DECCMA

Working Paper

Transformational adaptation: A review of examples from 4 deltas to inform the design of DECCMA's Adaptation Policy Trajectories

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About DECCMA Working Papers

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Titles in this series are intended to share initial findings and lessons from research studies commissioned by the program. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the DECCMA project, they have not undergone an external review process. Opinions stated are those of the author(s) and do not necessarily reflect the policies or opinions of IDRC, DFID, or partners. Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

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Introduction

This document outlines examples of transformational adaptation from four deltas: the Mekong, Mississippi, Rhine-Meuse and Yangtze. The intention was to find examples of transformational adaptation that can be used to inform the design of adaptation policy trajectories for use in the DECCMA Integrated Assessment Model. There will be four adaptation policy trajectories – minimum intervention, economic capacity expansion, system efficiency enhancement, and system restructuring. Whilst DECCMA has empirical examples of the first three from the results of a 6000 household survey across three deltas in Bangladesh, Ghana and India, there are few examples that fit system restructuring. In order to populate this pathway, examples of transformational adaptation from four other deltas are outlined here. More information on the adaptation policy trajectories is found in another DECCMA working paper (Suckall et al, 2017).

Transformational adaptation

There are various definitions of transformational adaptation. It is frequently contrasted with incremental adaptation and is characterised by three components (Lonsdale et al, 2015):

- system-wide change or changes across more than one systems;
- a focus on the future and long-term change;
- direct questioning of the effectiveness of existing systems, social injustices and power imbalances.

Transformational adaptation is still very vague and defined in different ways, with different scales, sectoral scopes, and intended (or desired) outcomes (Mustelin and Handmer, 2013). As O'Brien notes (2012) it means "*different things to different people or groups, and it is not always clear what exactly needs to be transformed and why, whose interest these transformations serve, and what will be the consequences*" (p670).

One of the most fundamental differences with regards to transformational adaptation is whether it is viewed as a broader difference from the norm compared to incremental adaptation (figure 1), or whether it requires a paradigm shift or step change (Klein et al, 2014). Either way, it is defined as relative to an existing state, and that existing state varies from delta to delta, so there is a need for geographical differences. There are also debates over whether adaptation leads to the transformation, or whether a societal transformation is the adaptation (Tschakert et al, 2013). For this reason ASSAR use the term transformative adaptation (as adaptation that generates transformation), which they contrast with transformational adaptation (where adaptation is the transformation)(Few et al, 2016).

The concept of "adaptation turning points" has been developed with regard to the Rhine. These are defined as a situation where a socio-political threshold is reached, due to climate change induced changes in the biophysical system (Werners, 2012). This was used in the Bottom-up Climate Adaptation Strategies Towards a Sustainable Europe (BASE) project[1]. This can highlight thresholds for activities – for example there is a significant risk of failure of salmon reintroduction on the Rhine because of projected increases in water temperatures in changing climate (Bölscher et al, 2013). I don't think we wish to go into this level of detail but, where it exists, it would illuminate the difference between system efficiency and transformation (as well as highlighting potential for maladaptation).

[1]http://base-adaptation.eu/

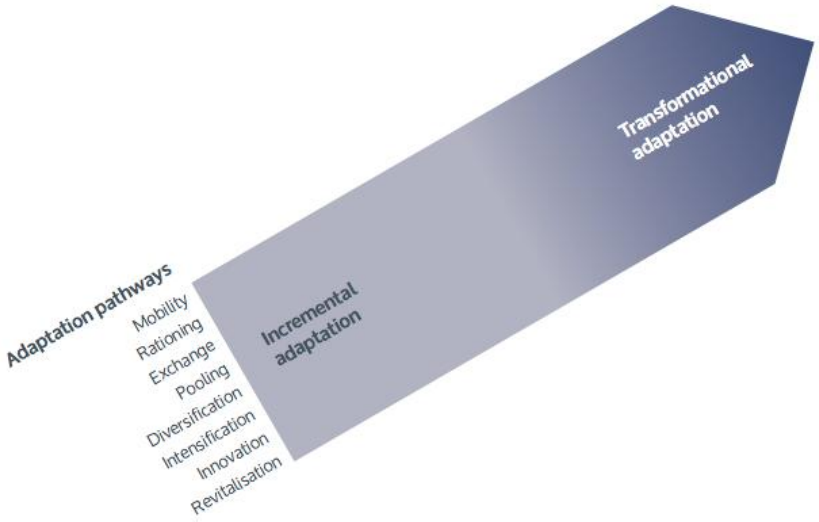

Figure 1: Differences between incremental and transformational adaptation (Source: Lonsdale et al, 2015).

Method

Here I am consistent with the school of thought that transformational adaptation requires a step change (Klein et al, 2014). For the adaptation policy trajectories this is an important way of distinguishing the system efficiency trajectory from the system restructuring. However, it makes it difficult because there are very few tangible examples of transformation to use to populate the system restructuring trajectory. Rather than giving examples of transformational adaptation and applying my own judgement, which likely differs from that of others, here I have outlined all the examples that I have found.

The examples are based on a review of the first five pages of Google search results for "adaptation and [delta name]". This has been done in four major deltas – the Mekong, Mississippi, Rhine-Meuse and Yangtze. All adaptations mentioned in the literature have been included – this means that some adaptations are cited more than once (sometimes only minimally differently). Because I am applying a narrow definition of transformation, this should stop any exclusion errors. The main criterion used was whether the proposed adaptation is different from the norm. However, this is contingent on knowing the norm (in most cases it has been possible to add a few sentences about changes in the overall approach to river and delta management). Purely local initiatives are excluded since DECCMA needs to model at macro scale, as are existing adaptations (unless there was evidence of plans/recommendations to scale them up).

A note on gender

One key theme that is common amongst the deltas is mention of the fact that intensification of agriculture and maximizing use of water have occurred at the expense of environmental sustainability and social equity (Käkönen, 2008). Questioning of social imbalances is also included in the definition of transformational adaptation by Lonsdale et al (2015). Very few adaptations explicitly mention this and because of that it is difficult to discern. There is a Yangtze Three Gorges Dam example which I have not put as transformational adaptation because of the social implications of the dam – but that is

based on my prior knowledge. Based on the broad components of adaptation that we are considering (i.e. addressing drivers of vulnerability, DRR, landscape/ ecosystem resilience), DECCMA will likely have to give some hypothetical examples to fill gaps. In keeping with DECCMA's commitment to gender-sensitivity, the gender and social equity component will be highlighted in our model.

Examples

Mekong delta

The Mekong River Commission Climate Change and Adaptation Initiative 2011-15 developed a "Mekong Adaptation Strategy and sector guidelines for climate change adaptation planning supporting the adoption of IWRM based strategies and guidelines"[2], and then an Integrated Water Resources Management-based Basin Development Strategy 2016-2020[3] – so integrated water resource management is the capstone of their adaptation planning approach. It does not mention anything on hard infrastructure.

Adaptation	Transformational?	Link to other DECCMA pathway	Source
Scaling of climate-resilient rice farming techniques from 52-160,000ha in Vietnam through the national government plan	No	System efficiency enhancement	USAID Adaptation and Resilience to Climate Change (2011-16) http://www.mekongarcc.net/ synthesis report http://www.mekongarcc.net/sites/default/files/mekongarcc_draft_synthesis_report.pdf (basically they demonstrated things and these are their findings/recommendations for adaptation, some of which have been taken up – e.g. the upscaling and the mainstreaming into the Cambodian planning process)
Mainstreaming of participatory techniques for community development of climate change adaptation measures into the National Commune Investment Planning process in Cambodia	Yes (?)		
Ecosystem resilience-forest restoration and management builds community organization and social capital by the formation of management committees that protect and regulate use of community forests and mangrove restoration	Yes		
Bioengineering-the use of vegetation to improve the stability of slopes and shorelines that are susceptible to erosion and inundation, particularly around key infrastructure (e.g. roads)	No	Economic capacity expansion	
Agriculture-Development and use of new crop varieties; adjustment of the traditional cropping calendar; improved water conservation techniques; and improved soil management (to modify the greater agricultural intensification and use of monocultures that will require significant inputs to continue to be sustainable)	No	System efficiency enhancement	

[2]http://www.mrcmekong.org/assets/CCAI-2011-2015-documentFinal.pdf
[3]http://www.mrcmekong.org/assets/Publications/strategies-workprog/MRC-BDP-strategy-complete-final-02.16.pdf

Agriculture-livestock management activities include the construction of housing that improves ventilation and drainage, and the incorporation of organic bed materials with enzymes to break down waste (bio-mattress). Projects also include the use of native chicken and pig species that can handle higher temperatures. Vulnerable groups (women, ethnic minorities, and landless poor) in particular benefit from the supplemental income generated by livestock projects, thereby increasing their resilience to climate change.	Yes (commitment to vulnerable groups; otherwise efficiency)		
Fisheries-projects that improve the rice-shrimp rotational farming system in the Mekong Delta, such as installing shrimp nurseries to improve productivity of aquaculture ponds; monitoring water quality parameters including temperature, dissolved oxygen, and salinity levels to inform management decisions; and improving the selection, testing, and cooperative purchase of post larval shrimp.	No	System efficiency enhancement	
Fisheries-aquaculture systems in in-land areas include small-scale frog and catfish ponds to provide an additional protein and income source for households.	Yes (? new activity)		
Fisheries-protection and rehabilitation of upland catchments, as well as measures to enhance stream habitat such as the creation/maintenance of deep pool refuges and the removal of obstacles for migration	No	System efficiency enhancement	
Fisheries-protect aquaculture systems from flashfloods by improving the integrity of embankments and through construction of diversion canals to facilitate drainage of floodwaters during extreme events.	No	Economic capacity expansion	
Water infrastructure and management- rehabilitation of water supply systems including the installation of water filtration systems, and the use of water meters to monitor and respond to community water use	No	System efficiency enhancement	

Water infrastructure-irrigation and flood control projects, such as canal construction to supply water to agricultural fields during dry periods and dyke construction to mitigate flood events.	No	Economic capacity enhancement	
Staged and managed retreat of infrastructure and communities from the coast	Yes		
Expansion of the Mekong River Commission flood warning system to cover other extreme events induced by climate change (*daily forecasting and early warning)*	Yes		Mekong River Commission Climate Change and Adaptation Initiative
Integrating indigenous knowledge into the drought management programme on monitoring, analysis and implementation of regional drought adaptation and mitigation strategies (2016-20)	No	Minimum intervention	
Providing downscaled information about climate change to facilitate the Watershed Management Programme	No	Minimum intervention	

Mississippi

Adaptation strategies are based on a coastal restoration and soft engineering approach, and looking at watershed scale. The Federal Emergency Management Agency (FEMA) has completely modified its response strategy since Hurricane Katrina exposed so many shortcomings. They no longer wait until a disaster happened to assess how bad it was and send requested supplies. Hurricane Katrina also sparked a national discussion over the merits of spending billions of federal dollars on rebuilding and protecting a city that will inevitably be hit by more hurricanes. Some are now highlighting that adaptation may mean retraining fishermen and paying residents to move out of the floodplain[4].

Of note, whilst typically deemed to be a low cost alternative, evidence highlights that "soft" ecosystem-based approaches, such as the restoration of drowned delta areas, are expensive. The plan for the Mississippi will run for 50 years, and cost between US$500 million and $1.5 billion a year[5]. This would be designed to stave off future land loss, but not recover the vast amount of wetlands already gone.

[4]https://www.scientificamerican.com/article/rising-sea-levels-may-limit-new-orleans-adaptation-efforts/

[5]http://www.nature.com/news/climate-change-protect-the-world-s-deltas-1.16428

Adaptation	Transformational?	Link to other DECCMA pathway	Source
Promote wetland accretion by introducing sediment	Yes (wetland approach is a change from the norm)		Assessment of Sea Level Rise in Coastal Mississippi, Mississippi Department of Marine Resources, 2011 http://www.dmr.state.ms.us/images/cmp/2011-slr-final.pdf
Prohibit hard shore protection	Yes		
Remove existing hard protection or other barriers to tidal and riverine flow (e.g. riverine and tidal dike removal	Yes		
Incorporate wetland protection into infrastructure planning (e.g. transportation planning, sewer utilities).	Yes		
Preserve and restore the structural complexity and biodiversity of vegetation in tidal marshes, and seagrass meadows.	Yes		
Identify and protect ecologically significant areas such as nursery grounds, spawning grounds, and areas of high species diversity (e.g. GEMS, coastal preserves).	Yes		
Maintain / restore wetlands. Invasive species management; preserve habitat for vulnerable species.	Yes		
Trap or add sand through beach nourishment – the addition of sand to a shoreline to enhance or create a beach area.	Yes		
Create a regional sediment management plan.	Yes		
Develop adaptive storm water management practices (e.g. promoting natural buffers, adequate culvert sizing).	Yes		
Integrate coastal management into land use planning.	Yes		
Integrated Coastal Zone Management – using an integrated approach to achieve sustainability and resiliency.	Yes		
Incorporate consideration of climate change and sea level rise impacts into planning for new infrastructure (homes, buildings, water, sewer, streets, critical facilities, etc.)	Yes		
Shoreline maintenance-replace shoreline armoring with living shorelines – through beach nourishment, vegetation, etc.	Yes		

Create dunes along the backshore of beaches; includes planting dune grasses and sand fencing to induce settling of wind-blown sand.	Yes		
Use natural breakwaters such as oyster reefs or other man-made / natural materials to dissipate wave action and protect shorelines.	Yes		
Redefine riverine flood hazard zones to match projected expansion of flooding frequency and extent.	Yes		
Strengthen rules that prevent the introduction of invasive species (e.g. enforce no discharge zones for ballast water).	Yes		
Remove invasive species and restore native species.	Yes		
Expand the planning horizon of land use and comprehensive planning to incorporate longer climate predictions.	Yes		
Adapt protections of important and critical habitats as the locations of these areas change with climate and sea level changes.	Yes		
Preservation of habitats for vulnerable species	Yes		
Design estuaries with dynamic boundaries and buffers.	Yes		
Replicate habitat types in multiple areas to spread risks associated with climate change	Yes		
Design and implement new coastal drainage systems.	Yes		
Integrate climate change scenarios into water supply system	Yes		
Manage water demand (through water reuse, recycling, rainwater harvesting, desalination, etc.)	Yes		
Consider modifications to local Flood Hazard Prevention Ordinances to increase freeboard requirements.	Yes		
Consider incorporation of sea level rise and climate change impacts into local, regional, and state hazard mitigation plans.	Yes		
Incorporate risk-based land use planning into local comprehensive plans	Yes		
Legislation for investment and lending, e.g. for communities currently participating in FEMA's Community Rating System (CRS) consider program or policy changes that would	Yes		

specifically address Activity 430 – Credit for Higher Regulatory Standard, Activity 430 – Credit for Coastal A Zone Regulations, and Activity 610 – Credit for Flood Warning Systems; or, for communities not currently participating in FEMA's CRS, consider enrollment in the program.			
Agricultural production- purchasing hedging contracts, such as forwards or futures, or altering marketing strategies, such as holding corn in storage, using a different form of transportation, or selling it into a different market altogether.	No	System efficiency enhancement	Property and Environment Research Center (PERC) reports: Market adaptation to climate change 35 (2) 2016
Third-party insurance or hedging products such as environmentally indexed insurance or catastrophe bonds to spread risk	No	System efficiency enhancement	
Natural infrastructure, which includes "green infrastructure" such as wetlands and barrier islands	Yes		Environmental Defense Fund http://mississippiriverdelta.org/adapting-to-climate-change-using-natural-infrastructure/
Incorporating green infrastructure with traditional "gray infrastructure," such as floodwalls and levees, (to both protect cities and people as well as increase the effectiveness of this existing flood protection infrastructure)	Yes		
Rebuilding marshes with dredged sediments	Yes		http://www.nature.com/news/climate-change-protect-the-world-s-deltas-1.16428 Cited here as being used or planned by the likes of the Louisiana Coastal Protection and Restoration Authority
Installing coastal protection	No	Economic capacity expansion	
Diverting river channels to build land	Yes		

Rhine

Adaptation	Transformational?	Link to other DECCMA pathway	Source
Take into account climate change in the flood risk and low flow management plans on the basis of an assessment of the sensitivity of the flood scenarios considered	Yes		Strategy for the International River Basin District (IRBD) Rhine for adapting to climate change, 2015 http://www.iksr.org/fileadmin/user_upload/Dokumente_en/Reports/219_en.pdf
Raise public awareness - strengthen private precaution, preventive behaviour and reduce vulnerability, preventive construction	Yes		
Improve forecasting and dissemination of flood, low flows, and pollution	No	Economic capacity enhancement	
Reactivate floodplains and increase water retention, long term securing of potential floodplain areas or retention areas	Yes		
Decentralized water retention (on the surface, improved infiltration) and water retention in the Rhine catchment (tributaries and their catchments)	Yes		
Land use control by reducing soil sealing and conserving floodplain areas (urban and land-use planning)	No	System efficiency enhancement	
Technical flood protection, as far as achieving the environmental targets of the WFD, will not be interfered with and the flood risk in other states up- or downstream will not be increased	No	System efficiency enhancement	
Financial preventive and aftercare measures; regeneration	Yes		
Emergency planning and coping with floods: Risk prevention, civil protection and emergency drills.	No	Minimum intervention	
Preventive construction, technical solutions (e.g. collect precipitation water), alternative uses.	Yes		
Optimizing the use of fertilizers and plant protection agents and enhancing organic farming (measures also concerning other fields) to reduce diffuse pollution by nitrogen, phosphorous, plant protection agents, PCB, PAH, zinc and copper.	No	Economic capacity expansion	
Flora and fauna habitats are to be protected and to be made more nature-near, including redesigned banks and habitat	Yes		

network connectivity (clearing of fish migration routes, e.g. "*Flussrevitalisierungen*" in Switzerland, "*Trame verte et bleue*" in France, "*Integriertes Rheinprogramm*" in Baden-Württemberg and "*Aktion Blau Plus*" in Rhineland-Palatinate, and "More Room for the River" in the Netherlands.			
Ecological flood protection, taking into account the ecological functionality of the riparian structures and the floodplains	Yes		
Ecological flooding of polders or relocations of dikes as a win-win measure to enhance biodiversity and reduce the damage potential	Yes		
Connection of drinking water supply networks, water management, reduce losses	No	System efficiency enhancement	
Water abstraction during low flow: Regulation of water abstraction quantities, exceptional regulations, during low flow	Yes		
Check/adapt discharge permits and derogations for discharging cooling water from thermal power plants and industrial plants; eventually restrict production during low flow	No	System efficiency enhancement	
Determine a biological minimum water flow for hydropower plants in bypass rivers, with orders to stop plant operation when river discharge falls below the value determined	Yes		
Fish bans when justified during dry periods or hot spells	No	System efficiency enhancement	
Less shipping load or restriction of navigation during low flow, adapt the size of ships, deepen the navigation channel	Yes		
Adapt existing agricultural practice (recovering of precipitation water, choice of suitable plant species requiring less water, use of irrigation techniques using less water, e.g. drip irrigation, etc.)	Yes (because of choice of species, assuming difference)		
Use Water Nature Trails to attract attention to the abundance of nature and to the development of climate change, to flood risks	Yes		
Navigation-Lighter and wider vessels, increase storage capacity	Yes		Marcela Riqulme Solar, 2013 Inland Waterway Transport in the Rhine River Basin: Searching for Adaptation Turning Points
Navigation- Dredging measures, Canalization, Longitudinal dams	No	Economic capacity expansion	

Strengthening the dykes to become unbreachable (Delta dykes)	No	Economic capacity enhancement	PBL - Climate Adaptation in the Dutch Delta http://www.pbl.nl/en/publications/2012/climate-adaptation-in-the-dutch-delta
Adjusting the New Waterway (where 80% of the Rhine is discharged into the sea) to prevent fresh water shortage	Yes		
Management of new spatial developments in riverine areas to reserve areas within the Rhine-Meuse floodplain for managing the consequences of potentially higher river discharges and higher sea levels	Yes		
Revising the strategy behind the National Ecological Network to climate-proof ecosystems and spatial connectivity in coastal dunes, peat marshes and the Rhine-Meuse floodplain, and restoring natural processes in the Wadden Sea, the south-west delta area and the coastal zone.	Yes		
Municipal regulations for modified infrastructure (e.g. sewerage systems) in urban areas	Yes		
Continued nourishment at the seaward side of Rotterdam	No		Bottom up climate adaptation strategies towards a sustainable Europe http://base-adaptation.eu/adapting-flood-risk-management-rhine-meuse-delta-rotterdam-netherlands
Disaster risk management for the Maeslant storm surge barrier and introduction of sea locks (due to start in 2040); disaster management to protect the electricity grid and high-risk businesses	No	Economic capacity expansion	
Using the widened river as a tidal park.	Yes		
Dyke upgrading to a higher protection level	No	Economic capacity expansion	Delta programme Rhine Estuary-Drechtsteden https://english.deltacommissaris.nl/delta-programme/contents/regions-and-generic-topics/rhine-estuary-drechtsteden
Spatial planning-Strategic Adaptation Agenda project for the areas outside the dykes, the Spatial Adaptation City Deal, and the Agniesebuurt/Zomerhofkwartier testing ground impact project (second phase)	No	System efficiency enhancement	
Gradual expansion of the emergency supply from the Waal and the Amsterdam-Rijn canal and a more resilient freshwater supply from the Brielse Meer lake	No	System efficiency enhancement	
“Smart water management” to reduce salinisation in the Hollandsche Ijssel, the Amsterdam-Rijn canal, the Noordzee canal, and near the Hagestein weir.	Yes		

Innovative plans for urban water management-the construction of the water plaza and various rain gardens- in Agniesebuurt/Zomerhofkwartier	Yes		
Additional flood defence measures, such as retention basins and dike heightening	No	Economic capacity expansion	Assessment of upstream flood risk in the Rhine Basin (HSGR02) http://www.knowledgeforclimate.nl/watersafety/HSGR02

Yangtze

In a break from the past, since its 1998 "32 Character Policy", the Chinese government has focused on environmental restoration – a 'soft path' - rather than engineering solutions (Wang et al, 2007). There is some literature on a programme from 2002 between WWF and government agencies and local communities with the purpose of reconnecting three lakes (Zhangdu, Hong and Tian-e-zhou) in Hubei Province to the river by opening sluice gates seasonally and improving lake management.

Adaptation	Transformational?	Link to other DECCMA pathway	Source
Reforming legal principles, legal instruments and institutional setting, including integrated water planning and environmental impacts assessment	Yes		He, X., 2013. Mainstreaming climate change adaptation in the Yangtze water resources management in China : a legal and institutional perspective. PhD University of Western Sydney
32 Character Policy was backed up by policy directives, targets, substantial funding, and reporting mechanisms to enable effective implementation at the provincial and county scales. The policy is proactive, long term (to 2030), flexible (with China's five-year national planning cycle), and robust in that floodplain restoration is a 'no regrets' measure.	Yes		Pittock, Jamie and Ming Xu. World Resources Report Case Study. Controlling Yangtze River Floods: A New Approach. World Resources Report, Washington DC. Available online at http://www.worldresourcesreport.org
Build capacities to deal with climate change by improving economic status, living conditions and public facilities, such as energy and power supply, transportation network, river and coastal dike reinforcement, and irrigation systems.	No	Economic capacity expansion	Summary of the First-ever Yangtze River Basin Climate Change Vulnerability and Adaptation Report http://www.gwp.org/globalassets/global/toolbox

			/case-studies/asia-and-caucasus/china.-adaption-measures-for-yangtze-river-basin-403.pdf
Promote Integrated River Basin Management (IRBM) by systematically optimizing the management of the major hydro-engineering projects, adopting market-based water allocation strategy, and increasing environmental flows to ensure the minimum ecological water demand.	Yes		
Adjust cropping systems, breed new strains and improve crop management practices for adapting to the new climate (replacing corn with rice)	No	System efficiency enhancement	
Protect natural forests from logging by establishing a new ecological compensation system in the YRB; improve the management of plantations by planting more native tree species and selecting southern provenances for new plantations; enhance the management of natural reserves for protecting biodiversity and ecosystem integrity.	No (more of the same)	System efficiency enhancement	
Increasing forest coverage by enhancing forest protection and afforestation of steep farmlands (1998 32 Character Policy)	No (suggests it's already being done)	System efficiency enhancement	CCICED. 2010. Ecosystem services and management strategy in China: Study report for AGM 2010. Beijing: China Council for International Cooperation on Environment and Development.
Restoring floodplains by removing embankments and returning agricultural polders to floodplains to increase floodwater retention capacity (1998 32 Character Policy)	Yes		
Resettling farmers by building new townships and providing them with jobs instead of subsidies (1998 32 Character Policy)	Yes		
Strengthening other levees and dredging riverbeds (1998 32 Character Policy)	No	Economic capacity expansion	
Construction of estuary weir in the northern branch at the upstream entrance (width = 2km)	No	Economic capacity expansion	http://www.conference.ifas.ufl.edu/emecs9/Presentations/Tuesday/Salon%205/pm/Plenary/(5)%20Watanabe.pdf
Increase the Yangtze river flow rate during dry season with the integrated Yangtze river watershed management and Three Gorges Dam.	Yes (but what of social issues?)		
Regional and city planning including the location of water intake in upstream of the Yangtze river	Yes		
Operation of high efficient desalination plant during dry season	Yes		

Introduction of water saving system in order to reduce water demand	Yes		
Real-time control of water supply-demand in the Yangtze river watershed and Shanghai	No	Economic capacity expansion	
Agricultural insurance system with village-level information and technology dissemination mechanism	No	Economic capacity enhancement	Chen Li, Zuo Ting, Rabina G. Rasaily, 2010. Farmer's Adaptation to Climate Risk in the Context of China -: A research on Jianghan Plain of Yangtze River Basin. International Conference on Agricultural Risk and Food Security, https://doi.org/10.1016/j.aaspro.2010.09.014
Elevation of the wastewater treatment plants (WWTPs) above flood level. The Dashaba WWTP has been located above the 1 in 50 return flood level (at the expense of an additional pumping station) to ensure its protection.	No	Economic capacity expansion	Hubei Enshi Qing River Upstream Environment Rehabilitation Project (RRP PRC 47048) Summary of climate change assessment and adaptation measures http://adb.org/Documents/RRPs/?id=47048-002-3
Design of the increased treatment capacity of WWTPs allows for maximum runoff from initial rainstorm. The WWTP capacities are for wastewater volumes to 2030 and cover the predicted 10% volume increase in storm events.	Yes		
Siting of all WWTPs adjacent to Qing River, which allows pumping of dilution water from the river in times of extreme drought to protect treatment processes.	No	Enhanced system efficiency	
Embankment heights have been designed for the design level flood (1 in 50 year return for built-up areas and 1 in 20 year return for non-urban areas) with an additional 0.2 m margin for wave action plus 0.5 m safety margin (giving an additional height above the design flood level of 0.7 m).	No	Economic capacity expansion	
The engineering design of embankments are adapted to asset protection from flooding (robust concrete structures for unstable banks in built up areas and reinforced sloping "green" embankments for non-urban and agricultural lands. The embankments are designed with engineered foundations in	Yes		

concrete and gabion sections to provide strength against the predicted higher frequency of flooding and water velocity.			
Sea level rise strategy in the Shanghai city have been proposed to the Shanghai government as (1) recent actions (2012-2015) to upgrade the city water supply and drainage engineering and protective engineering; (2) interim actions (2016-2020) to improve sea level monitoring and early warning system, and then the special, city, regional planning considering sea level rise; (3) long term actions (2021-2030) to implement both the safety and the transformation and development of the city.	Yes (only because the idea of a strategy is new)		Heqin Cheng, Jiyu Chen, Zujun Chen, Renliang Ruan, Guiquan Xu, Gang Zeng, Jianrong Zhu, Zhijun Dai, Shenghua Gu, Xianlin Zhang and Hanmei Wang, Anthropogenic sea level rise and adaptation in the Yangtze estuary https://agu.confex.com/agu/os16/preliminaryview.cgi/Paper89351.html

Conclusion

This document has outlined examples of transformational adaptation from four deltas: the Mekong, Mississippi, Rhine-Meuse and Yangtze. The intention was to find examples of transformational adaptation that can be used to inform the design of adaptation policy trajectories for use in the DECCMA Integrated Assessment Model, since examples of these are scarce from our empirical examples across three deltas in Bangladesh, Ghana and India. All four deltas assessed here contain examples of transformational adaptation, with the Mississippi having a notable focus on transformational adaptation as compared to adaptations that would fall under the three other policy trajectories. Transformational adaptation examples relate to a step change in approach to management of the deltas as opposed to system efficiency. In particular this is shown across all four deltas to incorporate an element of return towards equilibrium of the natural environment, as opposed to trying to impose human management onto it. Evidence of transformational adaptation in some deltas provides examples that can be applied in others.

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