviews of Syvitsky et al. (2009), Ericson et al. (2006) and Bucx et al. (2010).

After our initial survey, we followed a step-wise procedure, described below, to select the deltas that should be included in the TWAP study. In this procedure we used the following criteria:

- area of upstream river basin;
- delta area;
- delta population;
- ecological or agricultural importance;
- data availability.

Step 1
Combining the World Delta Database with the overviews of Syvitsky et al. (2009), Ericson et al. (2006) and Bucx et al. (2010) leads to a worldwide dataset of 84 important deltas.

Step 2
Screening the worldwide dataset of 84 deltas with the TWAP database results in a subset of 40 deltas that are all part of a transboundary river basin.

Step 3
Using data on upstream basin area (TWAP), delta surface area (Ericson et al., 2006; for two deltas information from the internet was used to assess delta surface area), delta population (Ericson et al.,

2006; for one delta information from the internet was used to assess delta population), and an assessment of data availability, the subset of 40 deltas has been subdivided into six classes:

- ***** basin area >100000 km^2 and delta area >1000 km^2 and delta population >1000000 and large data availability;
- **** basin area >100000 km^2 and delta area >1000 km^2 and delta population >1000000;
- *** basin area >100000 km^2 and delta area >1000 km^2;
- ** basin area <100000 km^2 or delta area <1000 km^2;
- * basin area <100000 km^2 and delta area <1000 km^2;
- 0 basin area >100000 km^2, but no other data.

All deltas rating *** and higher, 23 in number, have been selected. From the deltas with a large upstream river basin, but limited data availability (class 0), three out of seven have been selected, primarily based on conjectured human population and relative data availability. Inland deltas, like the Okavango Delta, have been excluded. All selected deltas meet the criterion of ecological and/or agricultural importance. Table 1 gives an overview of the selected deltas with some basic data. Note that the delta area and population given in Table 1 are from the literature (almost all data are from Ericson et al., 2006) and only serve the purpose of delta selection. In the following stages of the project these data will be updated based on our own spatial data and analyses.

Table 1: Overview of selected deltas

	Classification	Basin area (km^2)	Delta area (km^2)	Delta population
America				
Amazon	****	5883400	106000	2930000
Colorado	***	655000	6340	336000
Grijalva	****	126800	10400	1040000
Mississippi	*****	3176500	28800	1790000
Orinoco	***	927400	25600	99200
Parana (La Plata)	***	2954500	12900	444000
Rio Grande	****	656100	13900	2030000
Yukon	***	829700	5020	1040
Europe				
Danube	***	790100	4010	156000
Rhine-Meuse	*****	172900	3810	1940000
Rhone	***	100200	1220	92100
Volga	***/****	1554900	27224	
Wisla	***	194000	1700	250000
Asia				
Ganges-Brahmaputra	*****	1634900	87300	111000000
Hong (Red)	****	157100	4590	5710000
Indus	***	1138800	6780	391000
Irrawaddy	****	404200	30400	9720000
Mekong	*****	787800	49100	20200000
Shatt-al-Arab	***	789000	3850	419000
Africa				
Congo	0	3674850		
Limpopo	0	413560		
Niger	****	2105190	17700	3730000
Nile	*****	3020100	24900	47800000
Senegal	***	434520	3240	260000
Volta	***	411200	2430	385000
Zambezi	0	1353200		

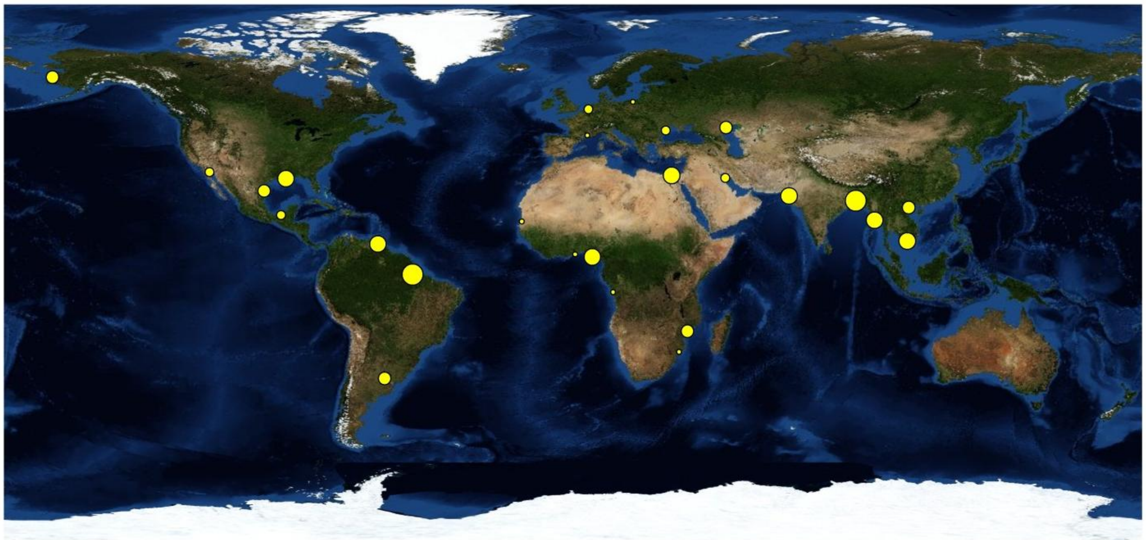

Figure 1 Global distribution of the selected deltas. The size of the yellow dots indicates the relative surface area of the delineated deltas

3.3 Delineation of deltas

Based on a geomorphological analysis using available remote sensing images (Google Earth and others), and working from our delta definition given above, we have delineated the selected deltas in a GIS (shape file TWAP_deltas) as accurately as possible. To assist in geomorphological interpretation of remote sensing images, we have generated worldwide contour lines (2.5, 5.0, 7.5 and 10 m altitude) based on SRTM data with GIS software. We have also consulted shape files of deltas created for the Syvitsky et al. (2009) paper. However, no delta delineations in our delta shape file have been copied from other files; all boundaries have been manually drawn based on our own geomorphological judgements. In this process we have also used a large number of geological, geomorphological and paleogeographical maps from published journal articles. In Figure 1 the global distribution of the selected and delineated deltas is shown, as well as the relative surface area of the deltas.

4. Relative Importance of the Delta in relation to the Basin

In order to get an insight in the importance of the delta in comparison to the corresponding river basin, three indicators have been used:

- Delta – basin area ratio (in %)
- Delta – basin population ratio (in %)
- Relative population density, being the ratio between the population density in the delta and population density in the whole basin.

After the selection of the deltas and the delineation of the deltas on the basis of geomorphological characteristics, the area of deltas has been calculated. The delta population has been derived from the global datasets of CIESIN (Center for International Earth Science Information Network) (see also section 5.4). The data on the area and the population of the corresponding basins have been provided by other partners in the TWAP consortium.

Table 2: Relative importance of the deltas in relation to their respective basins.

Deltas	Area			Population			Relative Population Density (number)
	Delta (km2)	Basin (km2)	Ratio (%)	Delta (number)	Basin (number)	Ratio (%)	
	A	B	C= A/B*100	D	E	F= D/E*100	G=E/C
America							
Amazon	50353	5888270	0.86	361486	32163919	1.12	1.31
Colorado	4069	626050	0.65	187840	8794418	2.13	3.28
Grijalva	7660	125675	6.09	345273	8302439	4.16	0.68
Mississippi	28989	3208420	0.90	1803749	78173975	2.31	2.55
Orinoco	28372	934340	3.04	177690	12165297	1.46	0.48
Parana	19348	2927110	0.66	806750	88221216	0.91	1.38
Rio Grande	11190	538402	2.08	1578188	10968793	14.39	6.92
Yukon	20438	838169	2.44	1948	140461	1.39	0.57
Europe							
Danube	4506	796498	0.57	97837	80184793	0.12	0.22
Rhine-Meuse	7222	163609	4.41	5552466	48831090	11.37	2.58
Rhone	1638	96868	1.69	104941	10055260	1.04	0.62
Volga	12900	1411750	0.91	288381	58620871	0.49	0.54
Wisla	1626	192043	0.85	437618	23147770	1.89	2.23
Asia							
Ganges-B-M	77050	1653990	4.66	102656355	704221090	14.58	3.13
Hong (Red)	11874	139930	8.49	17715720	17864328	99.17	11.69
Indus	26245	855900	3.07	3713066	189911699	1.96	0.64
Irrawaddy	30272	375475	8.06	9397116	28582552	32.88	4.08

Deltas	Area			Population			Relative Population Density (number)
	Delta (km^2)	Basin (km^2)	Ratio (%)	Delta (number)	Basin (number)	Ratio (%)	
	A	B	C= A/B*100	D	E	F= D/E*100	G=E/C
Mekong	25920	773231	3.35	15512624	58742817	26.41	7.88
Shatt-al-Arab	5912	868060	0.68	1059649	65437198	1.62	2.38
Africa							
Congo	1655	3689190	0.04	48277	90605235	0.05	1.19
Limpopo	880	406520	0.22	215678	15159368	1.42	6.57
Niger	29458	2111480	1.40	8635666	93617850	9.22	6.61
Nile	22859	2932700	0.78	42381848	174365405	24.31	31.19
Senegal	2991	448422	0.67	163725	7409034	2.21	3.31
Volta	880	410992	0.21	148244	24282921	0.61	2.85
Zambezi	11106	1373190	0.81	339406	37979690	0.89	1.10
TOTAL (26 deltas)	445414	33786284	1.32	213731181	1967949487	10.86	8.24

Ganges-B-M = Ganges – Brahmaputra – Meghna

Legend

Relative importance categories	Area Ratio Delta/Basin (%)	Population Ratio Delta/Basin (%)	Relative Population Density Delta/Basin (Number)
1 Very low	0 - 1	0 -1	0 – 1
2 Low	1 – 2	1 - 3	1 – 3
3 Moderate	2 – 3	3 - 10	3 – 6
4 High	3 - 4	10 – 25	6 - 10
5 Very High	> 4	> 25	> 10

In terms of the 'area' the deltas occupy generally only a relatively small portion of the basin: for 65% of the deltas the delta – basin area ratio is lower than 3 % and on average for all 26 deltas only 1.3 %. None of the deltas has a delta – basin area ration that reaches the 10%: the Hong delta is scoring highest with a ratio of 8.5%.

In terms of population the relative importance of the deltas is more significant. Although the 26 deltas cover only 1.3 % of the area, they house almost 11% of the basin population. This high average ratio is mainly caused by only relative few deltas, because the delta – basin population ratio is lower than 10 % for 73% of the deltas. The most extreme figure is found again for the Hong Delta where 99% of the basin population lives in the delta. Three other deltas with high delta – basin population ratios are the Irrawaddy delta (33%), the Mekong delta (26%) and the Nile delta (24%). These 4 weight high in the average sore for the 26 deltas.

If we compare the population density in the delta with the density of the whole basin, we see that in 6 out of the 26 deltas the density in the delta is lower than the one of the whole basin. All those deltas are located in Europe and the America. This might be due to the level of wetland protection in these deltas, but this assumption needs further investigation. Only two deltas (Hong and Nile deltas) have a relative population density that is higher than the average of 8.24.

5. Delta Vulnerability

5.1 Summary of Delta vulnerability assessment

Rationale

The delta is a major component of a river basin. Due to their location and geomorphological characteristics many deltas have relatively high population densities, high agricultural outputs, considerable economic and ecosystem productivity and often still contain areas of international ecological importance. Their functioning is highly dependent on the characteristics and activities in the (transboundary) river basin. Of specific importance are the river flows with accompanying sediment and nutrient fluxes. This transboundary influence on deltas is a major contributing factor to their sustainability, which is further determined by 'local' characteristics, such as population pressures and sea level rise.

Delta vulnerability is a function of physical (fluvial) pressures, (local) state conditions and response capacities (governance).

Delta vulnerability Indicators

Delta Vulnerability is based on four indicators:

- Relative sea level rise (RSLR)
- Wetland ecological threat
- Population pressure
- Delta governance

At the start of the project it was decided that only a limited set of indicators would be used for the delta assessment, which best reflect vulnerability to the most important drivers of change and pressures. The RSLR includes sea level rise resulting from climate change, subsidence (natural and anthropogenic) and delta aggradation. The wetland ecosystems in deltas are particularly under pressure from urbanization, agricultural and aquaculture expansion, and industrialization. The wetland indicator is based on the ecological value and the documented threats to the wetlands. In addition to the generally high population pressure, rapid urbanization is occurring in many of the deltas. However, population density can also differ significantly between deltas. With deltas generally being under high pressure, good governance is of extreme importance for sustainable management and development. Three principles are used for the governance indicator: adaptivity, participation and fragmentation. These are assessed at four different levels of institutionalization. Compared to the five thematic groups of the river basin assessment, the RSLR corresponds best with Water Quantity, the Wetland Ecological Threat Indicator to Ecosystems, the Population Pressure Indicator to Socio-economics and the Delta Governance Indicator to Governance.

In the course of the project it was decided that an overall Vulnerability Index as an average of the scores of the four indicators was not appropriate since most of the extremes would be levelled out to a general average value between 2 (relative low risk) and 3 (relative moderate risk). Moreover combining the indicators would involve weighting, which might be done differently by different stakeholders, depending on their point of view. The final results are therefore presented for each of the individual Delta Vulnerability indicators separately.

The assessment methodology and results for the four Delta indicators are described in the sections 5.2. to 5.5. The meta-data sheets for each of the indicators are presented in the annexes 3 - 6.

Summary of Delta vulnerability assessment results

The overall vulnerability of the individual deltas is shown in Table3. The colours and numbers represent the relative risk categories.

Table 3. Overview of the relative risk categories for the four indicators (deltas).

	Deltas	Indicators			
		Relative Sea Level Rise	Wetland Ecological Threat	Population Pressure	Delta Governance
Americas	Amazon	2	2	1	3
	Colorado	4	1	2	5
	Grijalva	4	1	2	5
	Mississippi	4	1	2	2
	Orinoco	3	2	1	3
	Parana (La Plata)	3	2	2	3
	Rio Grande	5	1	3	3
	Yukon	2	2	1	2
Europe	Danube	2	5	1	4
	Rhine-Meuse	2	3	4	1
	Rhone	5	4	2	2
	Volga	1	5	1	4
	Wisla	3	1	4	2
Asia	Ganges-Brahmaputra-Meghna	5	2	5	4
	Hong (Red)	2	1	5	3
	Indus	5	2	3	4
	Irrawaddy	5	2	4	3
	Mekong	5	2	4	3
	Shatt-al-Arab	4	2	3	5
Africa	Congo	2	4	2	5
	Limpopo	2	2	3	3
	Niger	5	3	4	4
	Nile	4	2	5	4
	Senegal	4	2	2	4
	Volta	4	4	3	4
	Zambezi	4	2	2	3

Legend

	Relative risk categories
1	Very low
2	Low
3	Moderate
4	High
5	Very High

The assessment shows a broad geographical spread of results for each of the indicators. Many deltas score relatively high on some indicators and relatively low on others. It also makes clear that many deltas are quite vulnerable and some are highly vulnerable. The Ganges-Brahmaputra-Meghna delta appears to be the most vulnerable with two relative risk scores of 'very high' and one score of 'high'. The Niger and the Volta deltas follow with scores in the 'very high' and 'high' categories for three of the four indicators.

In general the deltas in Asia seem to be faced with the most serious challenges in terms of human vulnerability caused by a combination of a high score for relative sea-level rise combined with a high population pressure (and sometimes poor delta governance).

Of the 26 deltas assessed, 15 have at least two scores in the 'very high' and 'high' categories for two of the indicators. The Amazon, Orinoco and Yukon deltas appear to have relative low vulnerability.

The Relative Sea Level Rise Indicator has the highest number of 'very high' relative risk scores, followed by the Delta Governance Indicator. The Wetland Ecological Threat Indicator has the highest number of 'very low' and 'low' scores. However, this might also be a result of the methodology applied for this indicator.

Knowledge exchange between deltas (including lessons learned) and additional research are needed to address the knowledge gaps regarding the vulnerability of deltas and support the development and implementation of adaptive measures.

More in-depth information about the four indicators and incorporation of additional vulnerability indicators would give greater insight into the problems of deltas and the priorities for action to reduce their vulnerability.

More research is also needed to link the results of the delta assessment to the results of the river basin assessments in order to better understand the interaction between interventions upstream in the basin on the functioning of delta systems and vice versa.

5.2 Relative sea level rise

Key Findings:

1. *Sea level rise threatens deltas in Asia, Africa and America:* Most of the deltas at very high risk are in Asia (Ganges, Indus, Irrawaddy and Mekong). A considerable number of deltas in Africa and America are also at (very high) risk, especially the Niger and Rio Grande. Europe has the fewest transboundary deltas, with only the Rhone at very high risk. Higher risk of relative sea level rise means increased flood risk which may result in loss of life and (severe) loss of economic and ecological assets.
2. *Population increase is a major factor in the risk of sea level rise:* One of the important factors for the RSLR is increasing population in delta (mega) cities, especially in Asia. This often results in less delta aggradation and increased human-induced (accelerated) land subsidence caused by severe ground water extraction in order to meet high(er) water demand.

Rationale

Many deltas are threatened by relative sea level rise (RSLR) resulting in increased flood risk (both coastal and freshwater), which can result in loss of life and severe impacts on human development and ecosystems. RSLR is determined by the balance between: (1) delta aggradation, (2) land subsidence and (3) sea-level rise.

(1) Delta aggradation is caused by fluvial sediment supply, but may be strongly influenced by human flood protection infrastructure inhibiting the distribution of sediments over the delta surface.

(2) Land subsidence results from various processes, some of which are natural (e.g., tectonic and isostatic movement, sediment compaction), while others are highly human-influenced, as a result of drainage activities or subsurface mining.

(3) Sea-level rise is a world-wide process, but nevertheless spatially variable because of varying gravimetric effects.

The RSLR indicator is based on the total sinking rate of the delta surface in mm/year (caused by the three components mentioned above) relative to the local mean sea level.

Computation

For the TWAP assessment, aggradation, subsidence and sea level rise are assessed for each delta from published data (Syvitski *et al*. 2009 and Ericson *et al*. 2006). On the basis of the available quantitative data, each delta is assigned to one of five relative sea level rise (RSLR) categories, largely following Ericson (2006), with category 1 representing no RSLR (<= 0 mm/yr) and category 5 representing high RSLR (>5 mm/yr).

Results

Of the transboundary deltas assessed, the most at very high risk are in Asia (Ganges, Indus, Irrawaddy and Mekong). Many deltas are also at (very high) risk in Africa and America, especially the Niger and Rio Grande. Europe has the fewest transboundary deltas, with only the Rhone at very high risk.

Figure 2. Relative Sea Level Rise Indicator (deltas). Includes reduction in sediment supply, land subsidence and sea level rise. Deltas in the higher risk categories have increased flood risk.

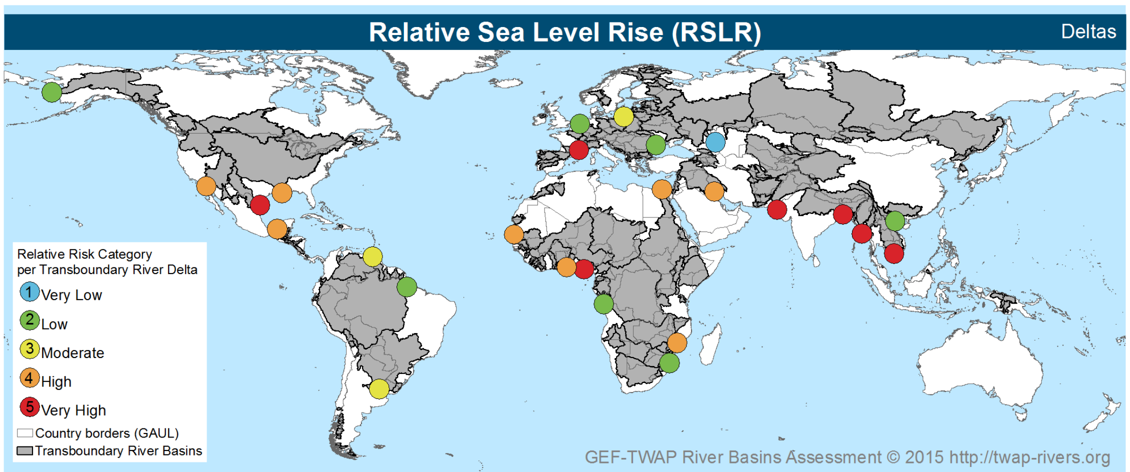

Table 4. Relative risk categories for Relative Sea Level Rise (RSLR) (deltas). Deltas in the high and very high relative risk categories have RSL of more than three mm/yr.

	Deltas	Relative risk category	RSLR (mm/year)	Source
Americas	Amazon	2	0 - 1.5	Ericson
	Colorado	4	2- 5	Syvitski
	Grijalva	4	3 - 5	Ericson
	Mississippi	4	2 - 5	Syvitski
	Orinoco	3	0.8 - 3	Syvitski
	Parana (La Plata)	3	2 - 3	Syvitski
	Rio Grande	5	5 - 7	Ericson
	Yukon	2	0 - 1.5	Ericson
Europe	Danube	2	1.2	Syvitski
	Rhine-Meuse	2	0 - 1.5	Ericson
	Rhone	5	2 - 6	Syvitski
	Volga	1	0	Li *et al*.
	Wisla	3	1.8	Syvitski
Asia	Ganges-Brahm'a-Meghna	5	8 - 18	Syvitski
	Hong (Red)	2	0 - 1.5	Ericson

RSLR (mm/year)	Relative Risk Category
<=0	1 Very low
>0 - 1.5	2 Low
1.5 - 3	3 Moderate
3 - 5	4 High
> 5	5 Very high

	Deltas	Relative risk category	RSLR (mm/year)	Source
	Indus	5	> 11	Syvitski
	Irrawaddy	5	3.4 - 6	Syvitski
	Mekong	5	6	Syvitski
	Shatt-al-Arab	4	4 - 5	Syvitski
Africa	Congo	2	?	Syvitski
Africa	Limpopo	2	0.3	Syvitski
Africa	Niger	5	7 - 32	Syvitski
Africa	Nile	4	4.8	Syvitski
Africa	Senegal	4	3 - 5	Ericson
Africa	Volta	4	3 - 5	Ericson
Africa	Zambezi	4	5	IPCC

Higher risk of RSLR means increased flood risk, which may result in loss of life and economic and ecological assets. This involves, among others, coastal erosion, loss of (wet)lands and other natural resources, damage to (critical) infrastructure, buildings and industrial areas. The higher the risk category the more severe the impacts of actual flooding. However several kinds of adaptive measures can be implemented to reduce the risks (green/soft measures, civil engineering/hard measures and institutional/organizational measures).

One of the important factors for the RSLR is increasing population in delta (mega)cities, especially in Asia. This often results in less delta aggradation and increased human-induced (accelerated) land subsidence caused by severe groundwater extraction to meet high(er) water demand.

Results for this indicator can be compared with the TWAP river basins Water Quantity thematic group to gain an understanding of the relative threat levels for deltas and their respective river basins.

Limitations and potential for future development

In the RSLR assessment, it was not possible to separately quantify the various components of aggradation, land subsidence and regional sea level rise.

Intra-delta spatial variability, which in many cases is high, is not taken into account; ranges provided are based on measurements at either different times or different areas of a delta (Syvitski 2009). Estimation of accelerated subsidence is problematic due to spatial and temporal variations depending on the location and intensity of the human activities causing the subsidence (Ericson 2006).

In the absence of reliable data, a factor of three times the natural subsidence rate is applied to define the upper limit of the potential accelerated subsidence based on the assumption that accelerated subsidence is a direct result of the magnitude of anthropogenic influence on delta sediment (Ericson 2006).

More research and data are needed for better estimation of the risk of RSLR and related impacts especially regarding land use, land subsidence and sediment supply.

5.3 Wetland ecological threat indicator

Key Findings:

1. *Valuable deltas are at risk:* The most valuable deltas (in terms of wetland area and ecological value) are the Danube and Volga deltas which still have large wetlands with high ecological value, but, as shown by the documented threats, they are also the deltas with wetland ecosystems that are most at risk.
2. *American deltas are at lower risk:* The deltas in the Americas seem to be less at risk than those in other continents. This is probably due to relative low human pressures and good governance.

Rationale

Wetlands are the most typical ecosystems in deltas. Information on wetlands in deltas provides an indication of their biodiversity value and level of natural state. In principle all types of wetlands can be found in deltas, including typical coastal wetlands such as mangrove, estuary and lagoon as well as freshwater wetlands (bogs, fens, lakes, marshes).

Computation

The determination of the Wetlands Ecological Threat Indicator is based on three main factors:

1. The share of wetland ecosystems within the delta, based on data from the Global Lakes and Wetlands Database (GLWD- 3) (Lehner and Döll 2004).
2. The ecological value determined by the presence of:
   a) Biodiversity Hotspot(s): regions of global conservation importance defined by the presence of high levels of threat (at least 70% habitat loss) in areas with high levels of species endemism (at least 1 500 endemic plant species) (Myers *et al*. 2000);
   b) Key Biodiversity Area(s) (KBA): sites identified as a conservation priority for a variety of species (birds, mammals, plants, etc.) (Langhammer *et al*. 2007);
   c) Ramsar site(s): areas that come under the Convention on Wetlands (Ramsar Convention), an intergovernmental treaty to maintain the ecological character of Wetlands of International Importance;
   d) Global 200: ecoregions with conservation priority, identified by WWF (Olson and Dinerstein 1998)[1];
   e) World Network of Biosphere Reserve(s): protected areas assigned under the Man and the Biosphere Programme (MAB-Reserve), UNESCO;
   f) Formally protected areas: covers a number of protection categories; the formal protection most relevant for biodiversity is IUCN category 1-2.
3. The environmental threat:
   a) Threats mentioned in descriptions of the biodiversity hotspots;
   b) Threats mentioned in the Global 200 regions;
   c) For those not covered, site descriptions from Ramsar or similar deltas were used.

The criteria are further explained in the Metadata sheet in Annex IX-6. Not all are formally recognized statuses for deltas.

'Share of wetlands' uses a score 1-5 on the basis of the share of wetlands compared to the total delta area (in %). The GLWD-3 contains 12 wetland classes, which are all given equal weight in the calculation of the fraction of the deltas classified as wetlands. In a few cases a correction was made for the share of wetlands, where it is known from the statistical data that they include mostly farming areas (e.g. rice paddies or other farming areas, as in the Hong, Mekong, Senegal and Volta deltas).

'Ecological value' combines the six criteria mentioned above. All were simply scored with 1 (or 0.5 if the criterion applies only for a small part of the area) and added together to determine the score for the ecological value.

'Environmental threat' is based on an inventory of the threats per delta ecosystem. Some 27 threats are cross-tabulated. The information is based on the descriptions available for the Biodiversity Hotspots and Global 200 areas (see above and meta data sheet). In the few cases where no information is available for an area, information is used for adjoining rivers with additional information from the formal Ramsar site description sheets. The number of threats are scaled using a 1 - 5 point scale.

Next, the 'Calculated average wetland ecological Value (CV)' is determined as the average of the scores of the share of wetlands and the ecological value. This results in a value ranging from 0.75 – 4.50.

[1] The Global 200 is the list of ecoregions identified by WWF, the global conservation organization, as priorities for conservation. According to WWF, an ecoregion is defined as a "relatively large unit of land or water containing a characteristic set of natural communities that share a large majority of their species, dynamics, and environmental conditions (Olson & Dinerstein 1998, 2002).

Then, the ‘Wetland Ecological Threat Indicator’ is calculated by multiplying the CV by the number of threats, resulting in values ranging from 2 – 17.5. Finally, this value is re-scaled to a scale 1-5, to make it comparable with the results from the other assessments of the other indicators.

Details of the various inventories and steps are given in Annex IX-6. The main results are presented below.

Results

The ecological value of deltas is defined by the presence of wetlands, as well as the classification of (parts of) the delta as important areas for biodiversity. The most valuable are the Danube and Volga deltas which are still large wetlands, but, in combination with the documented threats, they are also the deltas with wetland ecosystems that are most at risk. Deltas with a high relative risk score are the Rhone, the Ganges-Brahmaputra-Meghna, the Congo and the Volta.

The Deltas in the Americas seem to be less at risk than those in other continents, which is often related to the human pressures exerted, but in some cases governance may affect this result since formal conservation or acknowledgement of value may be in place.

Figure 3. Wetland Ecological Threat Indicator (deltas). Based on the proportion of wetlands in the delta, the ‘ecological value’ and the threats to the wetlands. The Danube and the Volga are at highest risk.

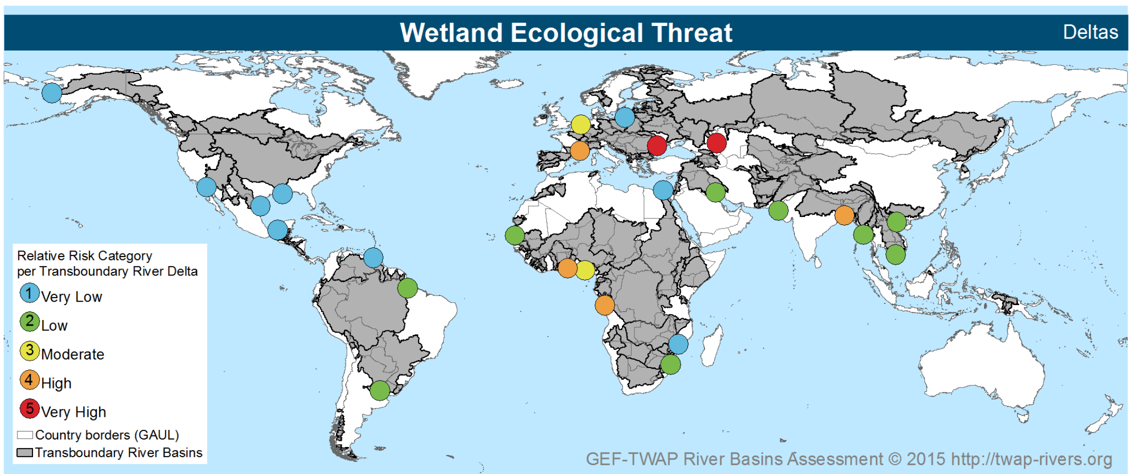

Table 5. Relative risk categories for Wetland Ecological Threat Indicator for the selected deltas.

Deltas	Relative Risk Category	Share wetland eco-systems (S)	Ecological value (V)	CV Calculated wetland ecological Value CV =(S+V)/2	Environ-mental threats (scaled) (T)	Wetland Ecological threat (CV*T)
America						
Amazon	2	4	0.5	2.25	3	6.75
Colorado	1	1	4	2.5	1	2.5
Grijalva	1	1	2	1.5	2	3
Mississippi	1	4	0	2	1	2
Orinoco	1	1	1.5	1.25	3	3.75
Parana (La Plata)	2	3	1.5	2.25	2	4.5
Rio Grande (R. Bravo)	1	1	1.5	1.25	2	2.5
Yukon	1	5	2	3.5	1	3.5
Europe						
Danube	5	5	4	4.5	3	13.5
Rhine-Meuse	3	3	2.5	2.75	3	8.25
Rhone	4	5	3	4	3	12
Volga	5	5	4	4.5	3	13.5
Wisla	1	1	1	1	3	3
Asia						
Ganges-Brahm'a-Meghna	4	4	4.5	4.25	3	12.75
Hong (Red River)	2	1.5*	3.5	2.5	2	5
Indus	2	3	3	2.5	2	5
Irrawaddy	2	3	2	2.5	2	5
Mekong	2	2.5*	2.5	2.5	2	5
Shatt-al-Arab	2	2	2	2	2	4
Africa						
Congo	4	2	2	2	5	10
Limpopo	2	4	1	2.5	2	5
Niger	3	3	2	2.5	3	7.5
Nile	1	1	0.5	0.75	5	3.75
Senegal	2	2.5*	1.5	2	2	4
Volta	4	2.5*	2	2.25	5	11.5
Zambezi	1	1	2.5	1.75	2	3.5

* corrected for large agricultural areas

Wetland Ecological Threat Indicator. (CV*T)	Relative Risk Category
1 - 4	1 Very low
4 - 7	2 Low
7 - 10	3 Moderate
10 -13	4 High
>13	5 Very high

Results for this indicator can be compared with the TWAP river basins Wetland Disconnectivity Indicator to gain an understanding of the relative threat to wetlands in the delta and the respective river basin.

Limitations and potential for future development

The indicator developed here is currently the best available, given the available data. There are however several shortcomings. The problem for some ecological indicators, for example the presence of a Ramsar site or protected status, is the fact that the assignment of a site on the official list is a function of political will rather than ecological criteria alone. We have therefore combined different ecological indicators, which are also partly based on objective scientific criteria such as species biodiversity or ecosystem value. Aberrations are therefore levelled out.

The data are better in the more developed countries, which may provide a slight bias, e.g. in Europe.

The wetland percentage of deltas as derived from the GLWD is an important indicator of the ecological value, but in some locations (such as the Mekong, Hong, Senegal and Volta deltas), the delta is almost fully classified as wetlands according to the global lake and wetland database, while it is generally known that large parts of these deltas are used for agriculture. This is probably because a large part of the agricultural land is still under natural annual flooding. Some correction of the wetland share and the combination of this indicator with the ecological indicator leads to a balanced result.

The ecological value is only a proxy for the real value, since there is no adequate database available.

The environmental threats are based on descriptions of deltas, rivers, and regions which differ in scale, author, and ecosystem. The purpose of the descriptions differ, as do the year of description. The number of threats are therefore not based on a balanced review of all deltas, rather it is an inventory of threats mentioned on different websites, and partly based on the country reports (e.g. on the Ramsar site sheets).This makes the source data rather diverse, and as a consequence the threats are difficult to compare for each delta. A more extensive review of all threats would be required for each delta to ensure that the descriptions are more homogeneous and comparable.

5.4 Population pressure

Key Findings:

1. Of the assessed deltas, those in the 'very high' relative risk category for population density are in Asia (Ganges and Hong) and Africa (Nile).
2. The deltas usually have much higher population densities than the river basins, which can increase pressures on upstream areas. If socio-economic indicators for the respective river basin reveal high risk and the population pressure in the delta is also high, the situation may be more acute.

Rationale

High population pressures pose challenging demands on delta resources, such as freshwater, fertile soils, space and ecosystem regulation functions. This can also impact upstream river basin resources and their management.

Population pressure is a relative measure on a scale of 1 to 5, based on the average number of people per square km.

Computation

CIESIN (Center for International Earth Science Information Network) holds global data sets on population (http://sedac.ciesin.columbia.edu/data/collection/gpw-v3).

The Gridded Population of the World (GPWv3) shows the distribution of human population across the globe. This is a gridded, or raster, data product that renders global population data at the scale and extent required to demonstrate the spatial relationship of human populations and the environment across the globe. The data contains a projection of the number of people living in each 2.5 arcseconds gridcell for 2010, based on census data of 2000.

These data are combined with the defined extent of the deltas to calculate an average population density per delta. First, the population in all 2.5 arcsecond cells that have their centroids within the polygons of the deltas are summed. Then an average population density is calculated using the area of the delta.

Results

Of the assessed deltas of transboundary basins, the most at risk, caused by a very high population density, are in Asia (Ganges and Hong) and Africa (Nile). A few deltas in Asia, Africa and Europe are at high risk (Mekong and Irrawaddy in Asia, Niger in Africa and the Rhine-Meuse and Wisla in Europe). The deltas in South America have a very low population density and are therefore considered not at risk.

The results of this indicator can be aligned with results of the socioeconomic indicators for the respective river basin. For example, if vulnerability in the river basin is high, and population pressure in the delta is high, the situation may be more acute.

Figure 4. Population Density Indicator (deltas). Deltas in the 'very high' relative risk category are in the Ganges and Hong deltas (Asia) and the Nile delta (Africa).

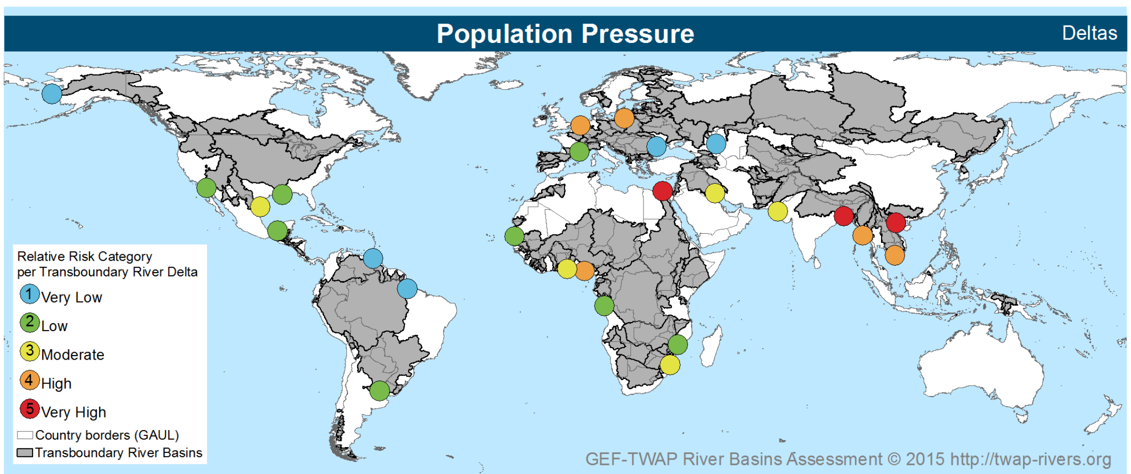

Table 6. Relative risk categories for the Population Density Indicator for the selected deltas

	Deltas	Relative risk category	Population Density
Americas	Amazon	1	7.2
	Colorado	2	46.1
	Grijalva	2	45.1
	Mississippi	2	62.2
	Orinoco	1	6.3
	Parana (La Plata)	2	41.7
	Rio Grande	3	141.0
	Yukon	1	0.10
Europe	Danube	1	21.7
	Rhine-Meuse	4	768.8
	Rhone	2	64.1
	Volga	1	22.4
	Wisla	4	269.2
Asia	Ganges-Brahm'a-Meghna	5	1 332.3
	Hong (Red)	5	1 491.9

Population Density (persons/km^2)	Relative Risk Category
0 – 25	1 Very low
25 – 100	2 Low
100 – 250	3 Moderate
250 – 1 000	4 High
> 1 000	5 Very high

	Deltas	Relative risk category	Population Density
	Indus	3	141.5
	Irrawaddy	4	310.4
	Mekong	4	598.5
	Shatt-al-Arab	3	179.2
Africa	Congo	2	29.2
	Limpopo	3	245.1
	Niger	4	293.2
	Nile	5	1 854.1
	Senegal	2	54.7
	Volta	3	168.4
	Zambezi	2	30.6

Limitations and potential for future development

The population pressure indicator quantifies the average population density in the delta. There is however no information on heterogeneity within the delta. There would be a difference if people are living together in some very densely populated cities, or are more or less spread over the total area. More detailed assessments with delineation of the urban areas are needed.

Similarly, the elevations where people live are not taken into account. Improvement of the quality of the assessment would require the use of digital elevation maps.

Vulnerability also depends, to a large extent, on the quality of housing, which very much depends on the income of the populations, which is not taken into account in this indicator. The assessments could be improved by making use of socio-economic data or surveys.

5.5 Delta governance

Key Findings:

1. *Delta governance risks are high in Africa and some northern deltas (Colorado and Danube):* The indicator shows that some of the least at-risk deltas are in Europe and North America. However, it also shows that some of the highest at-risk deltas are also in these continents (Colorado Delta and Danube Delta) because of the transboundary aspect. The African continent shows a moderate to very high risk for Delta Governance, thereby showing that this continent is at-risk from inadequate governance.

Rationale

Governance describes the structures and processes for collective decision-making involving governmental and non-governmental actors (Neye and Donahue 2000). Delta governance focuses on these aspects within a delta. The rationale behind this indicator is that deltas have multi-level, multi-stakeholder, multi-scale dimensions that require a specific approach for governance. As there is relatively little specific information on delta governance, the indicator assesses governance at the country level to approximate governance of the delta. Three key governance principles are used: adaptivity, participation and polycentric governance[2]. Adaptivity is a measure of the capacity of society and institutions to adapt to economic and political change. Participation focuses on transparency, accountability and participation (TAP) and can be used to analyse institutional

[2] In the annex and during the development of the methodology, the concept of fragmentation (Isailovic *et al.* 2013; Zelli 2011) was used. However as this concept has ambiguous connotations, it was changed to the term polycentric governance (Pahl-Wostl and Knieper 2014) as this concept explains a comparable dimension of governance, but is less ambiguous.

performance as well as how stakeholders behave and relate to each other. Finally polycentric governance emphasizes the presence of several independent centres of authority in a governance domain. This creates opportunities for further development of environmental policies through policy innovation, consensus building and negotiations. It is also said to perform well regarding complex issues such as climate change adaptation.

Different levels of institutionalization are used for the calculation of the Delta Governance Indicator. A typology of levels of institutionalization is helpful when conducting comprehensive institutional analysis. The typology used is based on the work by Williamson (1998), and Koppenjan, and Groenewegen (2005). The four levels are: (1) the meta level, i.e. norms, values, codes, orientation, culture, and informal institutions, (2) the macro level, i.e. formal rules, laws, regulations, constitutions and the process arrangements that constitute them, (3) the meso level, i.e. covenants, contracts, agreements, plans and the processes that constitute them and (4) the micro level, i.e. actors and interactions, aimed at creating or influencing services, provisions, planning, and outcomes.

Computation

The assessment is done to determine how the different countries score on the three key principles of delta governance on the different levels of institutionalization. This is done on the basis of various indicators from two sources:

- Actionable Governance Indicators (AGI Data Portal) [https://www.agidata.org/site/SourceProfile.aspx?id=21];
- Hofstede Centre, [http://geert-hofstede.com/].

The Delta Governance Indicator identifies the level of existence of the three key aspects of delta governance on a scale from 1 (practically no adaptivity, participation and hardly any polycentric governance) to 4 (a high score on adaptivity, participation and highly developed polycentric governance) based on 43 sub-indicators across the four institutional levels. In some cases there may be two sub-indicators per institutional level, and in which case the scores are averaged. Ultimately this means that there is one score for each institutional level of the indicator. For each of the three key aspects, the results for each institutional level are averaged. These three scores are then averaged to give an overall average for each Delta Country Unit (DCU). The results for each DCU are averaged on the basis of the relative area and population in each DCU compared with the entire delta, to provide the final delta governance score. More details on the computation are given in Annex IX-6.

Results

The Delta Governance Indicator shows that, on the basis of the levels of adaptivity, (institutional) polycentric governance and participation in the specific countries, there is a certain level of (institutional) delta governance capacity available. The indicator shows that some of the least at-risk deltas are, as expected, in Europe and North America. However it also shows that some of the highest at-risk deltas are also in these continents (Colorado and Danube Delta), mainly because of the transboundary aspect.

Although the dataset used is not specifically aimed at the management of natural resources and the environment, it does provide insight into the capacity of the countries to manage both the environmental and natural resources of the delta. This is because the institutional capacity of a country has a cross-sectoral impact, which also includes natural resources and the environment. The results provide an indication of the likelihood of transboundary cooperation and the state of delta governance.

Figure 5. Governance Indicator (deltas). Governance risks, based on adaptivity, participation and polycentric governance, are high in Africa and some northern deltas (Colorado and Danube)

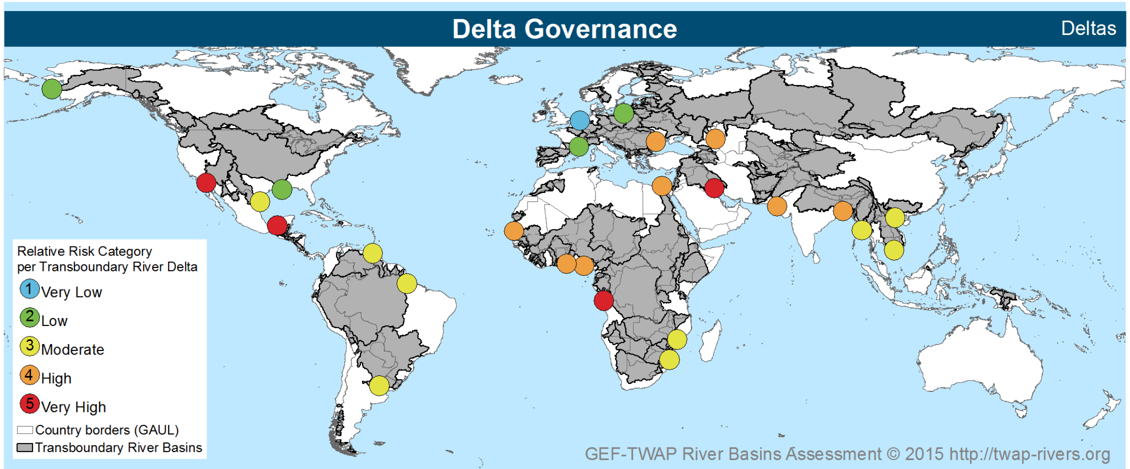

Table 7. Relative risk categories for the Governance Indicator for the selected deltas

	Deltas	Relative Risk Category	Governance score
Americas	Amazon	3	6.7
	Colorado	5	4.98
	Grijalva	5	4.98
	Mississippi	2	7.96
	Orinoco	3	6.90
	Parana (La Plata)	3	6.16
	Rio Grande	3	6.65
	Yukon	2	7.96
Europe	Danube	4	5.37
	Rhine-Meuse	1	8.37
	Rhone	2	7.24
	Volga	4	5.57
	Wisla	2	7.11
Asia	Ganges-Brahm'a-Meghna	4	5.53
	Hong (Red)	3	6.21
	Indus	4	5.25
	Irrawaddy	3[1]	...
	Mekong	3	6.13
	Shatt-al-Arab	5	4.90
Africa	Congo	5	4.85
	Limpopo	3	6.09
	Niger	4	5.31
	Nile	4	5.19
	Senegal	4	5.75
	Volta	4	5.72
	Zambezi	3	6.09

Governance score	Relative Risk Category
> 8	1 Very low
7 – 8	2 Low
6 – 7	3 Moderate
5 – 6	4 High
< 5	5 Very high

[1]This value is estimated since no governance data was available for the Irrawaddy delta

Limitations and potential for future development

The general limitations of governance-oriented indicators are that they are often based on survey or interview data which is often described by critics as ‘subjective’ and they therefore argue that the perception-based data on which these indicators are based reflect vague and generic perceptions rather than specific objective realities. Furthermore, as described above, the indicators used to construct the Delta Governance Indicator are not specifically aimed at natural resource management or the environment.

Additional assessment regarding delta governance could be done by means of (desk) research, questionnaires, interviews and (data) analyses.

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Annex 1 – Wetlands Ecological Treats Indicator

Calculated wetland ecological Value (CV)

	Wetland Fraction	Wetland Share Score***	Biodiversity Hotspot	KBA (IBA, IPA)	Ramsar site	Global 200	MAB- Reserve	Protected area (IUCN 1-2)	Ecological value (D+E+F+G+H+I)	Calculated wetland ecological Value ((C+J)/2)
A	B	C	D	E	F	G	H	I	J	K
America										
Amazon	0.805962	4	-	(yes)*	-	-	-	-	0.5	2.25
Colorado	0.128440	1	-	yes	yes	yes	yes	-	4	2.5
Grijalva	0.094499	1	yes	-	yes	-		-	2	1.5
Mississippi	0.831445	4	-	-	-	-	-	-	0	2
Orinoco	0.330887	1	-	(yes)*	-	(yes)*	-	(yes)*	1.5	1.25
Parana (La Plata)	0.782675	3	-	(yes)*	-	-	yes	-	1.5	2.25
Rio Grande (R. Bravo)	0.396238	1	-	-	(yes)*	-	yes	-	1.5	1.25
Yukon	0.940435	5		yes	-	-	-	yes	2	3.5
Europe										
Danube	0.919487	5	-	yes	yes	yes	yes	-	4	4.5
Rhine-Meuse	0.089470	3	-	yes	yes	-	-	(yes)*	2.5	2.75
Rhone	0.901131	5	-	yes	yes	-	yes	-	3	4
Volga	0.992367	5	-	yes	yes	yes	yes	-	4	4.5
Wisla	0.008594	1	-	yes	-	-	-	-	1	1
Asia										
Ganges-B.- M.	0.835816	4	-	yes	yes	yes	yes	(yes)*	4.5	4.25
Hong (Red River)	0.744592	1.5**	yes	(yes)*	-	yes	yes		3.5	2.5
Indus	0.488838	2	-	yes	yes	yes	-	-	3	2.5
Irrawaddy	0.630974	3	yes	yes	-	-	-		2	2.5
Mekong	0.996415	2.5**	yes	(yes)*	-	yes	-	-	2.5	2.5
Shatt-al-Arab	0.476185	2	-	yes	-	yes	-	-	2	2
Africa										
Congo	0.463517	2	-	-	yes	yes	-	-	2	2
Limpopo	0.879971	4	yes	-	-	-	-	-	1	2.5
Niger	0.706268	3	(yes)*	(yes)*	-	yes	-	-	2	2.5
Nile	0.149954	1	(yes)*	-	-	-	-	-	0.5	0.75
Senegal	0.952433	2.5**	-	(yes)*	(yes)*	-	-	(yes)*	1.5	2
Volta	0.938590	2.5**	-	yes	yes	-	-	-	2	2.25
Zambezi	0.258809	1	yes	yes	(yes)*	-	-	-	2.5	1.75

(yes)* indicates that the Delta only partly falls within this category
** corrected for large agricultural areas
*** see table below **** 1 is least valuable, 5 is most valuable

Legend

Wetland percentage	Wetland share score
0 - 40 %	1
40 – 60 %	2
60 – 80 %	3
80 – 90 %	4
90 – 100 %	5

Wetland threats

	Biodiversity Hotspot	Global 200	Deforestation	Unsustainable use NTFPs	Illegal logging & squatting	(Forest) fires	Timber production	Agribusiness	Agric. encroachment	Infrastructure dev., industry	Hydro-power dams	Oil drilling & pipelines	Roads, Infrastructure	Mining	Livestock grazing	Invasive exotic species	Poaching/fishing	Conflict	weak NGO presence	Land tenure	Pop. growth	Legal framework	Corruption	Habitat loss, fragmentation	Degradation marine rousources	Water extraction and use	Pollution	Tourism	Climate change	Ecological threats	Scaled value threats
America																															
Amazon	-	(X)*	x				x		x		x		x	x	x		x				x						x			7	3
Colorado	-	X				x									x	x														3	1
Grijalva[3]	(X)	-	x	x		x			x	x																				5	2
Mississippi	-	-							x																x		x			3	1
Orinoco	-	(X)*	x				x		x		x			x	x		x										x			7	3
Parana (La Plata)	-	-				x			x		x													x			x			5	2
Rio Grande (R. Bravo)	-	-	x										x		x													x		4	2
Yukon		-										x																		1	1
Europe																															
Danube	-	X							x	x	x		x				x	x			x						x			8	3
Rhine-Meuse	-	-						x		x	x		x			x	x							x	x	x				9	3
Rhone	-	-							x	x						x	x							x		x			x	7	3

[3] http://www.cepf.net/Documents/final.mesoamerica.northernmesoamerica.ep.pdf

	Biodiversity Hotspot	Global 200	Deforestation	Unsustainable use NTFPs	Illegal logging & squatting	(Forest) fires	Timber production	Agribusiness	Agric. encroachment	Infrastructure dev., industry	Hydro-power dams	Oil drilling & pipelines	Roads, Infrastructure	Mining	Livestock grazing	Invasive exotic species	Poaching/fishing	Conflict	weak NGO presence	Land tenure	Pop. growth	Legal framework	Corruption	Habitat loss, fragmentation	Degradation marine rousources	Water extraction and use	Pollution	Tourism	Climate change	Ecological threats	Scaled value threats
Volga	-	X									x						x		x			x	x			x	x			7	3
Wisla	-	-	x						x		x		x				x							x			x			7	3
Asia																															
Ganges-Brahmaputra -Meghna[4]	-	X	x	x	x				x		x		x												x	x				8	3
Hong (Red River)[5]	X	X	x	x			x										x												x	5	2
Indus	-	X									x					x								x		x	x			5	2
Irrawaddy[2]	X	-	x	x				x	x								x													5	2
Mekong	X	X	x	x			x										x												x	5	2
Shatt-al-Arab[6]	-	X				x						x	x				x										x			5	2
Africa																															
Congo	-	X	x		x	x	x		x				x	x			x	x	x		x	x		x	x					14	5
Limpopo[7]	X	-	x				x		x					x							x				x	x				6	2

[4] http://sites.wetlands.org/reports/ris/2BD001en.pdf
[5] http://www.cepf.net/SiteCollectionDocuments/indo_burma/IndoBurma_ecosystemprofile_2011_update.pdf
[6] http://ramsar.wetlands.org/Portals/15/KUWAIT.pdf
[7] http://www.cepf.net/where_we_work/regions/africa/maputaland/ecosystem_profile/Pages/threats.aspx

	Biodiversity Hotspot	Global 200	Deforestation	Unsustainable use NTFPs	Illegal logging & squatting	(Forest) fires	Timber production	Agribusiness	Agric. encroachment	Infrastructure dev., industry	Hydro-power dams	Oil drilling & pipelines	Roads, Infrastructure	Mining	Livestock grazing	Invasive exotic species	Poaching/fishing	Conflict	weak NGO presence	Land tenure	Pop. growth	Legal framework	Corruption	Habitat loss, fragmentation	Degradation marine rousources	Water extraction and use	Pollution	Tourism	Climate change	Ecological threats	Scaled value threats
Niger[8]	(X)*	X					x		x					x			x	x			x	x		x	x					9	3
Nile	(X)*	-				x			x	x	x		x	x	x		x				x			x	x	x	x	x	x	15	5
Senegal	-	-	x				x		x					x							x				x	x				6	2
Volta	-	-	x	x	x				x	x	x				x		x			x	x	x	x	x	x				x	15	5
Zambezi	X	-	x				x		x					x							x				x	x				6	2

[8] http://www.cepf.net/where_we_work/regions/africa/guinean_forests/ecosystem_profile/Pages/threat_assessment.aspx

Annex 2 - Governance indicator: Computation of results

The assessment is to determine how the different countries score on the three key principles of delta governance on the different levels of institutionalization. This is done on the basis of set of indicators from two sources:

- Actionable Governance Indicators (AGI Data Portal)[9]
  [https://www.agidata.org/site/SourceProfile.aspx?id=21]
- Hofstede Centre: [http://geert-hofstede.com/]

The Delta Governance Index identifies the level of existence of the three key aspects of delta governance on a scale from 1 (practically no adaptivity, participation and fragmentation) to 4 (a high score on adaptivity, participation and fragmentation). For the weighting it is important to point out that every sub indicator has the same factor. Which means that if one institutional level is based on two sub indicators, the scores of both sub indicators will be combined and dived by two. And in the end this means that there will be one score for each institutional level of the indicator.

Description of the (sub) indicators

Adaptivity:

<u>Uncertainty</u>

- The uncertainty avoidance dimension expresses the degree to which the members of a society feel uncomfortable with uncertainty and ambiguity. The fundamental issue here is how a society deals with the fact that the future can never be known: should we try to control the future or just let it happen? Countries exhibiting strong UAI maintain rigid codes of belief and behaviour and are intolerant of unorthodox behaviour and ideas. Weak UAI societies maintain a more relaxed attitude in which practice counts more than principles.

<u>A509:Adaption and Innovation</u>

- Society's capacity technological adaption and innovation
- Society's capacity for managerial adaptation and innovation
- Society's capacity for legal and institutional adaptation and innovation

<u>A311:Capacity for State reform</u>

- Administrations' ability to decide and actually implement reforms

<u>A502: Long-term vision</u>

- Are the actions of the public authorities in line with a long-term strategic vision?
- Is that strategic vision shared by society as a whole?
- Do the public authorities have the capacity to encourage public and private stakeholders to work towards that vision? (through tax and financial incentives etc.)

<u>A312: Capacity for sectoral reform</u>

- Authorities' ability to decide and actually implement:
  - o economic reforms
  - o social reforms (labour market, social rights etc.)
  - o health and education reforms
  - o societal reforms (family, religion etc.)
  - o environmental protection reforms

<u>A504: Spaces for reflection on the major national issues</u>

[9] That is the World Bank's new Governance and Anti-Corruption Strategy explicitly endorses greater use of disaggregated and actionable governance indicators (World Bank, 2014).

- Are there public or private "think tanks" producing analyses, forecasts and proposals on the major national issues?

A507: Quality of the public policy making process

- Is public policy experimentation prior to its general implementation a common practice?
- Is the evaluation of public policies a common practice?
- Authorities' capacity to adapt policies to changes in the economic and social contexts
- Do national public authorities and local stakeholders (local authorities, private sector, NGOs etc.) work together to develop and improve public policy effectiveness?
- Overall coherence of public policies

B501: Public support for innovation

- Do public authorities support public or private R&D?

P*articipation*

Participation refers to the possibility for citizens to provide informed, timely and meaningful input and to influence decisions at various levels. Therefor participation in decision-making processes in the water sector is a precondition for social accountability. Different mechanisms exist for public participation. This means that people can be encouraged to express themselves and influence decision and processes in the political, economic and social spheres.

Power Distance:

- This dimension expresses the degree to which the less powerful members of a society accept and expect that power is distributed unequally. The fundamental issue here is how a society handles inequalities among people. People in societies exhibiting a large degree of power distance accept a hierarchical order in which everybody has a place and which needs no further justification. In societies with low power distance, people strive to equalise the distribution of power and demand justification for inequalities of power.

A302: Intentional tensions caused by neighbouring counties

- Are neighbouring countries contributory factors to violent destabilisation, nuisance or conflict?

A301: Transparency of economic policy

- Is State economic policy (e.g. budgetary policy, fiscal policy etc.)

B304: Governance of natural resources

- Public authorities' transparency in the management of revenues from the exploitation of natural resources
- Allocation of revenues from the exploitation of natural resources to long-term investments
- Is the access of local and foreign firms to rights to exploit natural resources conditional on the achievement of objectives serving the general interest?

A102: Participation of the population

- Intensity of civil society's "checks and balance" function and political or social expression via the Internet, mobile phones etc.
- Public participation in political decisions (excluding elections)...
    - o at national level (e.g. surveys, commissions, public debates etc.)
    - o at local level (e.g. surveys, commissions, public debates etc.)

A307: Influence of economic stakeholders

- Do major national economic stakeholders (interest groups, lobby groups etc.) Influence economic legislation and tax policy?
- Do major foreign economic stakeholders (excluding international organisations) effectively influence public policies?

Fragmentation:

Fragmentation is a ubiquitous phenomenon of international relations, its degree however considerably varying across policy domain[10]. Governance and fragmentation means connecting. Coordination between different levels of government needs to occur both horizontally (between sectors) and vertically (between scale levels) and should involve private actors.

<u>B401: Significance of the public sector in the delivery of public services</u>

- Proportion of public services delivered by the public sector in the fields of Primary and secondary education, basic healthcare, water and sanitation, Telecommunications and public transport.

<u>A203: Internal conflicts</u>

- Intensity of internal conflicts of an ethnic, religious or regional nature
- Intensity of social conflicts (excluding conflicts relating to land)
- Intensity of conflicts connected with land-related issues
- Violence committed by the population against public officials (e.g. government, police, public transport, health personnel etc.)

<u>A108: Nomination of sub-national authorities</u>

- Are municipal authorities elected or appointed by the central authority across the country?
- Are the other sub-national authorities (e.g. Federal States in the case of Federations, regions, provinces etc.) elected or appointed by the central authority?

<u>A501: Coordination in the public sphere</u>

- Degree of coordination/collaboration between ministries and administrations

<u>A508: Obstacles to public action</u>

- Is the capacity of national public authorities hampered by political divisions, Pressure groups, external stakeholders and a lack of cooperation with neighbouring countrie

<u>B606: Share of land in public ownership</u>

<u>A306:Urban governance</u>

- Efficiency of planning and urban planning for major conglomerations and for Average-sized towns.

<u>A600: Security of property rights</u>

- Efficiency of the legal means to protect property rights in the event of conflict between private stakeholders?
- Generally speaking, does the State exercise arbitrary pressure on private property (red tape etc.)?
- Does the State pay compensation equal to the loss suffered in cases of expropriation (by law or fact) when the expropriation concerns land ownership or production means

[10] Zelli, F. (2011). The fragmentation of the global climate governance architecture.*Wiley Interdisciplinary Reviews: Climate Change*, *2*(2), 255-270.

Delta governance		Very Weak	Weak	Medium	Strong	Very Strong	Max score	Score Level (/ # Indicators)
Existence of adaptivity								
Meta level: norms and principles	1. Adaption and Innovation	0	1	2	3	4	8	4
	2. Uncertainty avoidance	0	1	2	3	4		
Macro level: rules and laws	3. Capacity for State reform	0	1	2	3	4	8	4
	4. Long-term vision	0	1	2	3	4		
Meso level: decision-making and collaboration	5. Capacity for sectoral reform	0	1	2	3	4	8	4
	6. Quality of the public policy making process	0	1	2	3	4		
Micro level: interactions	7. Spaces reflection major national issues	0	1	2	3	4	4	4
	8. Public support for innovation							
Existence of participation								
Meta level: norms and principles	9. Power distance	0	1	2	3	4	8	4
	10. Intentional tensions caused by neighbouring counties	0	1	2	3	4		
Macro level: rules and laws	11. Transparency of economic policy	0	1	2	3	4	4	4
Meso level: decision-making and collaboration	12. Governance of natural resources	0	1	2	3	4	4	4
Micro level: interactions	13. Participation of the population	0	1	2	3	4	4	4
Existence of fragmentation								
Meta level: norms and principles	14. Significance of the public sector delivery of public services	0	1	2	3	4	8	4
	15. Internal conflicts	0	1	2	3	4		
Macro level: rules and laws	16. Nomination of sub-national authorities	0	1	2	3	4	8	4
	17. Coordination in the public sphere	0	1	2	3	4		
Meso level: decision-making and collaboration	18. Obstacles to public action	0	1	2	3	4	8	4
	19. Share of land in public ownership	0	1	2	3	4		
Micro level: interactions	20. Urban governance	0	1	2	3	4	8	4
	21. Security of property rights	0	1	2	3	4		

Aggregated data set

Delta Name	Name Country	Classification	Indicator per Delta	DCU Weight	Adaptivity	Fragmentation	Participation	Totale Indicator	Weighted
Amazon	Brazil	3	6,7	1	2,24	2,18	2,28	6,7	6,70
Colorado	Mexico	5	4,98	1	1,45	1,79	1,74	4,98	4,98
Congo	Democratic Republic of the Congo	5	4,85	0,697021	1,18	1,46	1,83	4,47	3,12
Congo	Angola			0,302978	1,99	2	1,73	5,72	1,73
Danube	Romania	4	5,37	0,720956	1,83	1,8	1,63	5,26	3,79
Danube	Ukraine			0,279045	1,57	1,99	2,09	5,65	1,58
Ganges-Brahmaputra-Meghna	Bangladesh	4	5,53	0,66593	1,82	1,63	1,81	5,26	3,50
Ganges-Brahmaputra-Meghna	India			0,334069	2,26	1,56	2,24	6,06	2,02
Grijalva-Usumacinta	Mexico	5	4,98	1	1,45	1,79	1,74	4,98	4,98
Hong	Vietnam	3	6,21	1,000001	2,19	2,16	1,86	6,21	6,21
Indus	Pakistan	4	5,25	0,927746	1,8	1,42	1,97	5,19	4,82
Indus	India			0,072253	2,26	1,56	2,24	6,06	0,44
Irrawaddy	Burma	3	0,00	1	NO DATA	NO DATA	NO DATA	0	0,00
Limpopo	Mozambique	3	6,09	1	1,77	2,08	2,24	6,09	6,09
Mekong	Vietnam	3	6,13	0,889543	2,19	2,16	1,86	6,21	5,52
Mekong	Cambodia			0,110458	2,06	2,15	1,31	5,52	0,61
Mississippi	USA	2	7,96	1	2,86	2,47	2,63	7,96	7,96
Niger	Nigeria	4	5,31	1	1,68	1,82	1,81	5,31	5,31
Nile	Egypt	4	5,19	1	1,88	1,62	1,69	5,19	5,19
Orinoco	Venezuela	3	6,90	1	2,31	2,74	1,85	6,9	6,90
Parana	Argentina	3	6,16	1,000001	1,92	1,92	2,32	6,16	6,16
Rhine-Meuse	the Netherlands	1	8,37	0,993437	3,12	2,61	2,64	8,37	8,32
Rhine-Meuse	Germany			0,006426	3,3	2,6	2,49	8,39	0,05
Rhone	France	2	7,24	0,999999	2,19	2,58	2,47	7,24	7,24
Rio Grande	USA	3	6,65	0,561414	2,86	2,47	2,63	7,96	4,47
Rio Grande	Mexico			0,438584	1,45	1,79	1,74	4,98	2,18
Senegal	Senegal	4	5,75	0,677465	2,12	1,85	2,05	6,02	4,08
Senegal	Mauretania	4		0,322535	1,5	1,62	2,07	5,19	1,67
Shatt-al-Arab	Iraq	5	4,90	0,811771	1,21	1,95	1,61	4,77	3,87
Shatt-al-Arab	Iran			0,18823	1,55	2,19	1,73	5,47	1,03
Volga	Russia	4	5,57	0,968496	1,78	2,14	1,83	5,75	5,57
Volga	Kazachstan	4		0,031502	PM	PM	PM	0	0,00
Volta	Ghana	4	5,72	1	1,97	1,67	2,08	5,72	5,72
Wisla	Poland	2	7,11	1,000001	2,71	2,39	2,01	7,11	7,11
Yukon	USA	2	7,96	1	2,86	2,47	2,63	7,96	7,96
Zambezi	Mozambique	2	6,09	1,000002	1,77	2,08	2,24	6,09	6,09
								0	0,00

Classification	More then 8	1
	Between 7 and 8	2
	between 6 and 7	3
	Between 5 and 6	4
	Lower then 5	5

Computation of Delta Country Units (DCU) weights (related to the Delta Governance indicator)

To derive weighted delta results from national scores (of Governance indicators): national values assigned to DCUs should be weighted by the average of the proportion of land area and population in that DCU compared to the total basin.
In other words:

- DCU weight = Average((‘DCU land area’/’delta land area’),(‘DCU population’/’delta population’))
- The DCU weights should add up to 1 for the delta
- DCU weight x DCU score = DCU weighted score
- Add DCU weighted scores to obtain delta weighted score

The following table gives an overview of the DCU weights and data used for the computation

Delta country units					Deltas			
Delta	Area Km2 (A)	Country	Population (C)		Area Km2 (B)	Population (D)		DCU_weight Av((A/B);(C/D))
Amazon	50353	Brazil	361486		50353	361486		1,00
Colorado	4069	Mexico	187480		4069	187480		1,00
Congo	828	DR of Congo	43153		1655	48277		0,70
Congo	827	Angola	5124		1655	48277		0,30
Danube	3530	Romania	64416		4506	97837		0,72
Danube	975	Ukraine	33421,0		4506	97837		0,28
Ganges-B-M	54019	Bangladesh	64752908		77050	102656355		0,67
Ganges-B-M	23031	India	37903447		77050	102656355		0,33
Grijalva	7660	Mexico	345273		7660	345273		1,00
Hong	11874	Vietnam	17715720		11874	17715720		1,00
Indus	22651	Pakistan	3685079		26246	3713066		0,93
Indus	3595	India	27987		26246	3713066		0,07
Irrawaddy	30272	Burma	9397116		30272	9397116		1,00
Limpopo	880	Mozambique	215678		880	215678		1,00
Mekong	23079	Vietnam	13786135		25920	15512624		0,89
Mekong	2841	Cambodia	1726489		25920	15512624		0,11
Mississippi	28989	USA	1803749		28989	1803749		1,00
Niger	29458	Nigeria	8635666		29458	8635666		1,00
Nile	22858	Egypt	42381848		22858	42381848		1,00
Orinoco	28371	Venezuela	177690		28372	177690		1,00
Parana	19349	Argentina	806750		19349	806750		1,00
Rhine-Meuse	7151	the Netherlands	5534353		7222	5552466		0,99
Rhine-Meuse	69	Germany	18113		7222	5552466		0,01
Rhone	1638	France	104941		1638	104941		1,00
Rio Grande	5746	USA	961635		11190	1578188		0,56
Rio Grande	5444	Mexico	616553		11190	1578188		0,44
Senegal	1821	Senegal	122159		2991	163725		0,68
Senegal	1170	Mauretania	41566		2991	163725		0,32
Shatt-al-Arab	4683	Iraq	880989		5912	1059649		0,81
Shatt-al-Arab	1229	Iran	178660		5912	1059649		0,19
Volga	12149	Russia	286994		12900	288381		0,97
Volga	751	Kazachstan	1387		12900	288381		0,03
Volta	880	Ghana	148244		880	148244		1,00
Wisla	1626	Poland	437618		1626	437618		1,00
Yukon	20438	USA	1948		20438	1948		1,00
Zambezi	11106	Mozambique	339406		11106	339406		1,00

Annex 3 - Metadata sheet: Relative sea level rise indicator

Title:	Relative sea level rise indicator
Indicator Number:	18
Cluster:	Deltas
Rationale:	Many deltas are threatened by relative sea level rise (RSLR), which is basically determined by the balance between: (1) delta aggradation, (2) land subsidence and (3) sea-level rise.
Links :	Relevant to TWAP lakes (delta aggradation being affected by reservoirs), groundwater (land subsidence can be caused by over-abstraction from coastal aquifers), and LMEs and open ocean (sea-level rise).
Description:	The RSLR indicator is based on the total sinking rate of the delta surface relative to the local mean sea level in mm/year. This involves (1) delta aggradation, (2) land subsidence and (3) sea-level rise. (1) Delta aggradation is caused by fluvial sediment supply, but may be strongly influenced by human flood protection infrastructure inhibiting the distribution of sediments over the delta surface. (2) Land subsidence results from various processes, some of which are natural (e.g., tectonic and isostatic movements, sediment compaction), whereas others are highly human-influenced, being a result of drainage activities or subsurface mining. (3) Sea-level rise is a world-wide process, but nevertheless spatially variable because of varying gravimetric effects. The RSLR indicator is based on the total sinking rate of the delta surface (caused by the three components mentioned above) relative to the local mean sea level in mm/year.
Metrics:	
Computation:	For the TWAP assessment, aggradation, subsidence and sea level rise is assessed for each delta from published data (Syvitski et al 2009 and Ericson et al 2006). Based on the available quantitative data, each delta is assigned to one of five relative sea level rise (RSLR) categories, largely following Ericson (2006), with category 1 representing no RSLR (<= 0 mm/yr) and category 5 representing high RSLR (>5 mm/yr).
Units:	Dimensionless scale
Scoring system:	Point scale: 1 - 5
Limitations:	• In the RSLR assessment, it is not possible to separately quantify the various components of aggradation, land subsidence and regional sea level rise. • Intra-delta spatial variability, which in many cases is high, is not taken into account; the ranges provided cover either different times or different areas of a delta (Syvitski, 2009). Ericson states that the estimation of accelerated subsidence is problematic due to spatial and temporal variations based on the location and intensity of the human activities causing the acceleration (Ericson, 2006).

	• Ericson notes that, in the absence of reliable data, a factor of three times the natural subsidence rate is applied to define the upper limit of the potential accelerated subsidence based on the assumption that accelerated subsidence is a direct result of the magnitude of anthropogenic influence on delta sediment (Ericson, 2006). • Coastal erosion is not taken into account although it may be related to land subsidence.
Spatial Extent:	Delta (average value over total delta area); for 26 deltas
Spatial Resolution:	Depending on data source (i.e. SRTM and MODIS imagery, areal photographs, digitized historical maps, PSMSL data (global databank for long-term sea level change information)
Year of Publication:	2006 or 2009 References • Syvitsky, J.P.M., A.J. Kettner, I. Overeem, E.W.H. Hutton, M.T. Hannon, G.R. Brakenridge, J. Day, C. Vörösmarty, Y. Saito, L. Giosan & R.J. Nicholls, 2009, Sinking deltas due to human activities. Nature Geoscience 2, pp. 681-686. • Ericson, J.P., Vörösmarty, C.J., Dingman, S.L., Ward, L.G. & M. Meybeck, 2006, Effective sea-level rise and deltas: causes of change and human dimension implications. Global and Planetary Change 50, pp. 63-82. •
Time Period:	Depending on data source; up to 2003 (?) for Ericson, up to 2007 for Syvitski
Additional Notes:	
Date:	April 2014
Format:	
File Name:	
Contact person:	Delta-Alliance: Tom Bucx / Cees van de Guchte
Contact details:	tom.bucx@deltares.nl / cees.vandeguchte@deltares.nl

Annex 4 - Metadata sheet: Wetland ecological threat indicator

<table>
<tr><td>Title:</td><td>Wetland ecological threat indicator</td></tr>
<tr><td>Indicator Number:</td><td>19</td></tr>
<tr><td>Cluster:</td><td>Deltas</td></tr>
<tr><td>Rationale:</td><td>Wetlands are the most typical (characteristic / natural) ecosystems in deltas. Information on wetlands in deltas provides an indication of their biodiversity value and level of natural state. In principle all types of wetlands can be found in deltas, including typical coastal wetlands such as mangrove, estuary and lagoon as well as freshwater wetlands (bogs, fens, lakes, marshes).</td></tr>
<tr><td>Links :</td><td>The indicator may be important for LMEs – Large Marine Ecosystems;</td></tr>
<tr><td>Description:</td><td>The determination of the wetlands ecosystems indicator is based on three main factors:

• the share of wetland ecosystems within the delta;
• the ecological value determined by the presence of/in:
    o Biodiversity Hotspot(s)
    o Key Biodiversity Area(s) (KBA)
    o Ramsar site(s)
    o Global 200 region
    o Man and Biosphere Reserve (MAB-Resreve)
    o Formally protected area (IUCN Category 1 or 2);
• the environmental threat estimated based on the threats mentioned in the descriptions for:
    o Biodiversity Hotspot(s)
    o Global 200 region.
Occasionally, additional information can be gained from the site-descriptions (sheets) for similar Global 200 regions or site description form(s) for Ramsar site(s).
The indicators are further explained below. Note that not all are formally recognised statuses for deltas.

Description of the criteria

The ‘Share of wetland percentage of delta area’ is based on the Global Wetlands Data Base. This dataset shows the global distribution of wetlands. It was produced at UNEP-WCMC from various sources alongside the publication 'Wetlands in Danger", Dugan, P ed. (1993). http://www.unep-wcmc.org/global-wetlands-1993_719.html . This database has been updated by Lehner and Döll into the Global Lakes and Wetlands Database (GLWD- 3). It can be found at: http://www.wwfus.org/science/data.cfm (Center for Environmental Systems Research, University of Kassel, Germany AND World Wildlife Fund US, Washington, DC USA).

Biodiversity Hotspots (Myers et al., 2000) are regions of global conservation importance defined by the presence of high levels of threat (at least 70% habitat loss) in areas with high levels of species endemism (at least 1 500 endemic plant</td></tr>
</table>

species). These hotspots represent the broad-scale priority regions identified by Conservation International. The hotspots are currently terrestrially focused, but the process of identifying marine hotspots is under way. The hotspots are described at http://www.conservation.org/where/priority_areas/hotspots/Pages/hotspots_main.aspx and a map is found at: http://en.wikipedia.org/wiki/File:Biodiversity_Hotspots.svg.

The Global 200 are ecoregions with conservation priority, identified by WWF (Olson and Dinerstein, 1998). The list includes all types of habitats, not necessarily marine areas or deltas. A list of the ecoregions is found at: http://wwf.panda.org/about_our_earth/ecoregions/ecoregion_list/ and a map can be found at: http://assets.panda.org/img/original/ecoregions_map.jpg

In some cases, use is made from descriptions of KBAs, IBAs or Ramsar Sites.

Key Biodiversity Areas KBAs are sites identified as a conservation priority for a variety of species (not only birds but also mammals, plants, etc.) (Penny F. Langhammer et al., 2007). The selection is based on quantitative criteria used for BirdLife's Important Bird Areas (IBAs, see: http://www.birdlife.org/datazone/sitefactsheet.php?id=8060) or Important Plant Areas (IPAs). Sites are selected using standardized, globally applicable, threshold-based criteria, driven by the distribution and population of species that require site-level conservation. The criteria address two key issues for site conservation: vulnerability and irreplaceability. In some cases an indication is given of potential threats, mainly related to land use.

Ramsar sites resort under the Convention on Wetlands (Ramsar Convention), an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of their Wetlands of International Importance. The principle of "wise use", or sustainable use applies. Ramsar is not affiliated with the United Nations system of Multilateral Environmental Agreements. A map with Ramsar sites is found at: https://www.ibatforbusiness.org/map and also at: http://ramsar.wetlands.org/Database/SearchforRamsarsites/tabid/765/Default.aspx

MAB- Reserves are assigned to existing protected areas by UNESCO. These reserves are not covered by any one international convention and instead form part of the UNESCO Man and the Biosphere (MAB) Programme. The protected areas do not necessarily protect unique or important areas, and may exhibit a variety of objectives including research, monitoring, training and demonstration, as well as conservation. A characteristic is the sustainable use of the protected area, in which human presence and use of resources is promoted. A map and list of the MAB-sites is found at: http://www.unesco.org/mabdb/bios1-2.htm. In some cases areas are named as ‘biosphere reserve’, but not included in the UNESCO list, in those cases the list is misleading.

Protected area encompasses a number of protection categories, however, the most formal protection relevant for biodiversity is IUCN category 1-2. Category 1 is based on its importance for Science, in particular for areas of land and sea possessing outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or

	environmental monitoring, also wilderness protection for large, unmodified or slightly modified areas, with the aim of preserving their natural condition. Category 2 includes ecosystem protection and recreation, to protect the ecological integrity of the ecosystems and to exclude it from exploitation. A map of protected areas is at: https://www.ibatforbusiness.org/map . A further description of the conservation categories is found at: http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/
Metrics:	See above
Computation:	For the 'Share of Wetlands', the score 1-5 on the basis of the share of wetlands compared to the total delta area (in %) is given below the table of results. The GLWD- 3 distinguished 12 'wetland classes', which are all given equal weight in the calculation of the fraction of the delta classified as wetlands. In a few cases a correction was done for the share of wetlands, where it is known from the statistical data that they include mostly farming areas (e.g. rice paddies or other farming areas, as is the case for the Hong, Mekong, Senegal and Volta deltas). For the 'Ecological value' we combined the six criteria mentioned above. All these six criteria were simply scored with 1 (or 0.5 in the case that only for a small part of the area the criterion applied) and added together to determine the score for the ecological value. The 'Environmental threat' is based on an inventory of the threats per delta ecosystem. Some 27 threats are cross-tabulated; the information is based on the descriptions as available for the Biodiversity Hotspots and Global 200 areas (see above and meta data sheet). In few cases where no information is available for an area, information is used for adjoining rivers with additional information from the formal Ramsar site description sheets. The number of threats are scaled in a 1 - 5 points scale. Next, the Calculated average wetland ecological Value (CV) is determined as the average of the scores of the share of wetlands and the ecological value. This results in a value ranging from 0.75 – 4.50. Subsequently, the Wetland ecological threat indicator is calculated by multiplying the CV by the number of threats, which resulted in values ranging from 2 – 17.5. Finally, this value is re-scaled to a scale 1-5, to make it comparable with the results from the other assessments of the other indicators.
Units:	Point scale 1 to 5
Scoring system:	See above.
Limitations:	• The problem for some ecological indicators, like the presence of a Ramsar site or the protection status, is the fact that the assignment of a site on the official list is a function of political will rather than of ecological criteria alone. Therefore we combine different ecological indicators, which are partly also based on objective scientific criteria such as species biodiversity or ecosystem value. Aberrations will therefore be levelled out. • Depending on two databases is rather limited, and may result in biased results, particularly since the mentioned threats may not be exhaustive. • Only six deltas are located in a hotspot, some 10 in the Global 200 sites, and

	10 contain (one or more) Ramsar sites. For a larger number of deltas there is no information on threats. • The available data is better in the more developed countries, which may provide a slight bias e.g. in Europe. • The wetland percentage of deltas is an important indicator for the ecological value, but it is based on statistics and in some locations (such as the Mekong, Hong, Senegal and Volta Deltas), the delta is almost fully classified as wetlands according to the global lake and wetland database, while it is known that large proportions of these deltas are used as agricultural area. Some correction of the wetland share and the combination of this indicator with the ecological indicator leads to a balanced result. • The environmental threats are based on descriptions of deltas, rivers, and regions which differ in scale, author, and ecosystem. The purpose of the descriptions differed as well as the year of description. This makes the source data rather diverse, and therefore the threats are difficult to compare for each delta. A more extensive review of all threats would be required for each delta to ensure that the descriptions are more homogeneous and comparable.
Spatial Extent:	26 deltas
Spatial Resolution:	Not applicable
Year of Publication:	References Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. 403, 853-858. Olson, D.M., Dinerstein, E., 1998. The Global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions. Conservation Biology 12, 502-515. Penny F. Langhammer, Mohamed I. Bakarr, Leon A. Bennun, Thomas M. Brooks, Rob P. Clay, Will Darwall, Naamal De Silva, Graham J. Edgar, Güven Eken, Lincoln D.C. Fishpool, Gustavo A.B. da Fonseca, Matthew N. Foster, David H. Knox, Paul Matiku, Elizabeth A. Radford, Ana S.L. Rodrigues, Paul Salaman, Sechrest, W., Tordoff, A.W., 2007. Identification and gap analysis of key biodiversity areas: targets for comprehensive protected area systems. IUCN, Gland, Switzerland. See also references to internet sites 'Description'
Time Period: Additional Notes:	
Date:	20 June 2014
Format:	
File Name:	Metadata sheet Wetland ecosystem indicator
Contact person:	Wim van Driel
Contact details:	Wim.vandriel@wur.nl

Annex 5 - Metadata sheet: Population pressure indicator

Title:	Population pressure Indicator
Indicator Number:	20
Cluster:	Deltas
Rationale:	High population pressure poses challenging demands on delta resources, such as demands for freshwater, fertile soils, space and ecosystem regulation functions.
Links :	The indicator can be important for Groundwater
Description:	Population pressure index is a relative measure on a scale of 1 to 5 based on the average number of people per square km.
Metrics:	See below
Computation:	CIESIN (Center for International Earth Science Information Network) holds global data sets on population (http://sedac.ciesin.columbia.edu/data/collection/gpw-v3) The Gridded Population of the World (GPWv3) depicts the distribution of human population across the globe. This is a gridded, or raster, data product that renders global population data at the scale and extent required to demonstrate the spatial relationship of human populations and the environment across the globe. The data contains a projection of the amount of people living in each 2.5 arcseconds gridcell in the year 2010, based on census data of the year 2000 with an extrapolation. These data are combined with the defined extent of the deltas to calculate the average population density per delta. First, the population in all 2.5 arcsecond cells that have their centroids within the polygons of the deltas are summed. Subsequently an average population density is calculated using the area of the delta.
Units:	The average number of people per square km is translated into a 5 point scale from very low to very high.
Scoring system:	See above
Limitations:	• The population pressure index quantifies the average population density in the delta. There is however no information on heterogeneity within the delta. It could however make a difference whether people are living together in some very dense cities, or are more or less spread over the total area. • Similarly, the elevations where people live are not taken into account • The vulnerability is to a large extent also dependent on the quality of housing, which is very much dependent on the income of the populations, which is not taken into account in this indicator

Spatial Extent:	26 deltas
Spatial Resolution: Year of Publication:	
Time Period:	2010
Additional Notes:	
Date:	24 June 2014
Format:	
File Name:	Metadata sheet Population Pressure Indicator
Contact person:	Wim van Driel
Contact details:	Wim.vandriel@wur.nl

Annex 6 - Metadata Sheet: Delta governance indicator

Title:	Delta Governance Indicator
Indicator Number:	21
Cluster:	Deltas / Delta Vulnerability Index
Rationale:	In addition to governance issues in river basins, the Delta Governance Indicator signifies how the different countries score on governance of the delta. Therefore three key principles will be used: adaptivity, participation and fragmentation. The reason for those key principles lies with the definition of Governance. Adaptivity is how a contemporary state adapts to its economic and political environment with respect to how it operates. Participation focuses on transparency, accountability and participation (TAP) and can be used to analyse institutional performance as well as how stakeholders behave and relate to each other. Finally fragmentation is also said to be a necessary and to some extent unavoidable structural characteristic and quality of global governance[11] architectures in and beyond the environmental domain. It creates opportunities for further development of environmental policies through policy innovation, consensus building and negotiations.
Links :	*Governance of the delta may be relevant to LMEs and coastal aquifers.*
Description:	The Delta Governance Indicator measures how the different countries score on governance of the Delta
Metrics:	The Institutional Profiles Database (IPD) provides an original measure of the institutional characteristics of countries through composite indicators from perception data. The database was designed in order to facilitate and stimulate research on the relationship between institutions, long-term economic growth and development. - The 2012 edition of the database follows on from the 2001, 2006 and 2009 editions. - It covers 143 countries and contains 130 indicators. - The edition of the IPD is a result of a collaboration between the French Development Agency (AFD) and the Directorate General of the Treasury (DG Tresor). The perception data needed to build the indicators were gathered through a survey completed by country/regional Economic Services of the Ministry for Economy and Finance and the country AFD offices. The Centre for Prospective Studies and International Informative (CEPII) and the University of Maastricht are partners in this project.
Computation:	Each indicator is based on different sub-indicators. Each sub-indicator has the same factor, which means that all the sub-indicators combined and divided by

[11] Isailovic, M., O. Widerberg,. P. Pattberg. (2013). Fragmentation of Global Environmental Governance Architectures. IVM Institute for Environmental Studies. Amsterdam

	the total sub-indicators. All the countries that lie in the same delta are also combined and divided by two. It is important to stress here that the DCU factor is used for combining the countries.
Units:	*Score 1-5 Very weak – Very strong*
Risk categorization	*Should describe how and why the indicator scores are assigned to 1 of 5 risk categories. Should include table with proportion and number of basins and BCUs in each risk category.*
Limitations:	▪ *Including issues which may not be covered by the indicator, as well as any cautionary notes in interpreting the results.* ▪ *They may also be seen as 'challenges' which still need to be addressed.*
Year of Publication:	*2013.*
Time Period:	*The 2012 edition of the database follows on from the 2001, 2006 and 2009 editions.*
Date:	*13/08/2015*
Format:	*Microsoft Excel*
File Name:	
Contact person:	*Gerald Jan Ellen / Cees van de Guchte (Deltares)*
Contact details:	geraldjan.ellen@deltares.nl