3.7 Delta Vulnerability Index (Delta Alliance)

Short description of rationale of the indicator (3-5 sentences)
Delta vulnerability is a function of physical (fluvial) pressures, (local) state conditions and response capacities (governance).

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 pressure and sea level rise.

Computation of results (max half a page)
The overall Delta vulnerability index is a semi-quantitative index on a 5 point scale, based on five indicators which also use the 5 point scale. All scores are summed and divided by 5.
Dimensionless scale 1 to 5 (not vulnerable to highly vulnerable)
Using the scores (1 to 5) of five indicators (see details in paragraphs below):

- Delta drowning risk
- Salinization
- Wetland ecosystems
- Population pressure
- Delta governance

Limitations of analysis to date and expected improvements (max half a page)
The scoring is semi-quantitative. In case of specific situations one or more indicators with an extreme importance could also get another weight in the total score. Also during the process the assessment team might come to other insights to adapt the scoring.

Visualisation of preliminary results (map, table/diagram, max 2 pages)
To be added

➔ Map to be added

	Classification
America	
Amazon	
Colorado	
Grijalva	
Mississippi	
Orinoco	
Parana (La Plata)	
Rio Grande	
Yukon	

Europe	
Danube	
Rhine-Meuse	
Rhone	
Volga	
Wisla	
Asia	
Ganges-Brahmaputra-Meghna	
Hong (Red)	
Indus	
Irrawaddy	
Mekong	
Shatt-al-Arab	
Africa	
Congo	
Limpopo	
Niger	
Nile	
Senegal	
Volta	
Zambezi	

Contents of analysis
To be added

3.7.1 Delta drowning risk

Short description of rationale of the indicator (3-5 sentences)
Many deltas are threatened by drowning, which basically is determined by the balance between: (1) delta aggradation, (2) land subsidence and (3) sea-level rise. 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. 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. Sea-level rise is a world-wide process, but nevertheless spatially variable because of varying gravimetric effects. The drowning risk 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.

Computation of results (max half a page)
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 drowning risk categories, largely following Ericson (2006), with category 1 representing no drowning risk (<= 0 mm/yr) and category 5 representing high risk (>5 mm/yr).

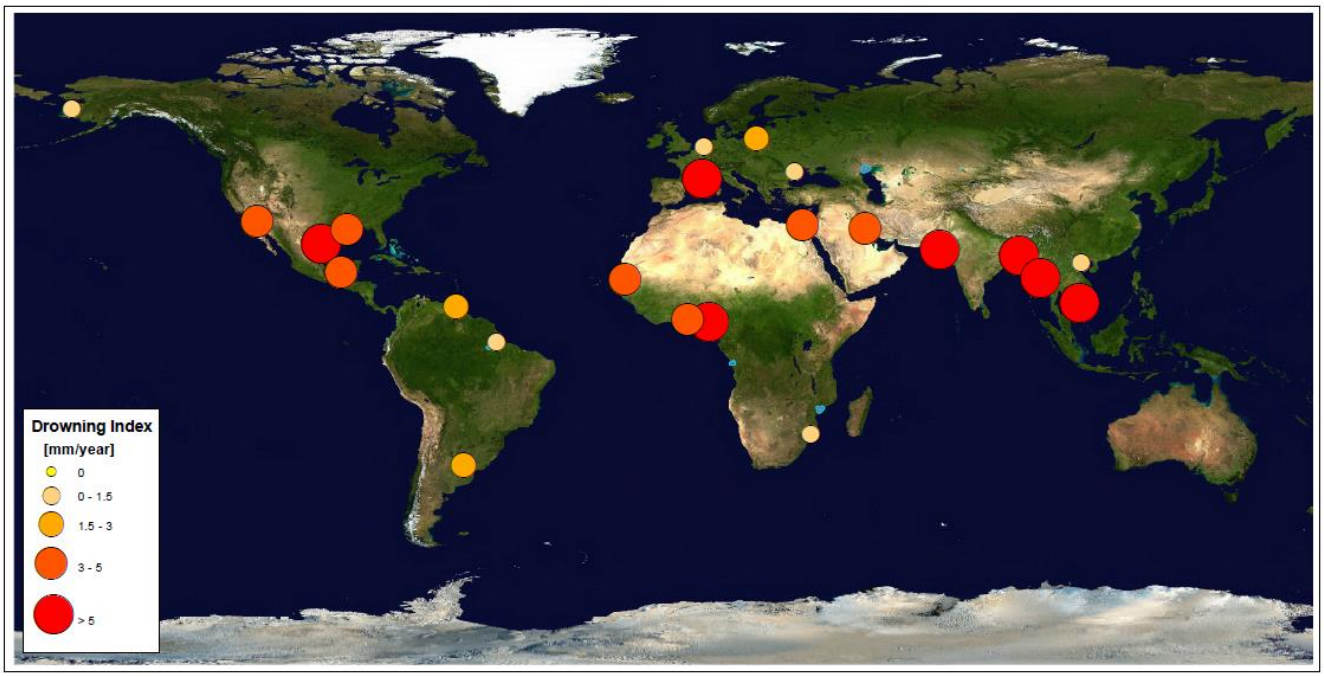
References

- 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.

Limitations of analysis to date and expected improvements (max half a page)

- In the delta drowning risk 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; 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.

Visualisation of preliminary results



	Classification	RSL (mm/yr)	Source
America			
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			
Wisla	3	1.8	Syvitski
Asia			
Ganges-Brahmaputra-Meghna	5	8 - 18	Syvitski
Hong (Red)	2	0 - 1.5	Ericson
Indus	5	> 11	Syvitski
Irrawaddy	5	3.4 - 6	Syvitski
Mekong	5	6	Syvitski
Shatt-al-Arab	4	4 - 5	Syvitski
Africa			
Congo			
Limpopo	2	0.3	Syvitski
Niger	5	7 - 32	Syvitski
Nile	4	4.8	Syvitski
Senegal	4	3 - 5	Ericson
Volta	4	3 - 5	Ericson
Zambezi			

RSL (Mm/yr)	Classification category
<=0	**1**
>0 - 1.5	**2**
1.5 - 3	**3**
3 - 5	**4**
> 5	**5**

Contents of analysis

- From the transboundary deltas assessed the most at highest risk are in Asia (Ganges, Indus, Irrawaddy and Mekong). In Africa and America also a considerable number of deltas are at (high) risk, especially the Niger and Rio Grande. Europe has the least transboundary deltas with only the Rhone at high risk.
- One of the important factors for the 'delta drowning risk' is increasing population in delta (mega) cities, especially in Asia. This results often in less delta aggregation and increased human induced (accelerated) land subsidence caused by severe ground water extraction in order to comply with high(er) water demand.

3.7.2 Salinization

Short description of rationale of the indicator (3-5 sentences)

Seawater intrusion into the lower reaches of a river (delta) affects the use of the river's water for domestic, agricultural and industrial use. The salinization indicator is based on the distance of salt intrusion from the river mouth into the river, as calculated in DIVA.

Computation of results (max half a page)

The DIVA model including the related global database is used to calculate the seawater intrusion. This in done in the so-called 'River effect module', applying the approach developed by Schijf and Schönfeld (1953) in order to estimate the length of the stationary saltwater wedge, which is a reasonable value for the distance of seawater intrusion. "Stationary" means that the river flow and sea level are fixed (i.e., assuming no tide). The salinization indicator is based on the ratio between the length of the saltwater wedge and the apex of the delta, with category 1 representing low salt intrusion and category 5 representing high salt intrusion up to the apex of the delta.

With the DIVA module it is also possible to calculate additional impacts:
- The (increase of the) impact length for four coastal storm surge levels, and the salinity intrusion length under different scenarios of sea-level rise. The former represents the extent to which a temporary rise in sea level during storm conditions is noticeable upstream, while the latter represents the length of the saltwater wedge gradually "crawling" upstream over the river bottom.
- The land area influenced by the salinity intrusion length. This area has the shape of an isosceles triangle, with the coastline representing the base and the salinity intrusion length determining the height of this triangle. The user can specify the vertex angle to set the width of the triangle.

References

- Hinkel J, Klein RJT, 2005. DINAS-COAST: developing a method and a tool for dynamic and interactive vulnerability assessment DIVA CD http://www.globalclimateforum.org/index.php?id=divamodel
- Schijf, J.B. and J.C. Schönfeld, 1953: Theoretical considerations on the motion of salt and fresh water. In: Proceedings of the Minnesota International Hydraulics Convention. Joint meeting of the International Association for Hydraulic Research and the Hydraulics Division of the American Society of Civil Engineers, Minnesota, 1–4 September 1953, St. Anthony Falls Hydraulic Laboratory, pp. 321–333.

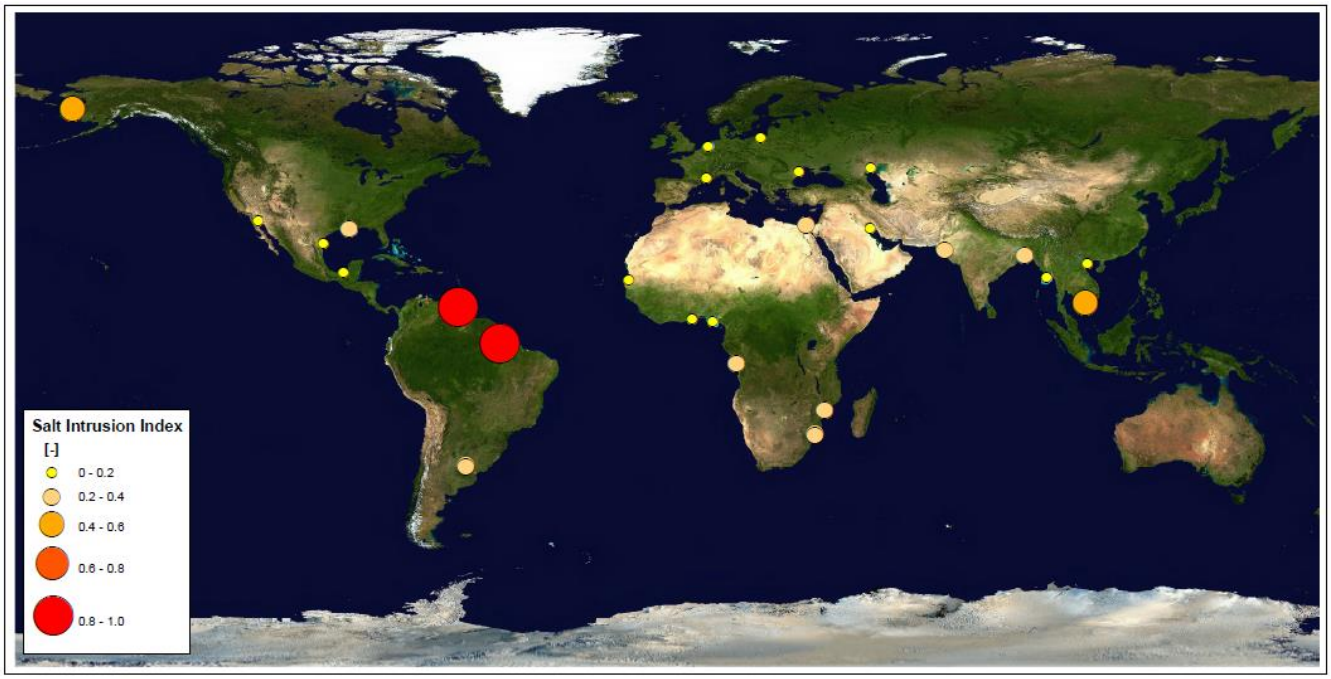
Limitations of analysis to date and expected improvements

- The formula of Schijf and Schönfeld (1953) is derived for a steady state situation, so river discharge variations, tidal effects and storm effects are not included. This results in a too low salt intrusion length for rivers with relatively strong tidal influence (e.g. Rhine-Meuse). Due to the seasonal discharges and tidal effect, salt water intrusion in the dry season and/or at high tide can be tens of kilometers further inland than in the wet season and/or at low tide.
- In the River effect module of DIVA the (upstream) river flow velocity is estimated using river depth, slope and a rather low Chézy coefficient. This results in a rather low velocity, which in turn results in an estimated salt intrusion length which is considered too high for the Amazon,

Brahmaputra, Ganges, Orinoco, Parana, Yukon (i.e. the rivers with very small slopes and relatively large depths)

- The calculation is done for the reference situation in the year 2000 without taking into account storm surge or sea level rise scenario

Visualisation of preliminary results



	Classification	Salinization rate	Salt intrusion length (km)	Delta mouth to appex distance (km)
America				
Amazon	5	1	863	450
Colorado	1	0,00	0	130
Grijalva	1	0,00	??	95
Mississippi	2	0,27	109	400
Orinoco	5	1	264	235
Parana (La Plata)	2	0,33	127	390
Rio Grande	1	0,00	0	160
Yukon	3	0,47	165	350
Europe				
Danube	1	0,05	7	150
Rhine-Meuse	1	0,07	17	230
Rhone	1	0,05	4	80
Volga	1	0,00	??	200
Wisla	1	0,00	??	88

Asia				
Ganges-Brahmaputra-Meghna	2	0,26	118	460
Hong (Red)	1	0,07	13	190
Indus	2	0,20	43	220
Irrawaddy	1	0,16	42	260
Mekong	3	0,47	142	300
Shatt-al-Arab	1	0,11	15	140
Africa				
Congo		0,21	19	90
Limpopo	2	0,26	17	65
Niger	1	0,12	27	225
Nile	2	0,23	51	225
Senegal	1	0,14	14	100
Volta	1	0,17	6	35
Zambezi	2	0,21	30	145

N.B. The yellow marked values can not be correct because the calculated salt intrusion length is unlikely high (for explanation see remarks above regarding the limitations of analysis)

Salinization rate	Classification category
0 – 0.2	**1**
0.2 – 0.4	**2**
0.4 – 0.6	**3**
0.6 – 0.8	**4**
0.8 – 1.0	**5**

Contents of analysis
To be added

3.7.3 Wetland ecosystems

Short description of rationale of the indicator (3-5 sentences)
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).

The existence of Ramsar sites of International Importance provides an indication of the biodiversity value in addition to the area (or percentage) of wetlands in a delta.

Relative amount of natural delta ecosystems.

Computation of results (max half a page)

The 'wetland percentage of delta area' will be based on the Global wetlands database. 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).

Description of GLWD-3 data set:
File name: glwd_3 (folders 'glwd_3' and 'info', legend 'glwd_3.avl')
File size: 26.9 MB (8.4 MB zipped)
File format: Grid in ArcView/ArcInfo coverage format
Data format: integer values, for coding see legend below
Spatial resolution: 30 x 30 second
Projection: Geographic, degrees longitude and latitude
Spatial domain: Global land area (except Antarctica and glaciated Greenland)
The existence of Ramsar sites will be based on the Ramsar list of wetlands of international importance. The basic Ramsar List records the name of each of these "Ramsar Sites", its date of designation, geographical position in-country, surface area, and centre-point coordinates, and it is available in Word and PDF formats.

References

- Dugan, P ed. (1993). 'Wetlands in Danger", http://www.unep-wcmc.org/global-wetlands-1993_719.html
- Lehner and Döll. Global Lakes and Wetlands Database (GLWD- 3) http://www.wwfus.org/science/data.cfm

Limitations of analysis to date and expected improvements (max half a page)

The problem of the Ramsar site as indicator 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 propose to use the wetland percentage of delta as major indicator and the existence of a Ramsar site as an additional indicator.

Visualisation of preliminary results (map, table/diagram, max 2 pages)

To be added

➔ Map to be added

	Classification	Value	Source
America			
Amazon			
Colorado			
Grijalva			
Mississippi			
Orinoco			
Parana (La Plata)			
Rio Grande			
Yukon			

Europe			
Danube			
Rhine-Meuse			
Rhone			
Volga			
Wisla			
Asia			
Ganges-Brahmaputra-Meghna			
Hong (Red)			
Indus			
Irrawaddy			
Mekong			
Shatt-al-Arab			
Africa			
Congo			
Limpopo			
Niger			
Nile			
Senegal			
Volta			
Zambezi			

Value	Classification category
	1
	2
	3
	4
	5

Contents of analysis
To be added

3.7.4 Population pressure

Short description of rationale of the indicator (3-5 sentences)
High population pressure poses challenging demands on delta resources, such as freshwater, fertile soils, space and ecosystem regulation functions.

Population pressure index is a relative measure on a scale of one 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. 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.

These data will be combined with geographically defined delta areas to arrive an average population density per delta. Five classes of density will be determined.

Dimensionless scale of 1 to 5 (low to very high population pressure)

Reference

http://sedac.ciesin.columbia.edu/data/collection/gpw-v3

Limitations of analysis to date and expected improvements (max half a page)

…..

To be added

Visualisation of preliminary results (map, table/diagram, max 2 pages)

To be added

➔ Map to be added

	Classification	Value	Source
America			
Amazon			
Colorado			
Grijalva			
Mississippi			
Orinoco			
Parana (La Plata)			
Rio Grande			
Yukon			
Europe			
Danube			
Rhine-Meuse			
Rhone			
Volga			
Wisla			
Asia			
Ganges-Brahmaputra-Meghna			
Hong (Red)			
Indus			
Irrawaddy			

Mekong			
Shatt-al-Arab			
Africa			
Congo			
Limpopo			
Niger			
Nile			
Senegal			
Volta			
Zambezi			

Value	Classification category
	1
	2
	3
	4
	5

Contents of analysis
To be added

3.7.5 Delta governance

Short description of rationale of the indicator (3-5 sentences)
In addition to governance issues in river basins, the Delta Governance Indicator signifies the level to which governments and stakeholders have understood, identified and operationalised the need for specific institutional arrangements for the delta as complex socio-ecological system. The Delta Governance Index identifies the level of existence of governance arrangements and institutions for deltas on a scale from 1 (practically no governance institutions) to 5 (governance institutions fully implemented). Note that this does not indicate if governance itself is functioning as intended.

Computation of results (max half a page)
The Delta Governance indicator is a semi-quantitative rating on a scale from 1 (practically no governance institutions) to 5 (governance institutions fully implemented). The rating is based on the responses to a questionnaire containing questions on the existence of institutional arrangements (committees, agencies, institutions, programmes etc.) and products (integrated (delta) plans, adaptive strategies and disaster management plans).

	Not relevant	Under development	Developed but implementation not yet started	Implementation started	Implementation advanced	Fully implemented			
Existence of institutional arrangements for delta issues:									
							Max score	weight	Max weighted score
Delta or coastal zone management policy	0	1	2	3	4	5	5	3	15
Adaptive strategies for future climate change	0	1	2	3	4	5	5	2	10
Disaster Management Plan / program /policy	0	1	2	3	4	5	5	2	10
Knowledge Institute for Delta Management	0	1	2	3	4	5	5	2	10
Delta (Planning) Committee / agency	0	1	2	3	4	5	5	4	20
Education program or institute on deltas	0	1	2	3	4	5	5	2	10
Civil organization(s) on delta wide issues	0	1	2	3	4	5	5	3	15
							35		90

Ranking of weighted final score:

Score	**Indicator**	**description**
0 – 20	1	Practically no governance institutions
21 – 40	2	Few institutions present
41 – 60	3	Several institutions present
61 – 80	4	Many institutions present
80 – 90	5	Governance institutions fully implemented

Limitations of analysis to date and expected improvements (max half a page)
Not sure how much response we get from the questionnaire.

Visualisation of preliminary results (map, table/diagram, max 2 pages)

➔ Map to be added

	Classification	**Score**	**Source**
America			
Amazon			
Colorado			
Grijalva			

Mississippi			
Orinoco			
Parana (La Plata)			
Rio Grande			
Yukon			
Europe			
Danube			
Rhine-Meuse			
Rhone			
Volga			
Wisla			
Asia			
Ganges-Brahmaputra-Meghna			
Hong (Red)			
Indus			
Irrawaddy			
Mekong			
Shatt-al-Arab			
Africa			
Congo			
Limpopo			
Niger			
Nile			
Senegal			
Volta			
Zambezi			

Value	Classification category
	1
	2
	3
	4
	5

Contents of analysis
To be added

Computation of results (max half a page)
To be added