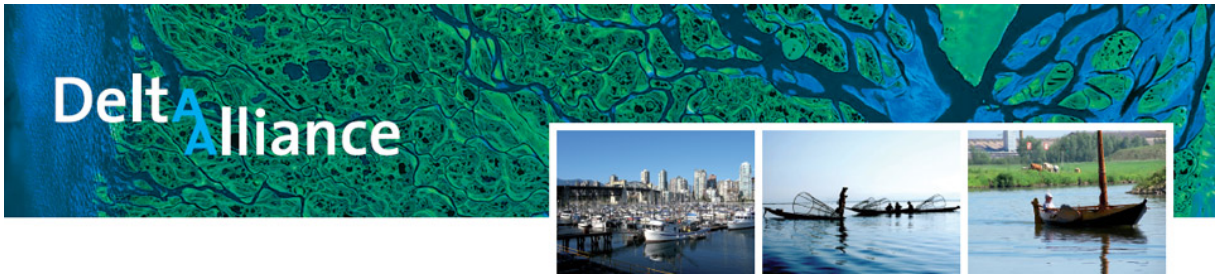

Transboundary Water Assessment Program

Deltas At Risk – proposal

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Introduction

The GEF (Global Environmental Facility) 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 is felt that deltas need special attention in the TWAP river basin assessment.

Delta Alliance recently has assessed the vulnerability and resilience of ten deltas based on a large number of indicators for physical-ecological, infrastructural, land use and governance characteristics (Bucx et al. 2010). Parts of the methodology developed for this assessment could be applied to deltas in the river basin assessment.

Evaluating the delta component in river basins to be analysed in the TWAP requires:

1. definition of deltas
2. identification of the deltas;
3. selection of the most relevant deltas;
4. development of suitable vulnerability indicators;
5. development of an overall delta vulnerability index.

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 propose 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.

Identification of deltas

The delta definition given above permits identification and delineation of deltas by geomorphological interpretation of remote sensing images. In most cases, deltas can be readily identified on Google Earth or other freely available satellite images. High resolution DEM data, and geological, geomorphological or soil maps may of course provide useful additional data for accurately determining delta boundaries, but are not essential for identification and crude delineation. 75 major deltas in the world and their physical characteristics are included in the World Delta Database (WDD, Louisiana State University: www.geol.lsu.edu/WDD). We will use this as base for delta identification in the TWAP river basin assessment and with the geomorphological delta definition in mind we will screen all 270 TWAP river basins for significant deltas.

Selection of deltas

In a next step we will select from this extensive delta database the 40 most important deltas based on the following criteria:

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

Probably the selected deltas will (largely) include deltas that are already present in de WDD, but our remote sensing survey guarantees that no important deltas will be missed.

Development of a suitable vulnerability indicators

Important threats to deltas as a human living environment are: subsidence/relative sea-level rise, increased intensity of extreme (hydro)meteorological events, inadequate (flood defense) infrastructure, coastal erosion, loss/degradation of ecosystems, salinisation, lack of governance an population pressure. These threats may be partially interrelated.

The idea is to develop an overall delta vulnerability index based on a small of vulnerability (sub-) indicators based on these threats. The following five indicators have been selected to compose the delta vulnerability index:

1. delta drowning risk indicator
2. wetland ecosystems indicator
3. salinization indicator
4. delta governance indicator
5. population pressure indicator

The Rationale, Definition, Units, Metrics, Computation, References and Limitations for each of the indicators are described in the same Indicator Description Sheet Templates as being used for the

transboundary water assessments. For all indicators a dimensionless scale of 1 (low vulnerability/pressure) to 5 (high vulnerability/pressure) will be used.

Development of an overall delta vulnerability index

An overall delta vulnerability index, is a semi-quantitative index on a 5 point scale based on the score of the five abovementioned vulnerability indicators. In principle all scores of the five indicators are summed ad divided by five. In case of specific situations one or more indicators with an extreme importance could get another weight in the total score. Also during the process the assessment team might come to other insights to adapt the scoring.

Literature

Bucx, T., Marchand, M., Makaske, B. & C. van de Guchte (2010) Comparative assessment of the vulnerability and resilience of 10 deltas; synthesis report. Delta Alliance report 1, Delta Alliance International, Delft/Wageningen, 100 p.

Description of the overall 'Delta Vulnerability Index'

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 pressure and sea level rise.

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

Units
Dimensionless scale 1 to 5 (not vulnerable to highly vulnerable)

Metrics
Using the scores (1 to 5) of five indicators (see details in sheets attached):

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

Computation
The overall Delta vulnerability index is a semi-quantitative index on a 5 point scale, based on the five variables which also use the 5 point scale. All scores are summed and divided by 5.

Reference
The same kind of scoring procedure has been applied in the Delta Alliance 'Comparative assessment of the vulnerability and resilience of 10 deltas' (Bucx et al, 2010).

Limitations
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.

Description of the indicator 'Delta drowning risk'

Rationale
Many deltas are threatened by drowning, which basically is determined by the balance between: (1) delta aggradation, (2) land-level lowering 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-level lowering results from various processes, some of which are natural (e.g., tectonic and isostatic movements, deep sediment compaction), whereas others may be 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.

Definition
Relative sinking rate of the delta surface.

Units
Mm/yr →score 1 to 5

Metrics
Delta aggradation rate
Land-level lowering rate
Relative sea level change

Computation
For the TWAP assessment aggradation, land-level lowering and sea level rise need to be assessed for each delta from published data. Preferably direct measurements of these variables will be used, but if not available model projections as well as data on sediment supply, human infrastructure, and mining activities may be useful for the drowning risk assessment. Based, as much as possible, on quantitative data, each delta will be assigned to one of five drowning risk categories, largely following Syvitsky et al. (2009), with category 1 representing great risk and category 5 representing no risk. An additional process that requires attention is coastal erosion that, apart from land-level lowering, may be a serious threat. Coastal erosion may be related to land-level lowering but may also be an independent process. Therefore, data on coastal erosion will be separately taken into account in the delta risk assessment.

Reference
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.

Limitations
In the delta drowning risk assessment, it will not be possible to separately quantify the various components of aggradation and land-level lowering, although where possible a crude estimate of the amount of human influence will be made. Intra-delta spatial variability, which in many cases is high, cannot be fully taken into account.

Description of indicator 'Wetland ecosystems'

Rationale
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.

Definition
Relative amount of natural delta ecosystems.

Units
Score 1 to 5

Metrics
- Wetland percentage of delta area (%).
- Existence of one or more Ramsar sites in delta (yes/no).

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.

Computation

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)
File contents: Grid cells are coded as following:
Cell value Lake or Wetland Type
1 Lake
2 Reservoir
3 River
4 Freshwater Marsh, Floodplain
5 Swamp Forest, Flooded Forest
6 Coastal Wetland (incl. Mangrove, Estuary, Delta, Lagoon)

7 Pan, Brackish/Saline Wetland
8 Bog, Fen, Mire (Peatland)
9 Intermittent Wetland/Lake
10 50-100% Wetland
11 25-50% Wetland
12 Wetland Complex (0-25% Wetland)

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.

Reference

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

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

Description of the indicator 'Salinisation'

Rationale
Seawater intrusion into the lower reaches of a river (delta) affects the use of the river's water for domestic, agricultural and industrial use

Definition
Distance of salt intrusion from the river mouth into the river

Units
Kilometers → score 1 to 5

Metrics
Relative sea level change
Bottom depth at the river mouth
River bottom slope

The DIVA model (River effect module) and related global database(s) (WDD) will be used which contains a set of variables of the major world rivers.

Computation
The approach developed by Schijf and Schönfeld (1953) is used 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).

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
Tidal effects are not included. For rivers at a tidal coast, seawater intrusion fluctuates in phase with the tide. At high tide (particularly at spring tide) intrusion can be tens of kilometers further inland than at low tide.

Description of the indicator 'Delta Governance'

Rationale
Delta problems require specific governance. 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.

Definition
The Delta Governance Index identifies the level of functioning of governance arrangements for deltas.

Units
Dimensionless scale 1 to 5 (No governance to well-functioning governance)

Metrics
Existence of integrated (delta) plans, adaptive strategies and disaster management plans.
Existence of integrating committees / agencies / institutions for delta management

Computation
Based on qualitative information obtained via questionnaire.

Reference
Bucx, T., M. Marchand, A. Makaske, C. van de Guchte, 2010: Comparative assessment of the vulnerability and resilience of 10 deltas – synthesis report. Delta Alliance report number 1. Delta Alliance International, Delft-Wageningen, The Netherlands

Limitations
There is also an important cultural dimension towards the assessment of governance issues.

Description of the indicator 'Population pressure'

Rationale
High population pressure poses challenging demands on delta resources, such as freshwater, fertile soils, space and ecosystem regulation functions.

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

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

Metrics
Population numbers
Delta area

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.

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

Limitations