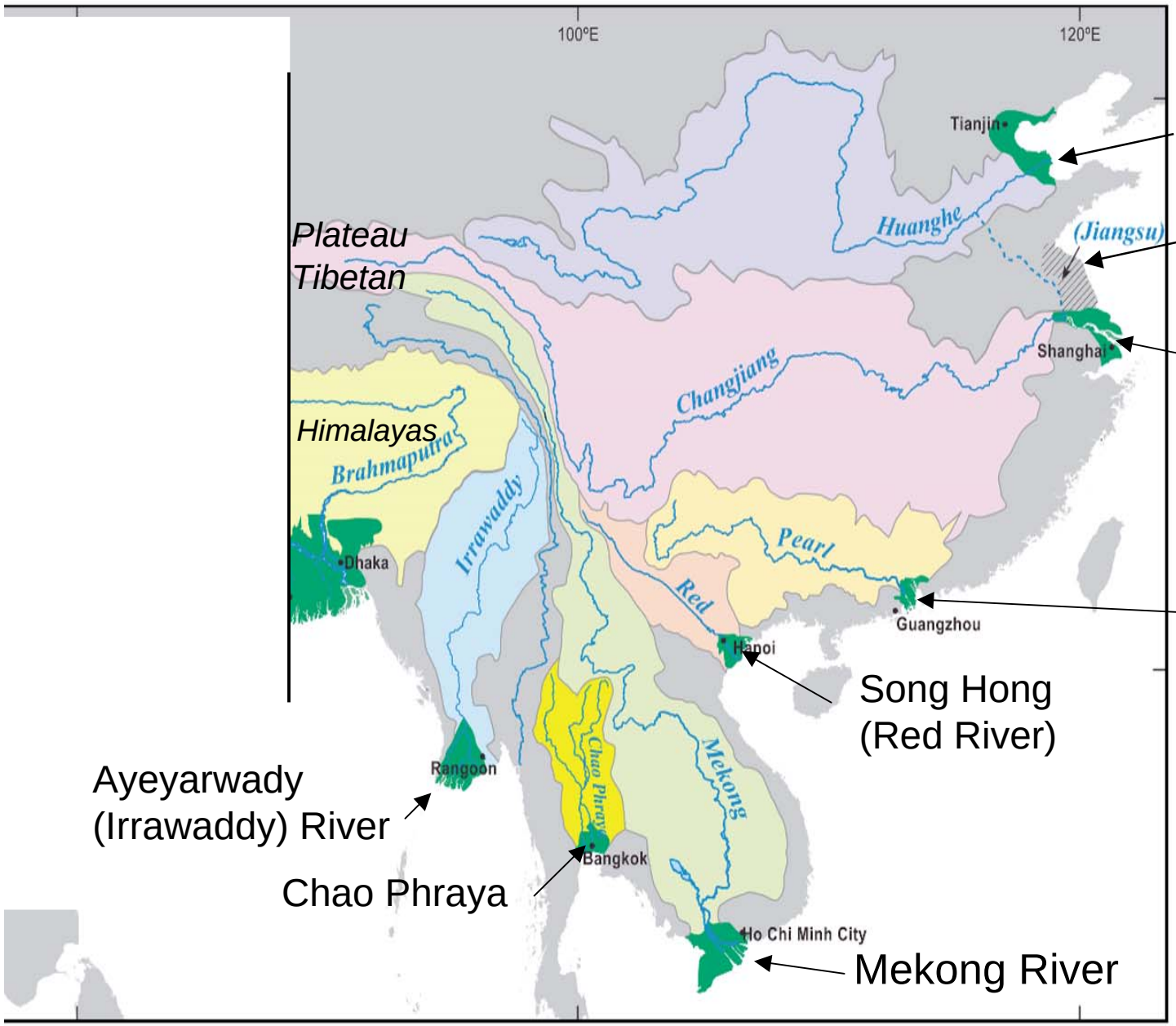
Deltas at Risk

Dynamics and vulnerability of river delta system

East Asia & Southeast Asia region

Yoshiki Saito

Geological Survey of Japan



Huanghe
(Yellow River)

Old Huanghe
(500 MT/y)

Changjiang
(Yangtze River)

Zhujiang
(Pearl River)

Song Hong
(Red River)

Ayeyarwady
(Irrawaddy) River

Chao Phraya

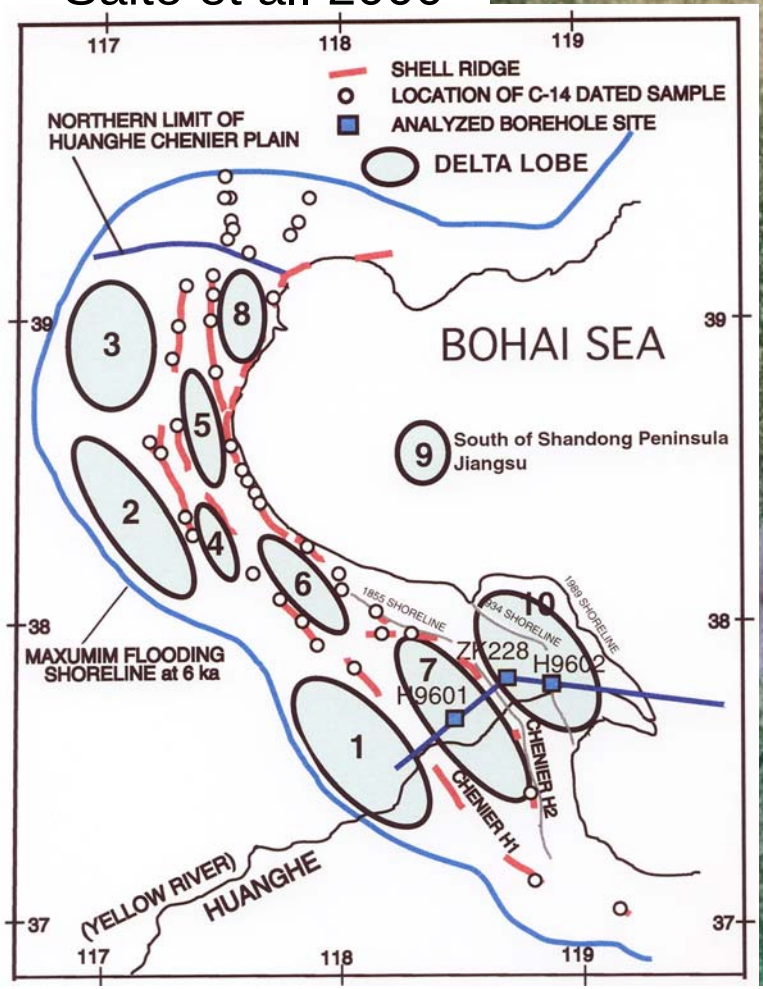
Mekong River

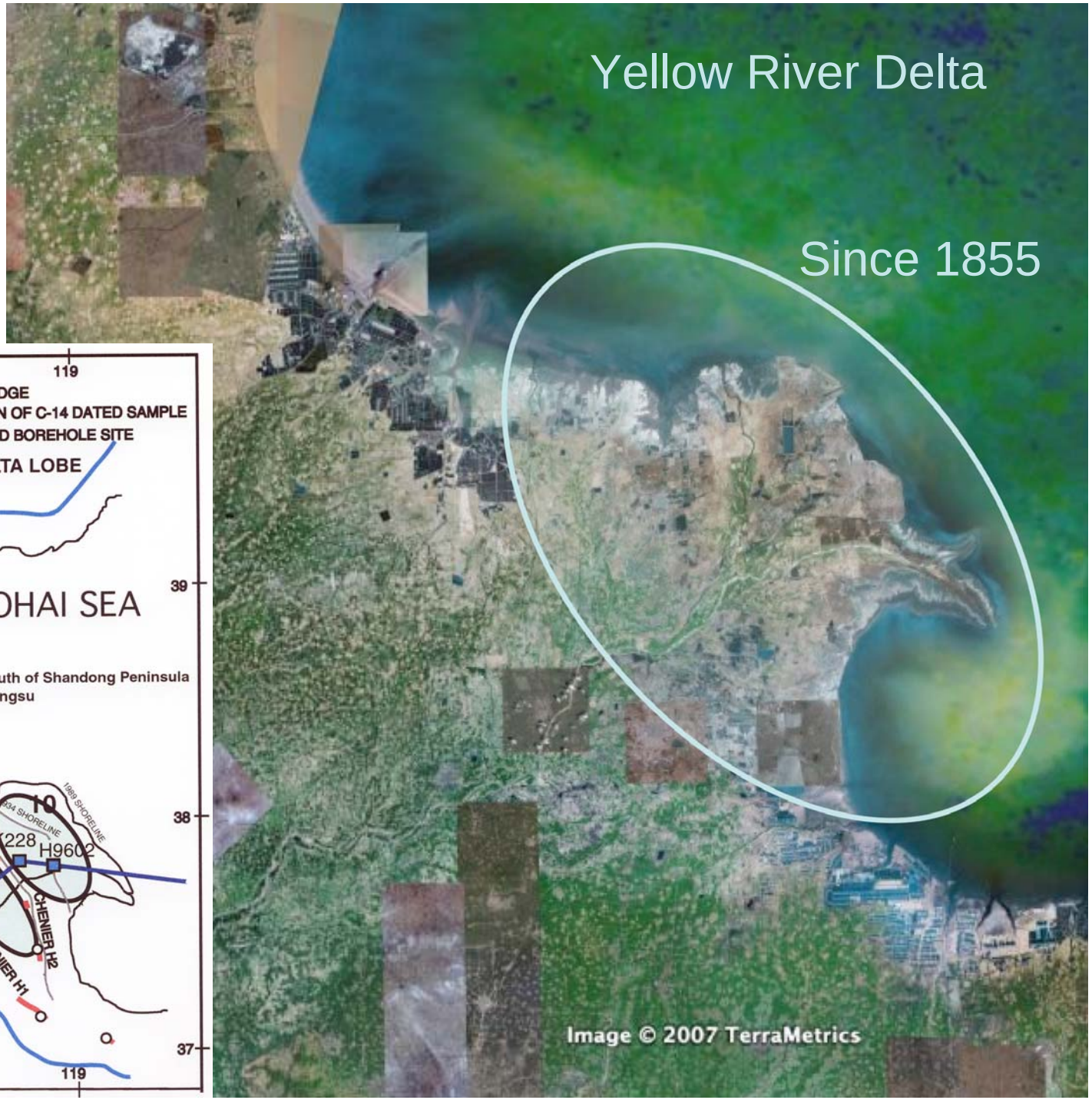
>40km2/y
New land
↓
shrinking

Woodroffe et al., 2006

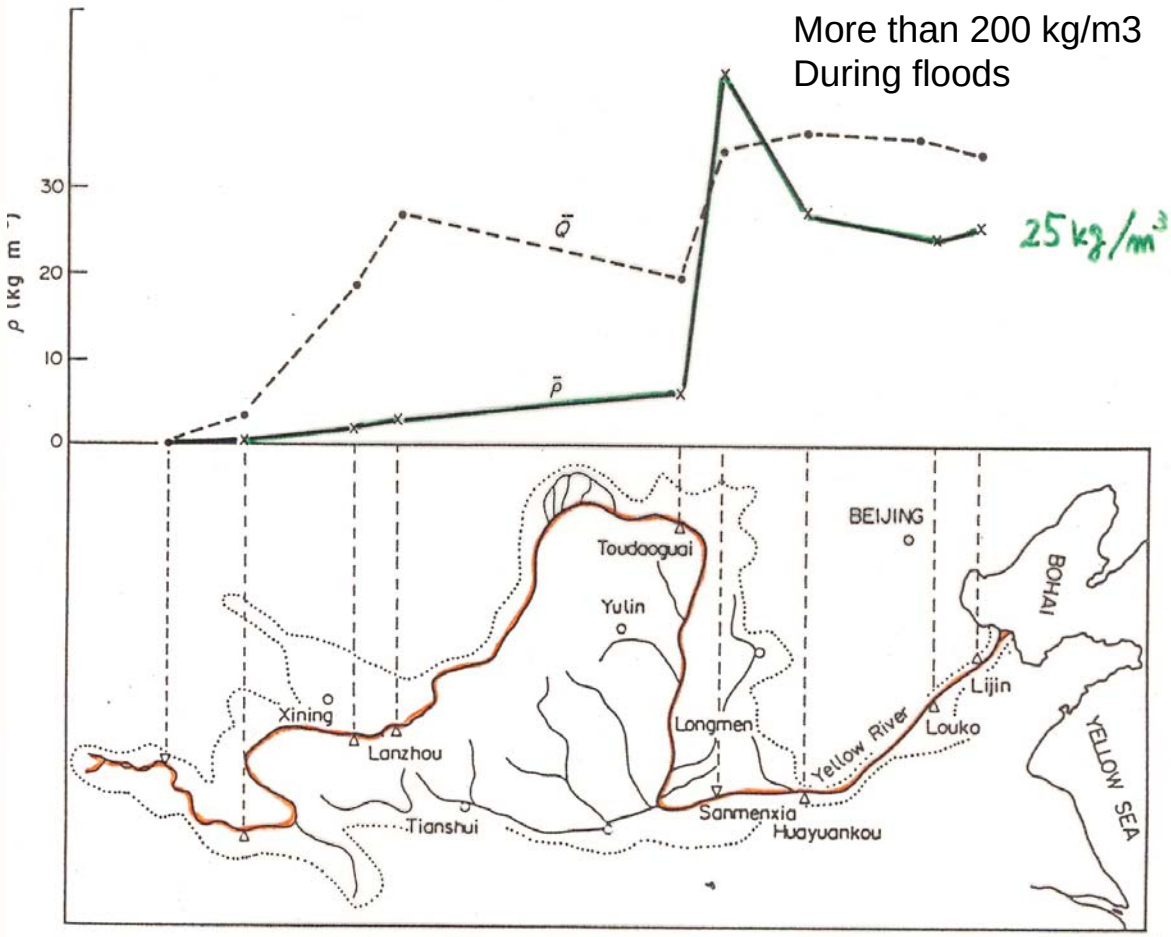
Holocene
10 superlobes

Saito et al. 2000



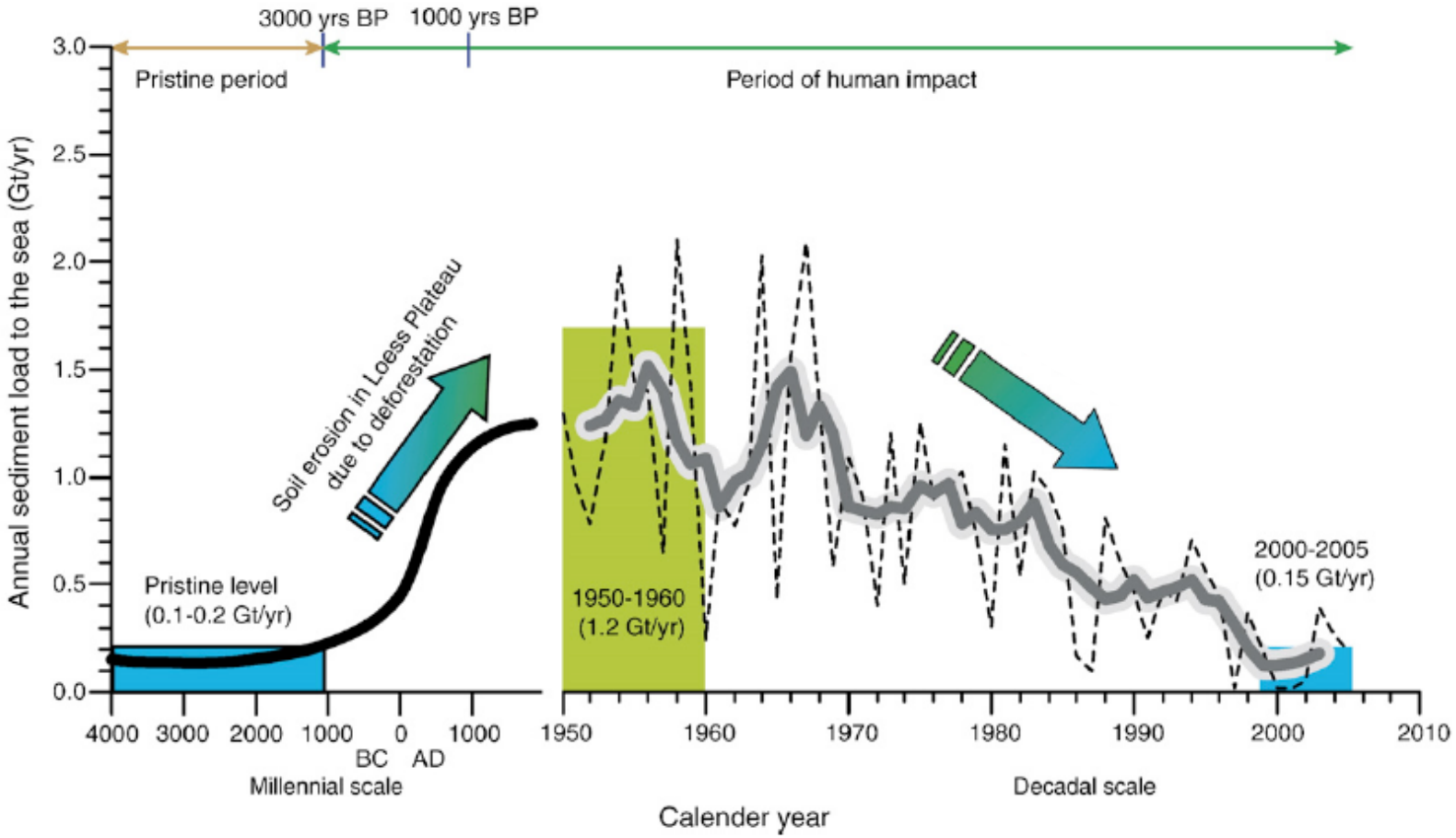


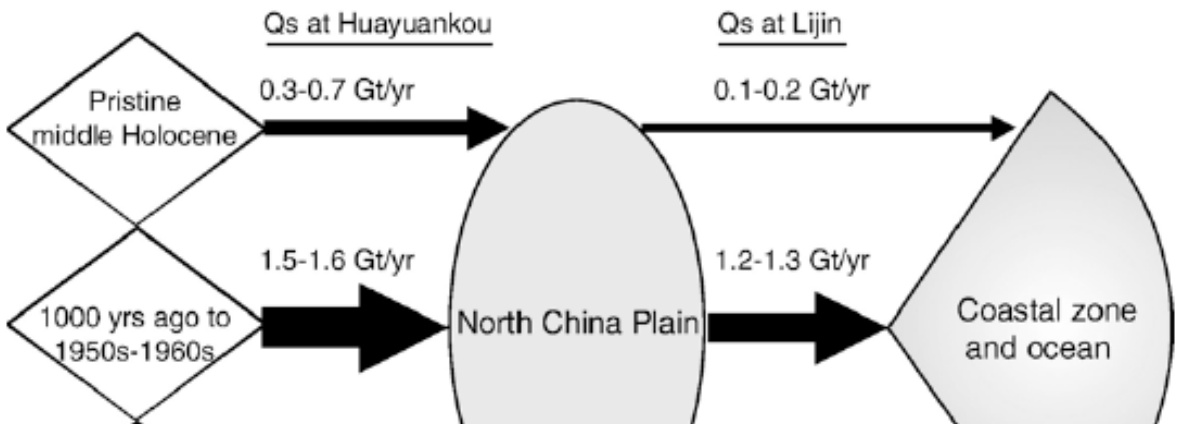
More than 200 kg/m3
During floods



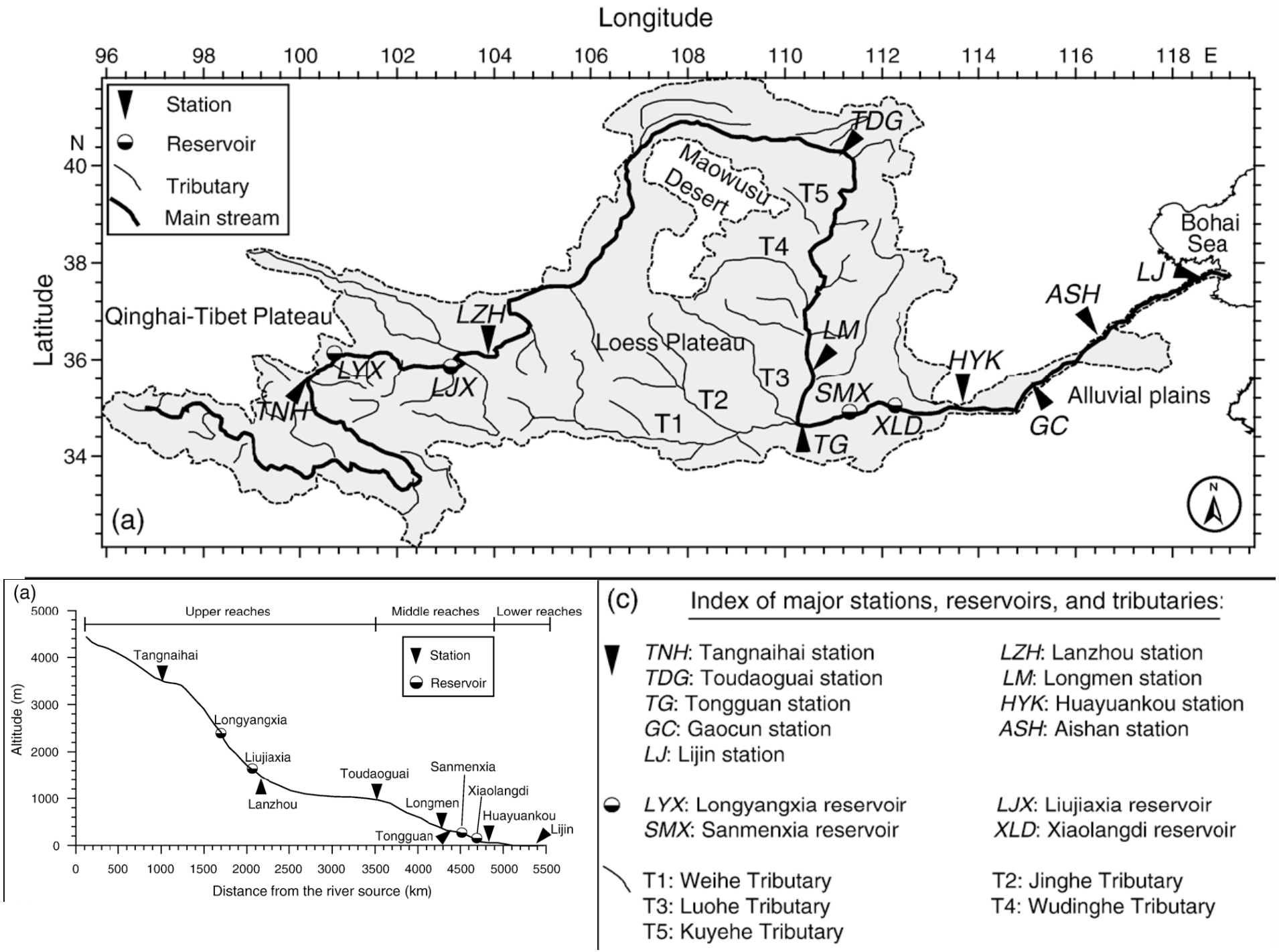
Yellow River Basin, showing 30-y average (1950–1979) of water discharge and sediment ntration data for nine stations along the river. Note the abrupt increase of sediment ntration after the river flows through the Loess Plateau. $\bar{Q}$ = water discharge, and $\bar{\rho}$ = sediment concentration.

Ren and Shi. 1986





Wang et al., 2007



(c) Index of major stations, reservoirs, and tributaries:

- *TNH*: Tangnaihai station
- *TDG*: Toudaoguai station
- *TG*: Tongguan station
- *GC*: Gaocun station
- *LJ*: Lijin station
- *LZH*: Lanzhou station
- *LM*: Longmen station
- *HYK*: Huayuankou station
- *ASH*: Aishan station

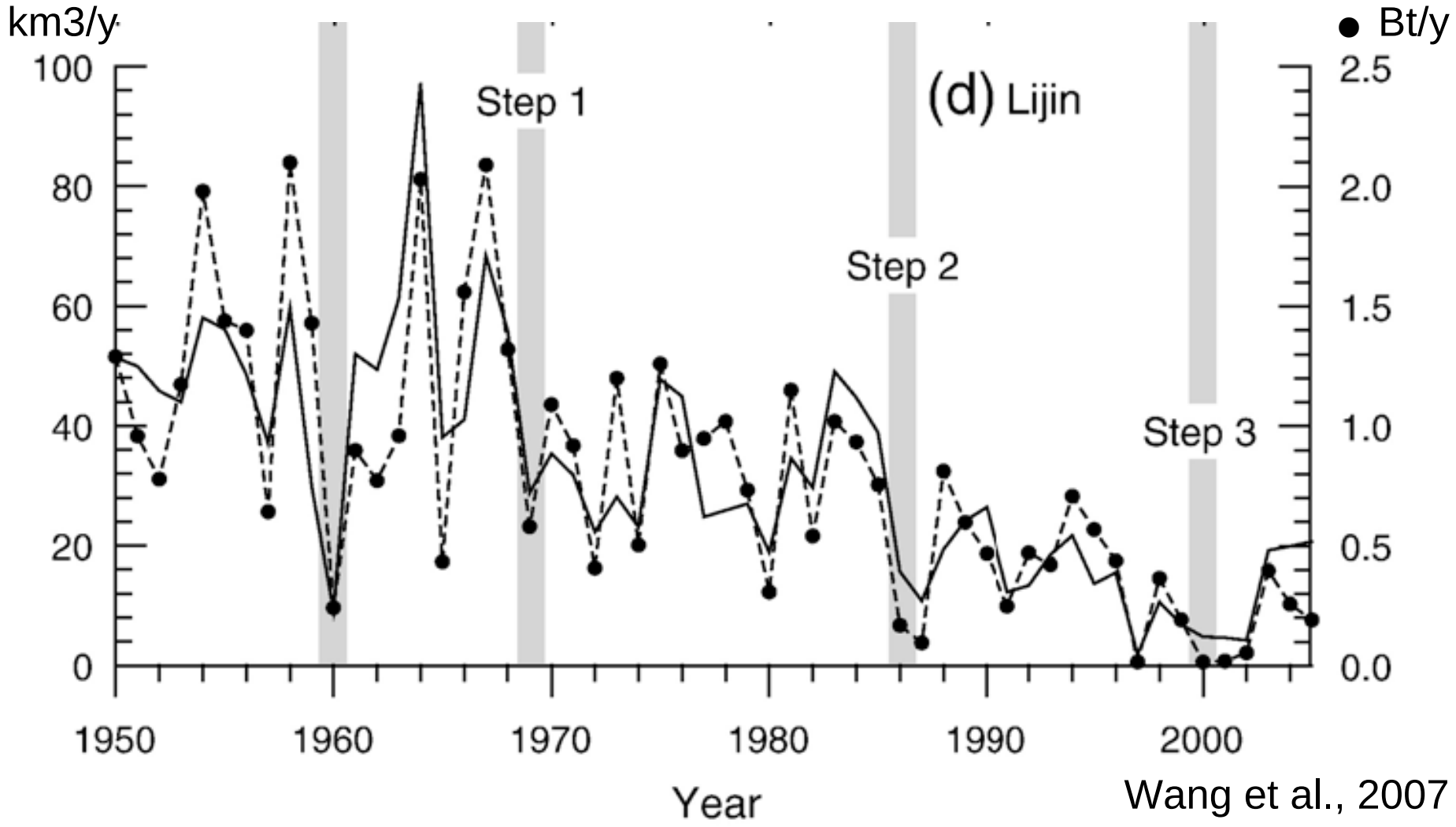
- *LYX*: Longyangxia reservoir
- *SMX*: Sanmenxia reservoir
- *LJX*: Liujiaxia reservoir
- *XLD*: Xiaolangdi reservoir

- T1: Weihe Tributary
- T2: Jinghe Tributary
- T3: Luohe Tributary
- T4: Wudinghe Tributary
- T5: Kuyehe Tributary

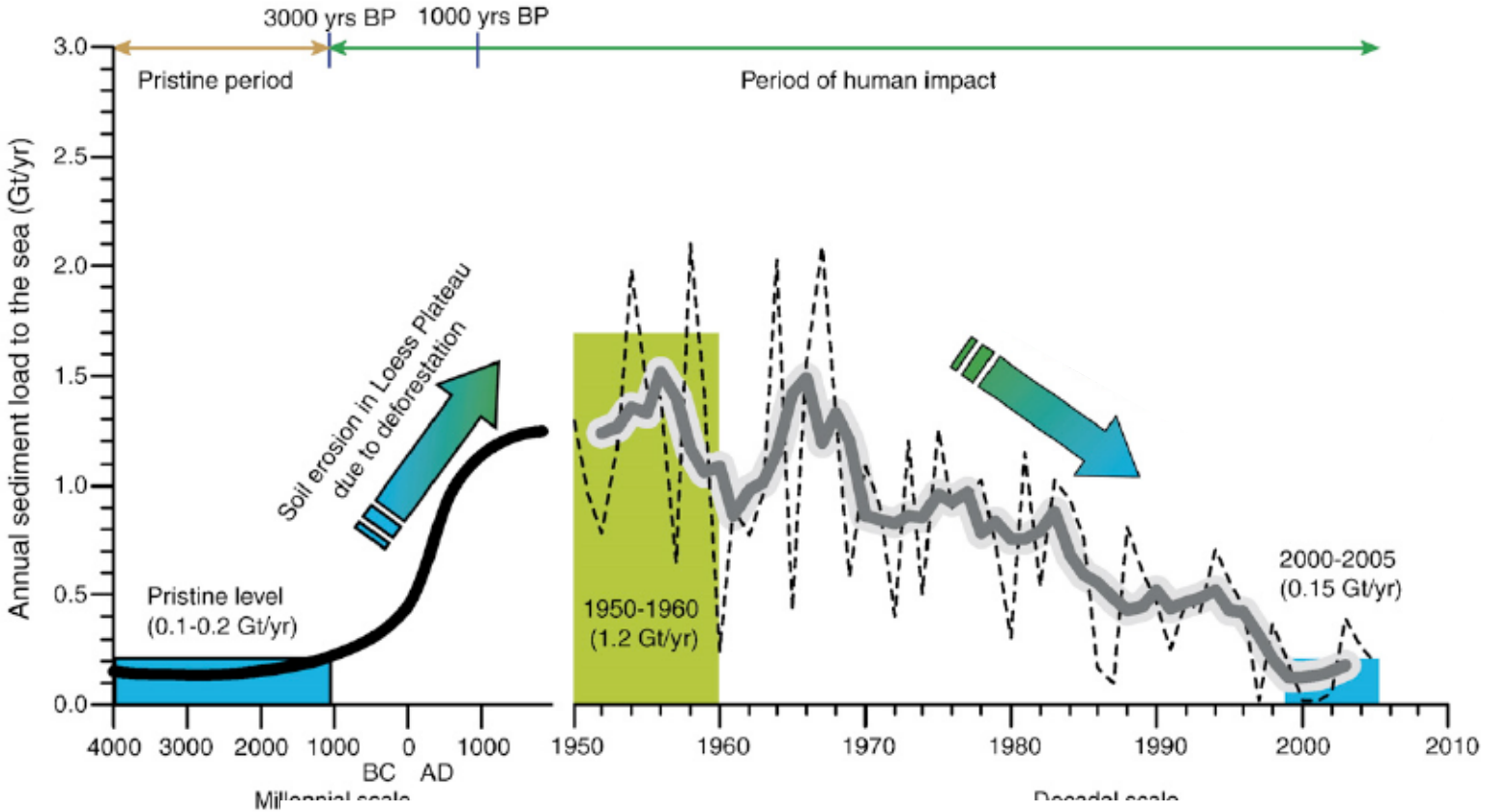
Sediment discharge at Lijin station

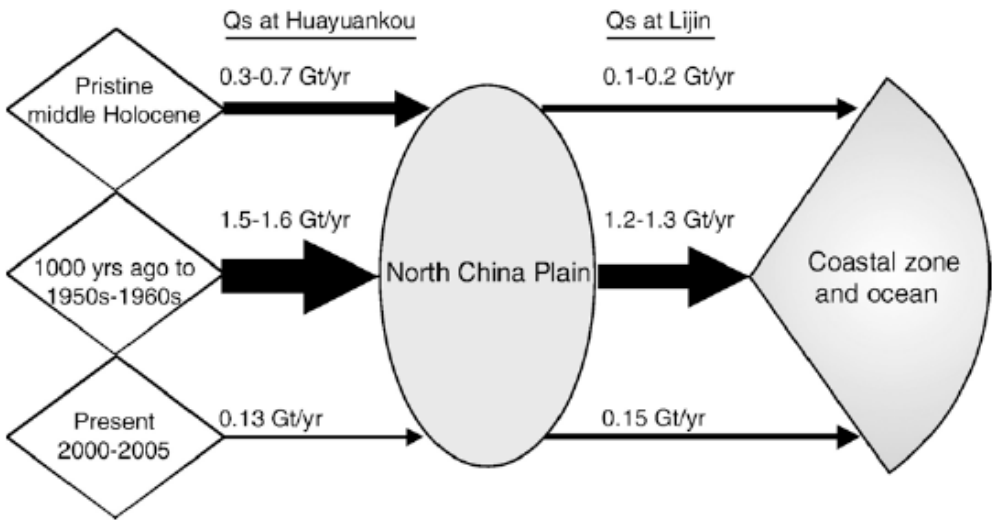
Big dams

Sanmenxia Liujiaxia Longyangxia Xiaolangdi

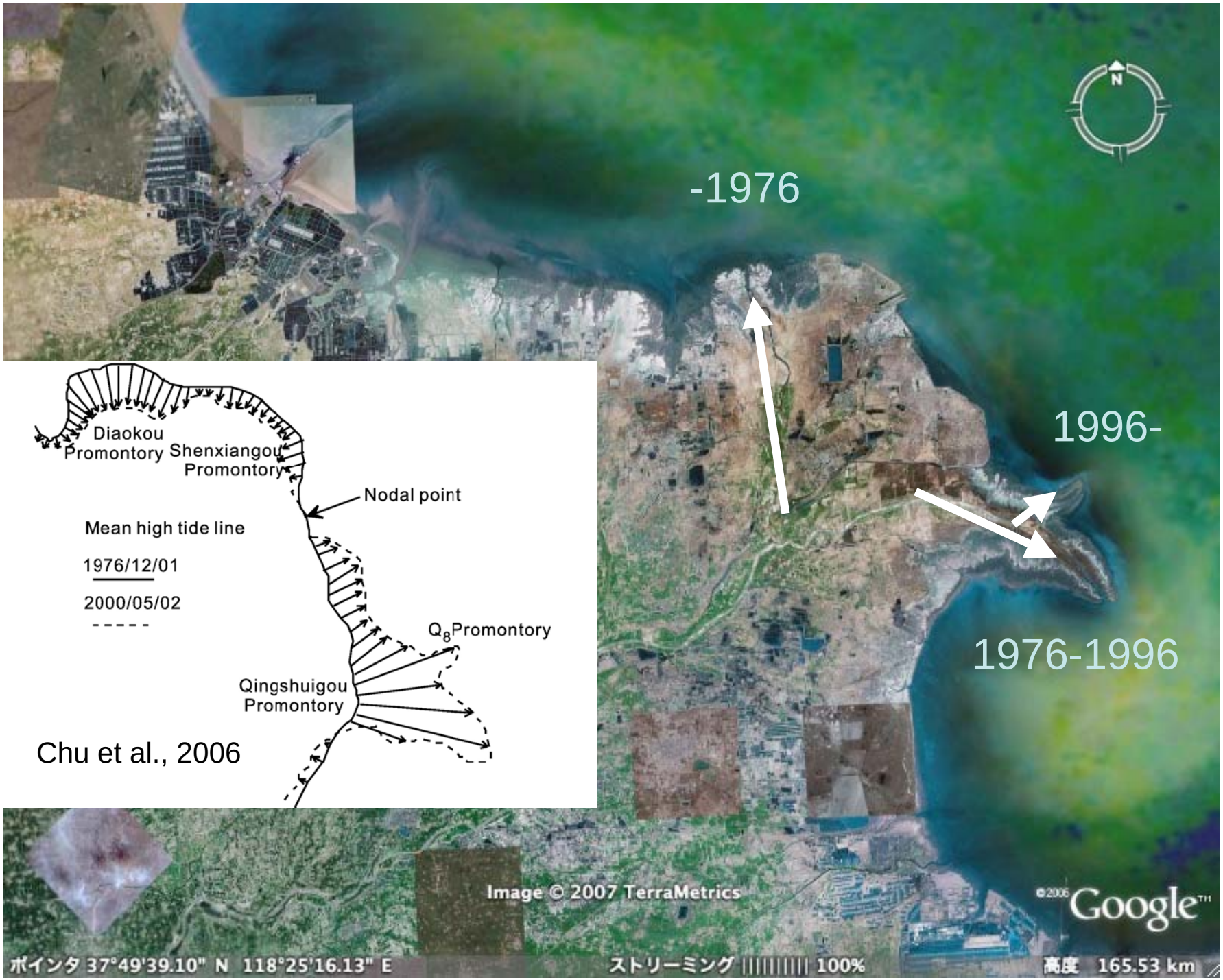


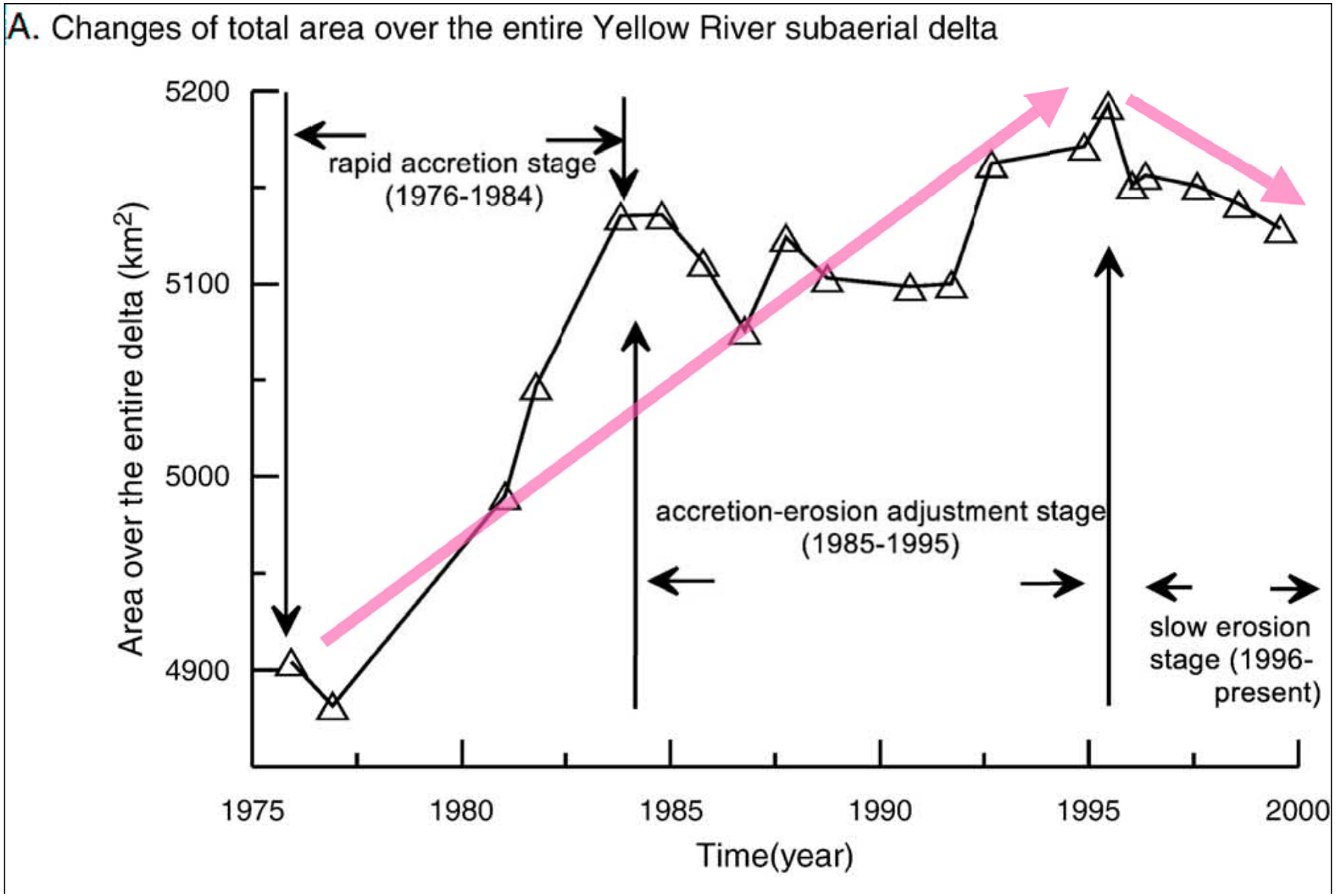
Wang et al., 2007



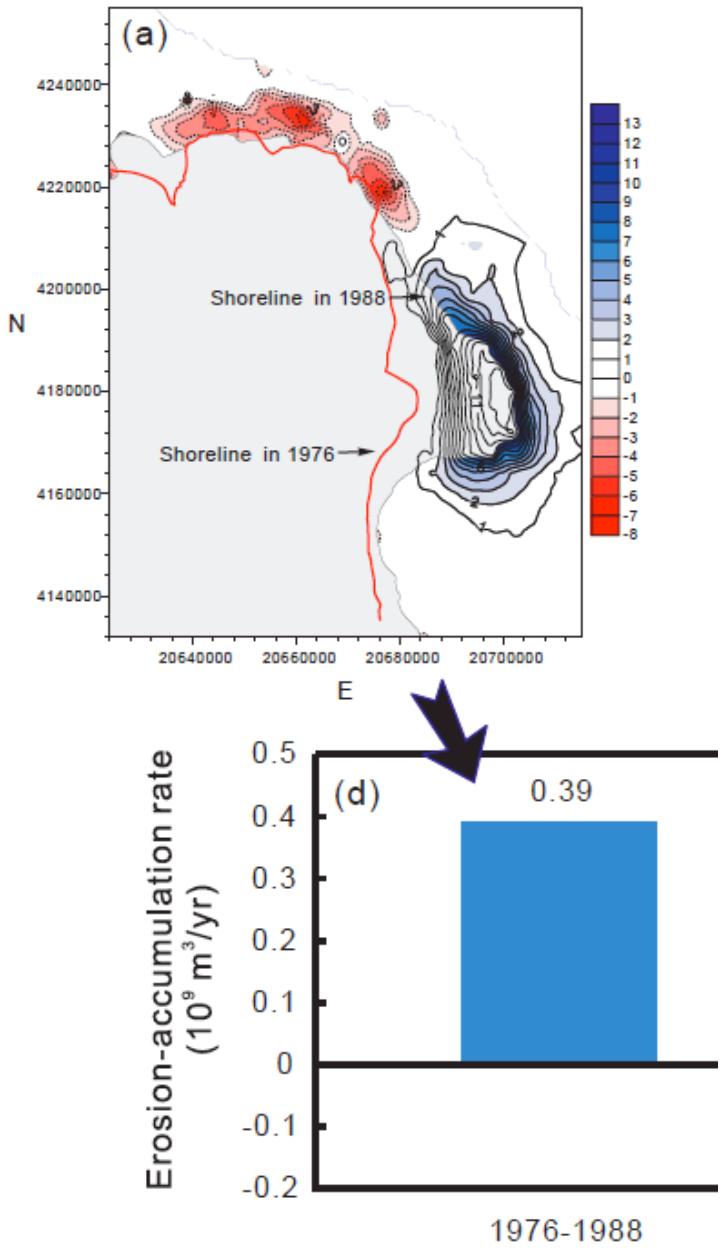


Wang et al., 2007

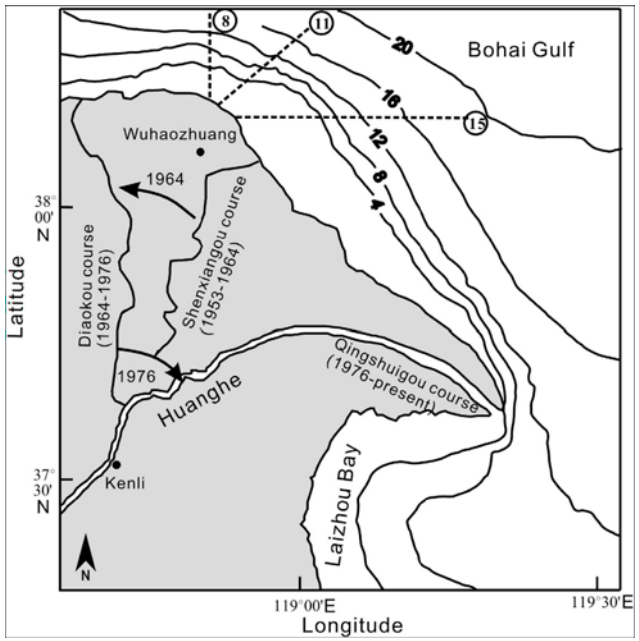

-1976
1996-
1976-1996
Diaokou Promontory
Shenxiangou Promontory
Nodal point
Mean high tide line
1976/12/01
2000/05/02
Q_8Promontory
Qingshuigou Promontory
Chu et al., 2006
Image © 2007 TerraMetrics
©2006 Google
ポインタ 37°49'39.10" N 118°25'16.13" E
ストリーミング 100%
高度 165.53 km

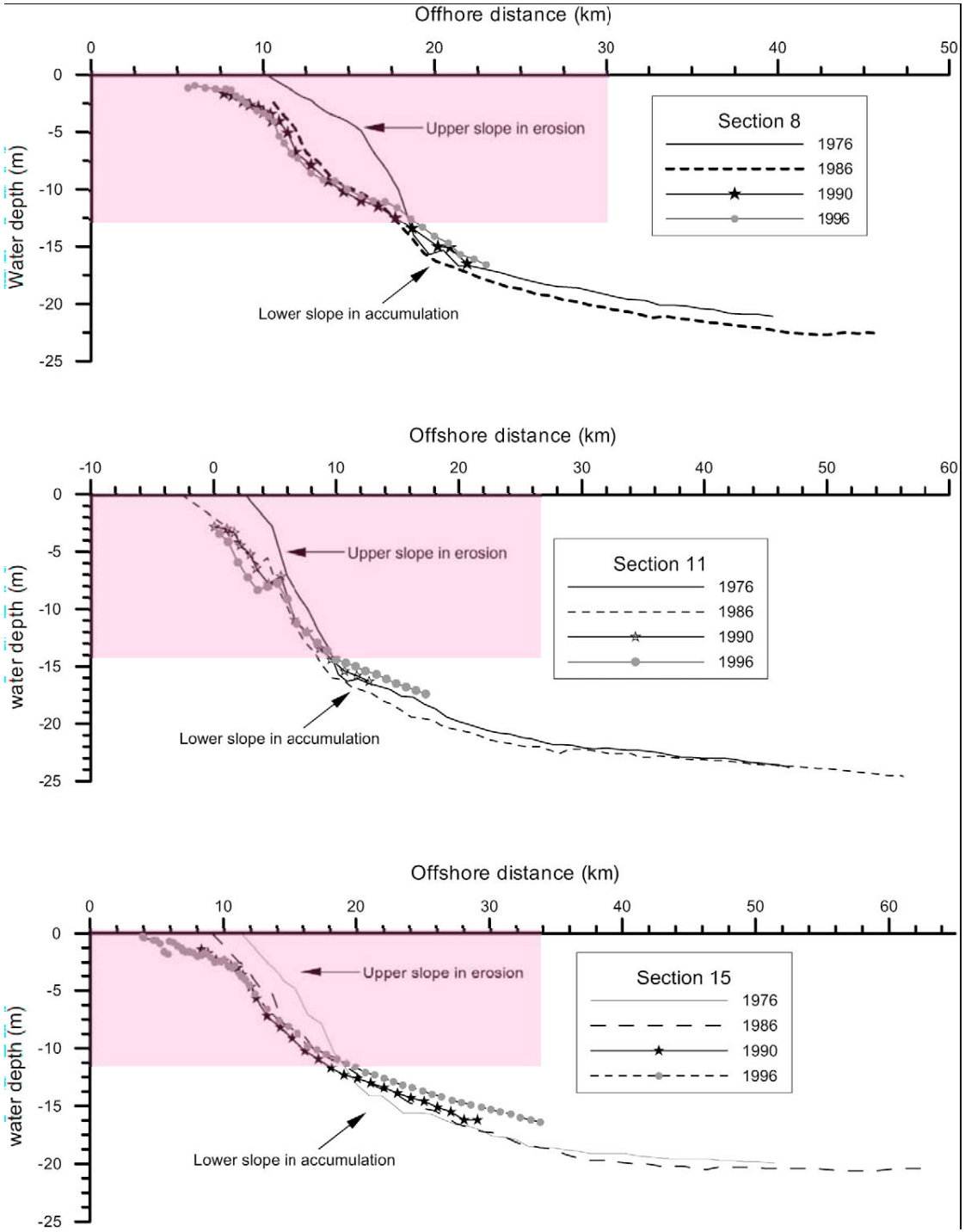


Satellite image analysis: Chu et al., 2006



Yang et al. in prep

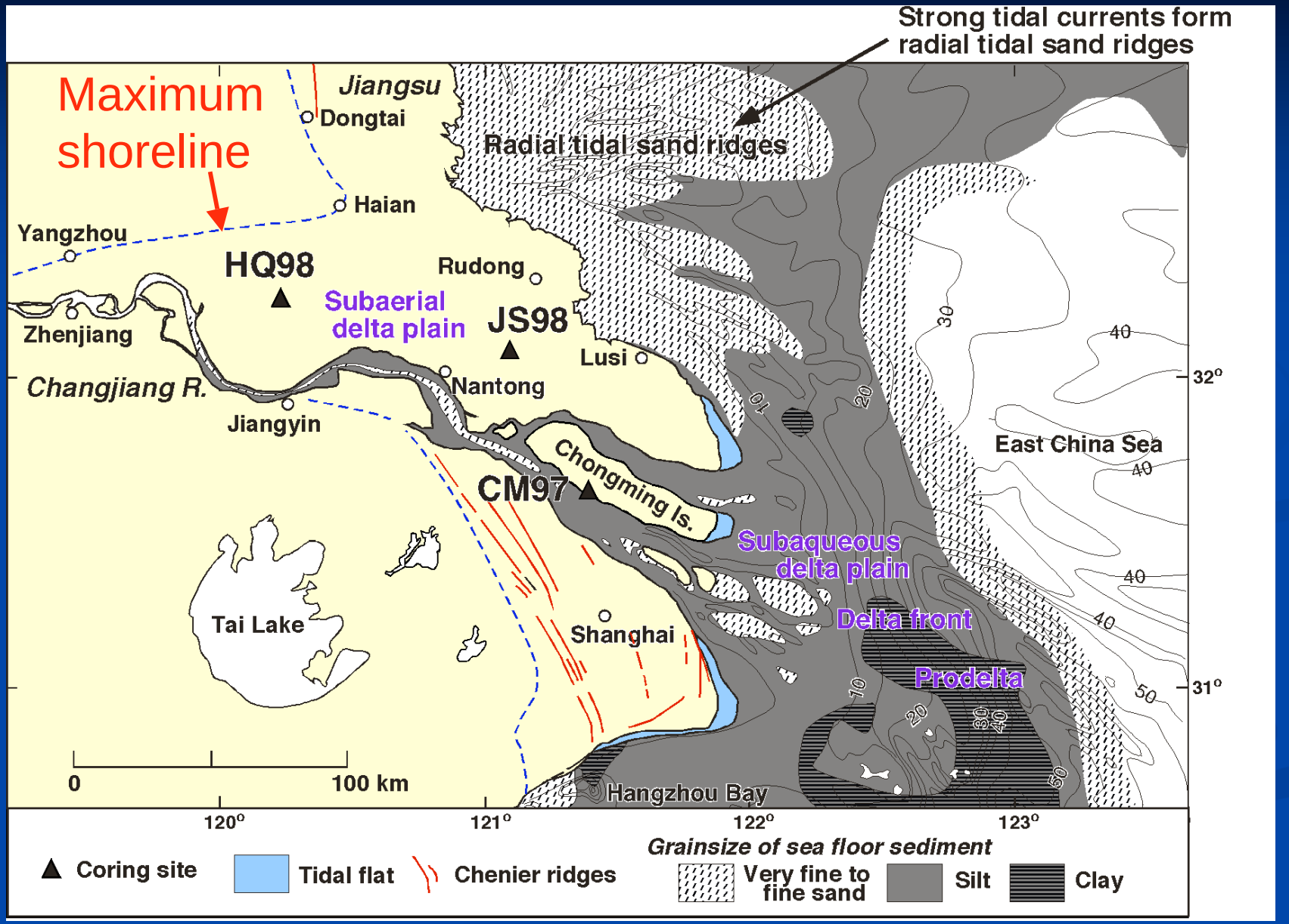




Boundary depth:11-14 m

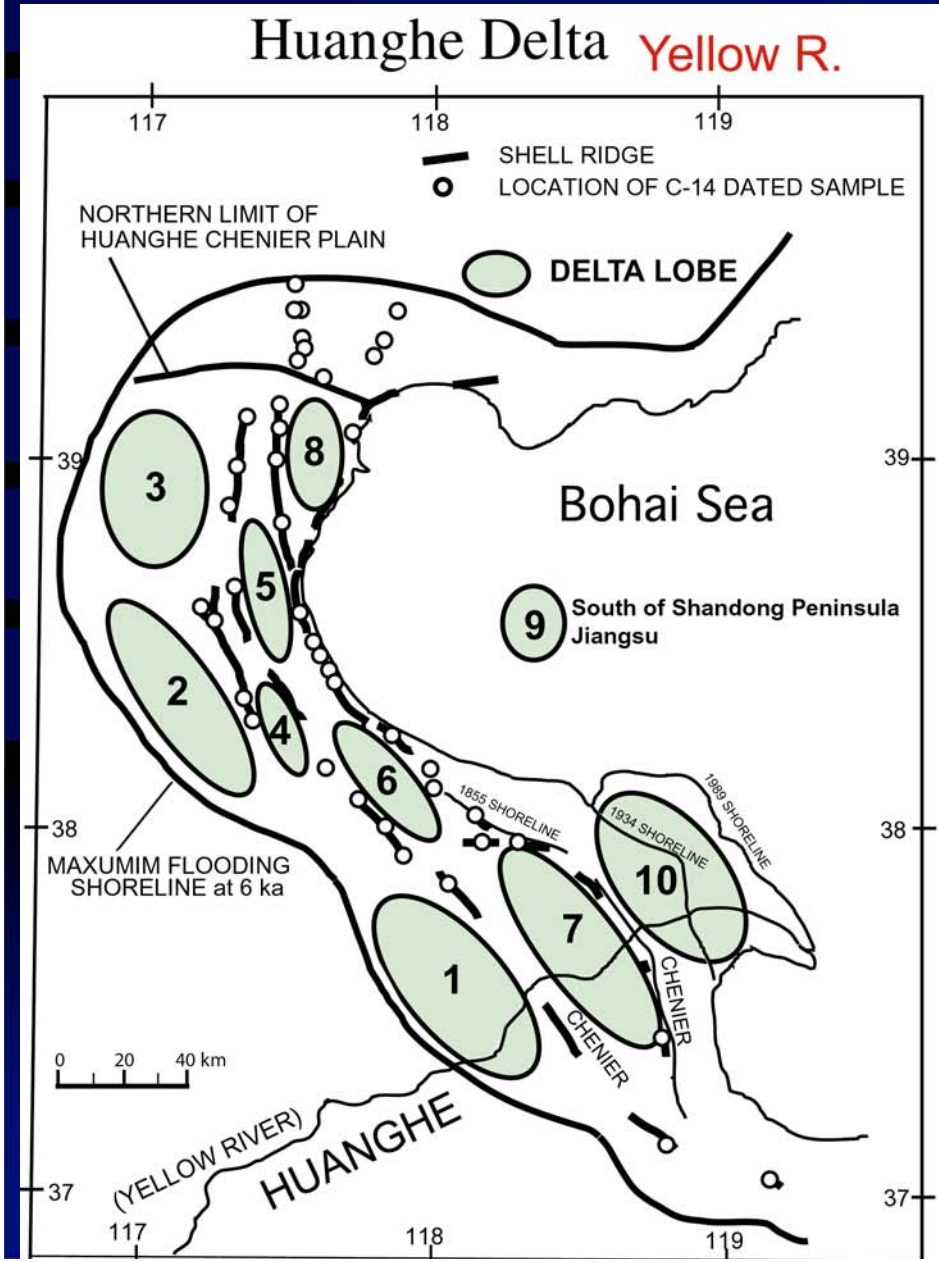
Wang et al.,2006

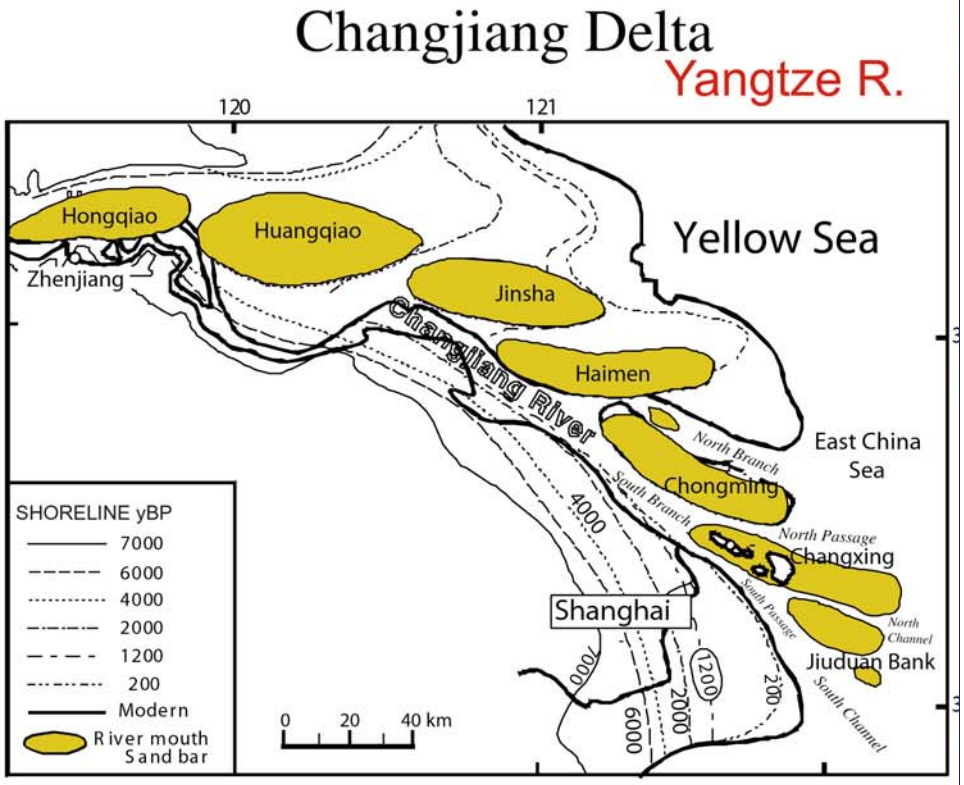
Changjiang (Yangtze delta), drilling core locations & sea-bottom sediment



The delta has prograded more than 250 km during the last 6000 years (= ca. 40m/yr)

YELLOW RIVER & YANGTZE DELTAS



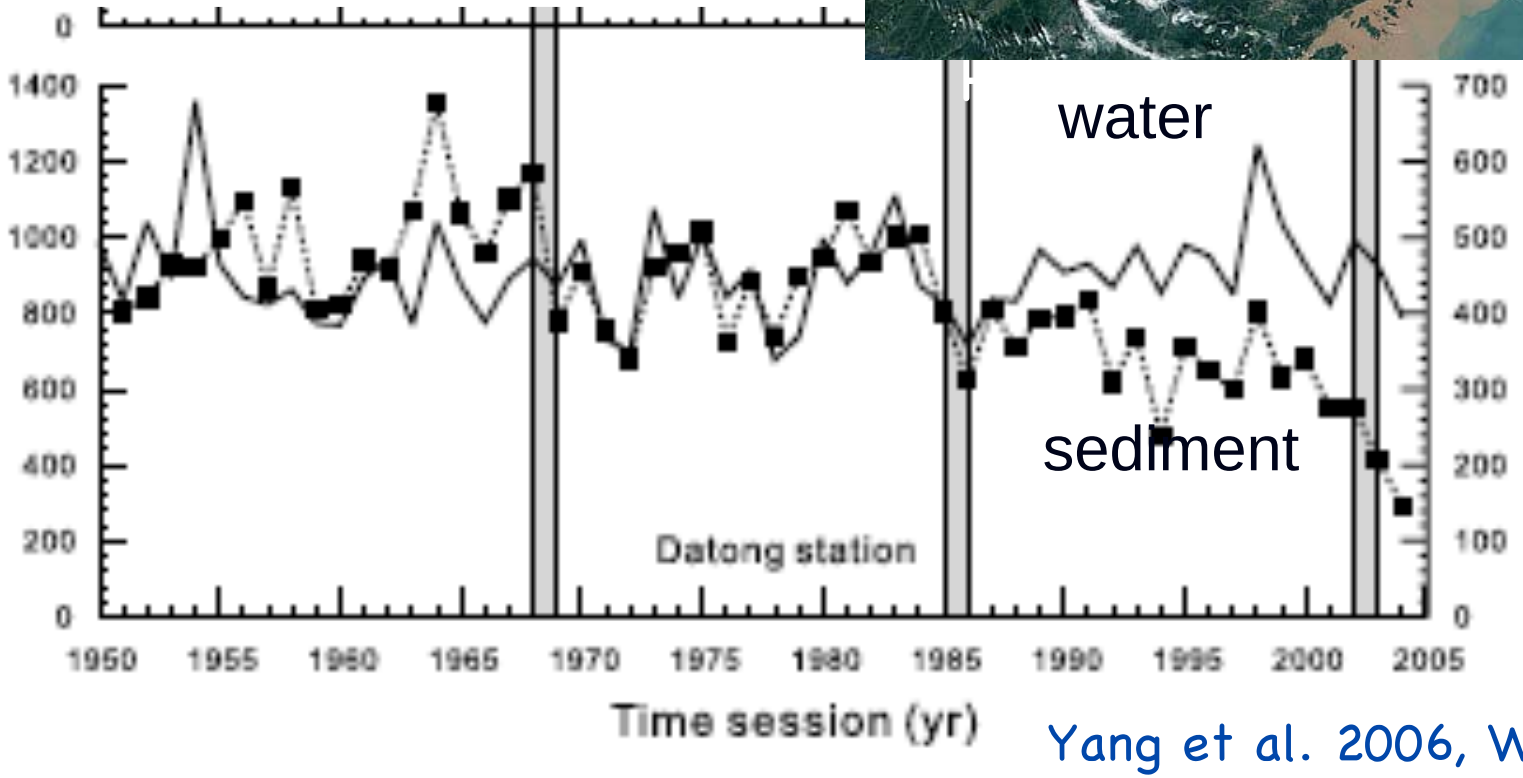


Saito et al., 2001, Geomorphology

Yangtze sediment discharge

480 MT/y to ca. 150 MT/y

Pristine: 200-250 MT/y before 2ka



Yang et al. 2006, WRR

Yangtze delta

Yang SL et al. GRL 2006

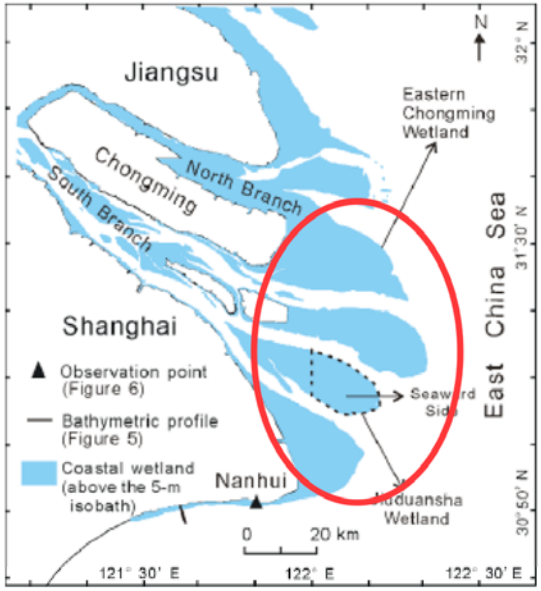


Figure 1. A map of the Yangtze delta (compiled with bathymetric maps updated in 2004) showing the study sites of intertidal elevation observation point, cross-shore bathymetric profile, and coastal wetlands (eastern and Jiuduansha).

Table 1. Temporal Variations in Area and Progradation Rate of Jiuduansha Wetland (Above the 5 m Isobath)[a]

	Whole		Side Toward the Sea[b]	
Year	Area, km^2	Rate, km^2/yr	Area, km^2	Rate, km^2/yr
2004	410	−1.0	236	−3.83
2000	414	2.0	251	3.08
1996	406	6.6	239	5.4
1958	156		34	

[a]Negative sign represents recession.
[b]Eastern area from longitude 122°E.

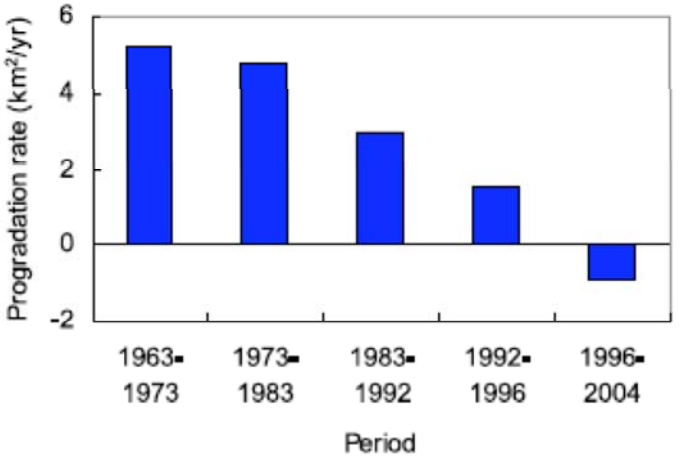
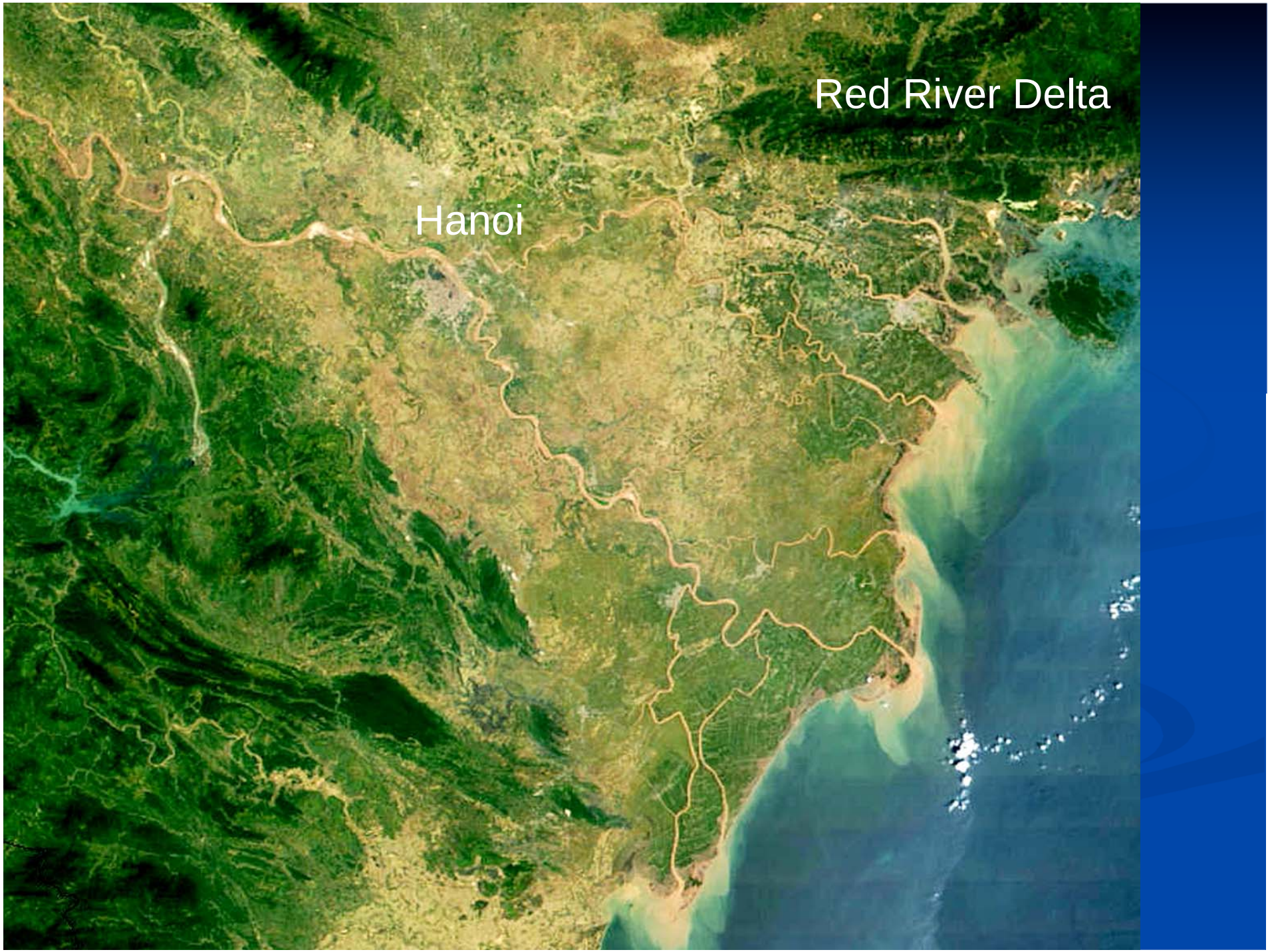
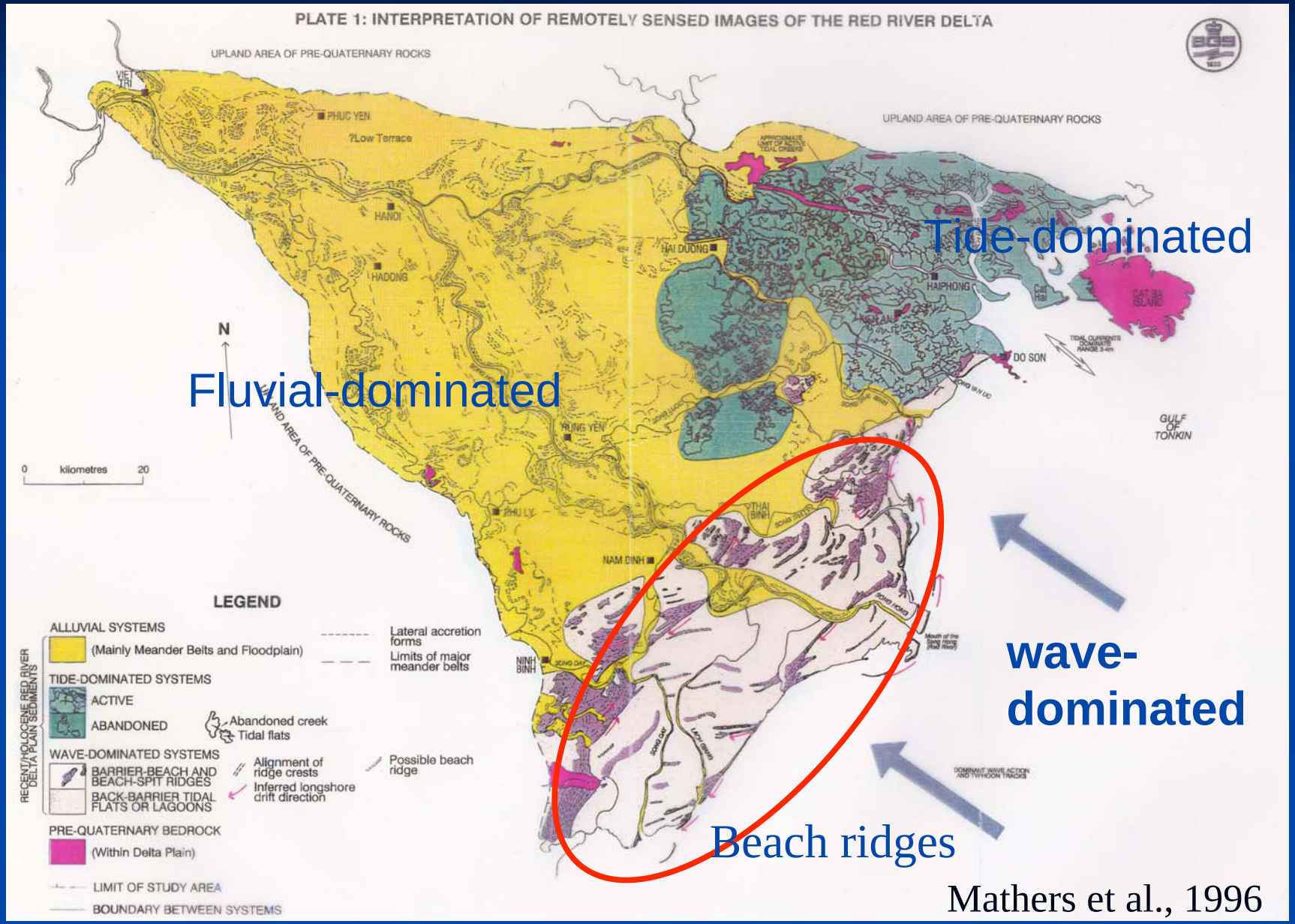


Figure 4. Temporal variations in progradation rate of the intertidal wetland at the eastern Chongming Island.


Red River Delta
Hanoi

SONG HONG (RED RIVER) DELTA EVOLUTION, VIETNAM



Mathers et al., 1996

Sediment discharge of the Red River

1959-1985: 114 MT/y
1986-1997: 79 MT/y
1992-2001: 51 MT/y

Hoa Binh dam (1989)

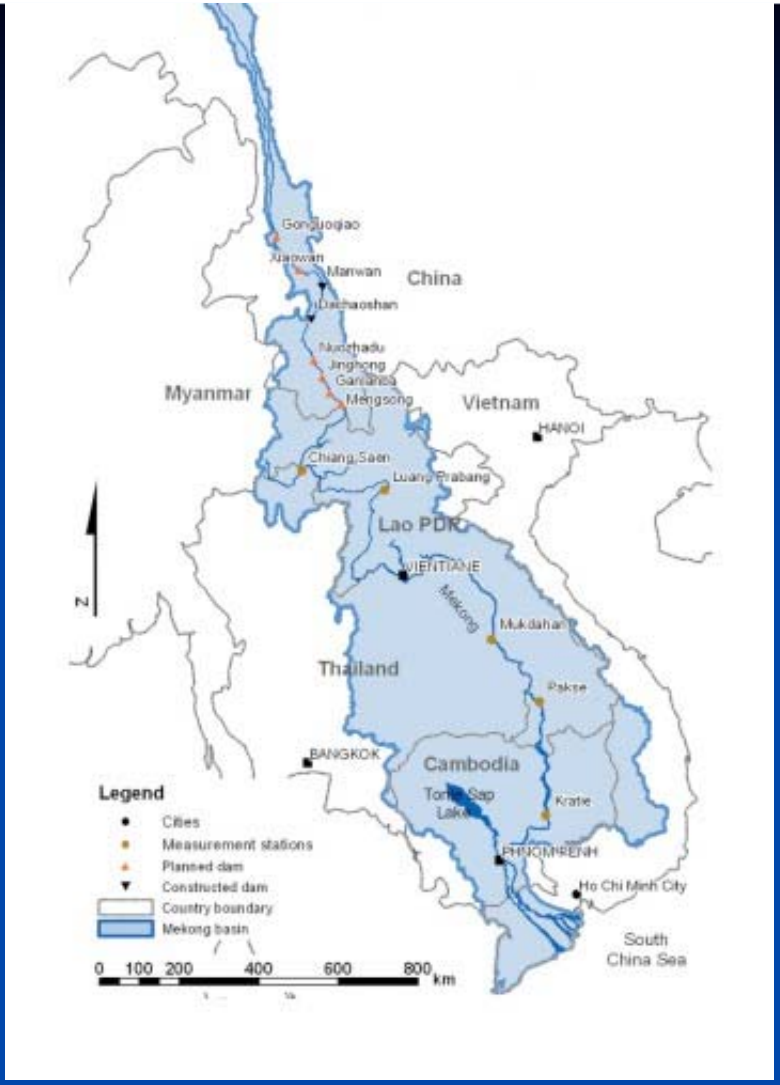
Main channel: 49 MT/y in 1949 to 11 MT/y in 2000

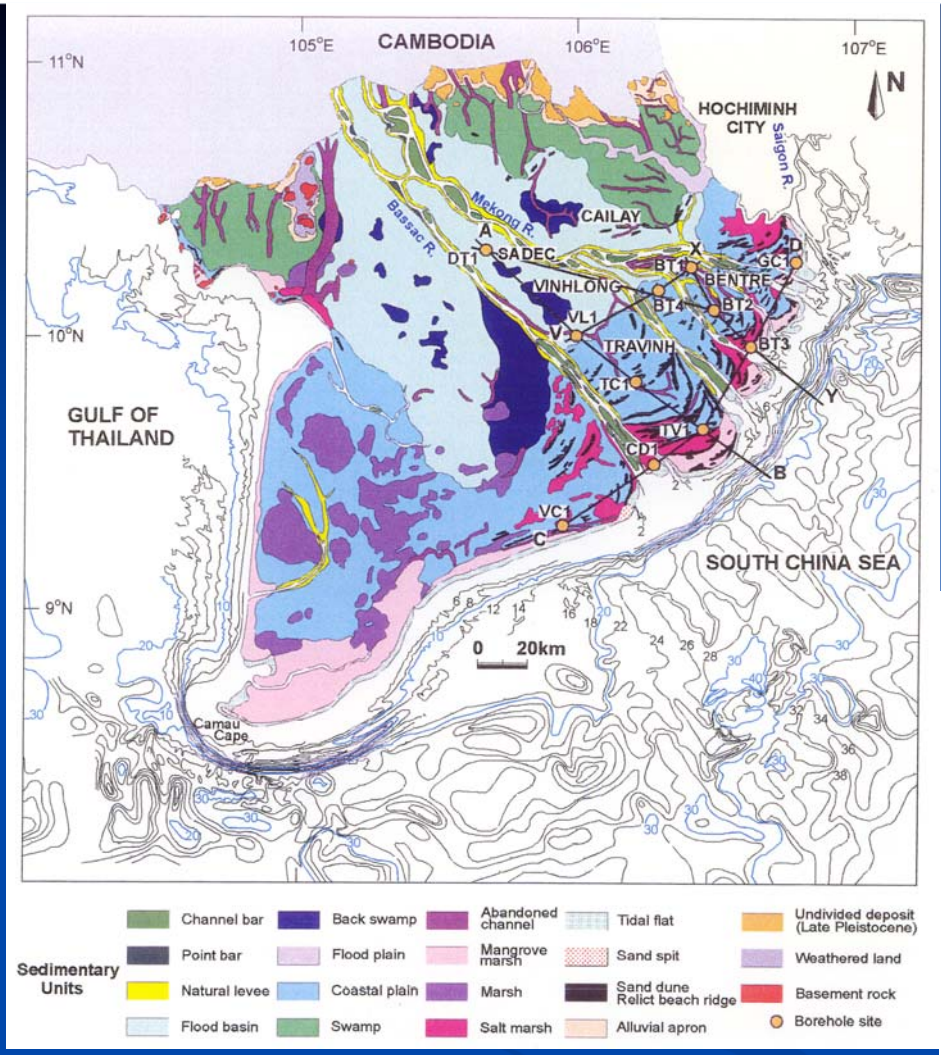
Pristine: 20 MT/y before 3-5 ka
More than 100 km progradation for the last 6 ky

Thanh et al., 2004
Van Maren, 2004
Saito et al., 2007
Tanabe et al., 2006

coastal erosion

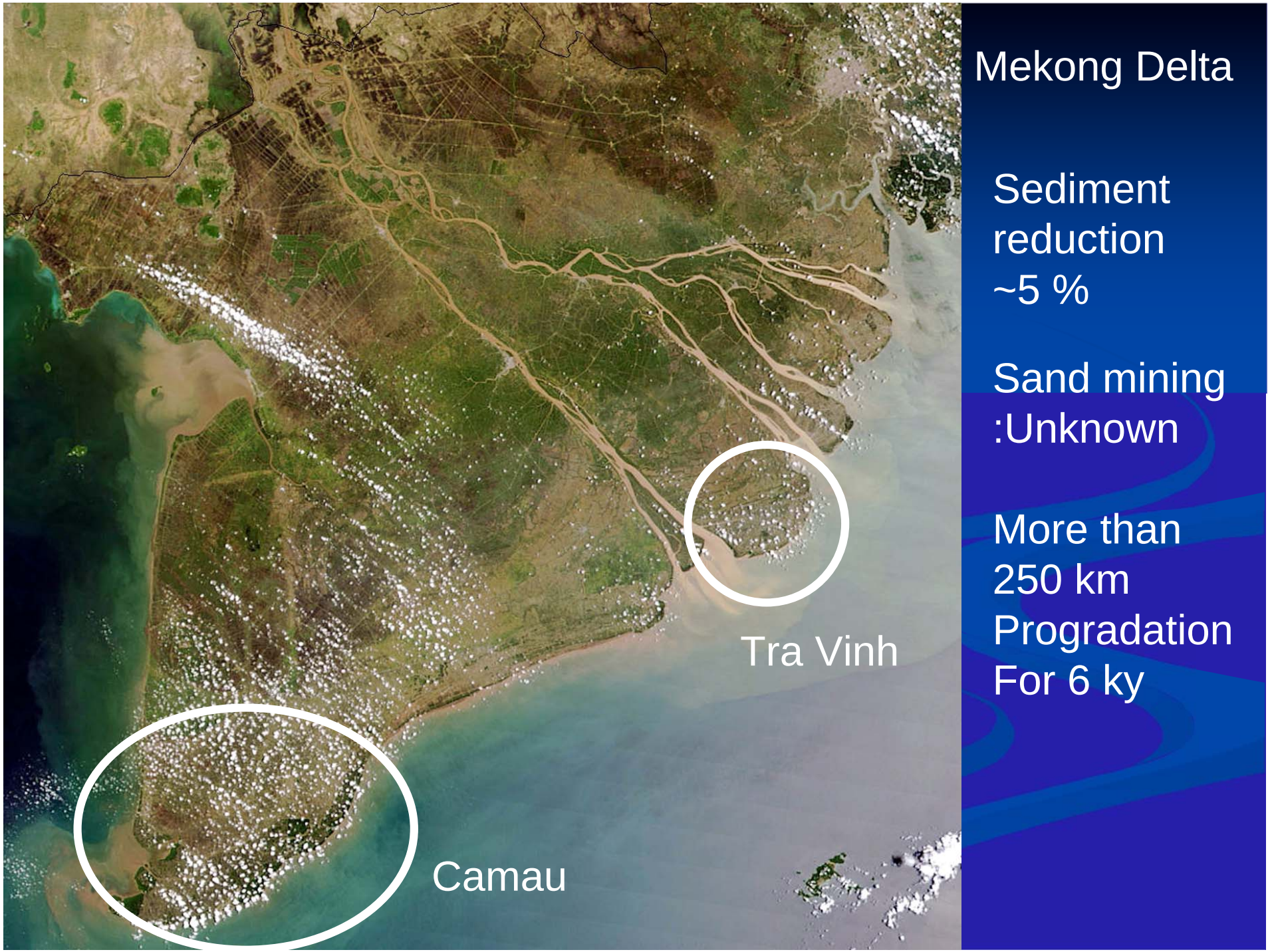
Thanh et al. 2004



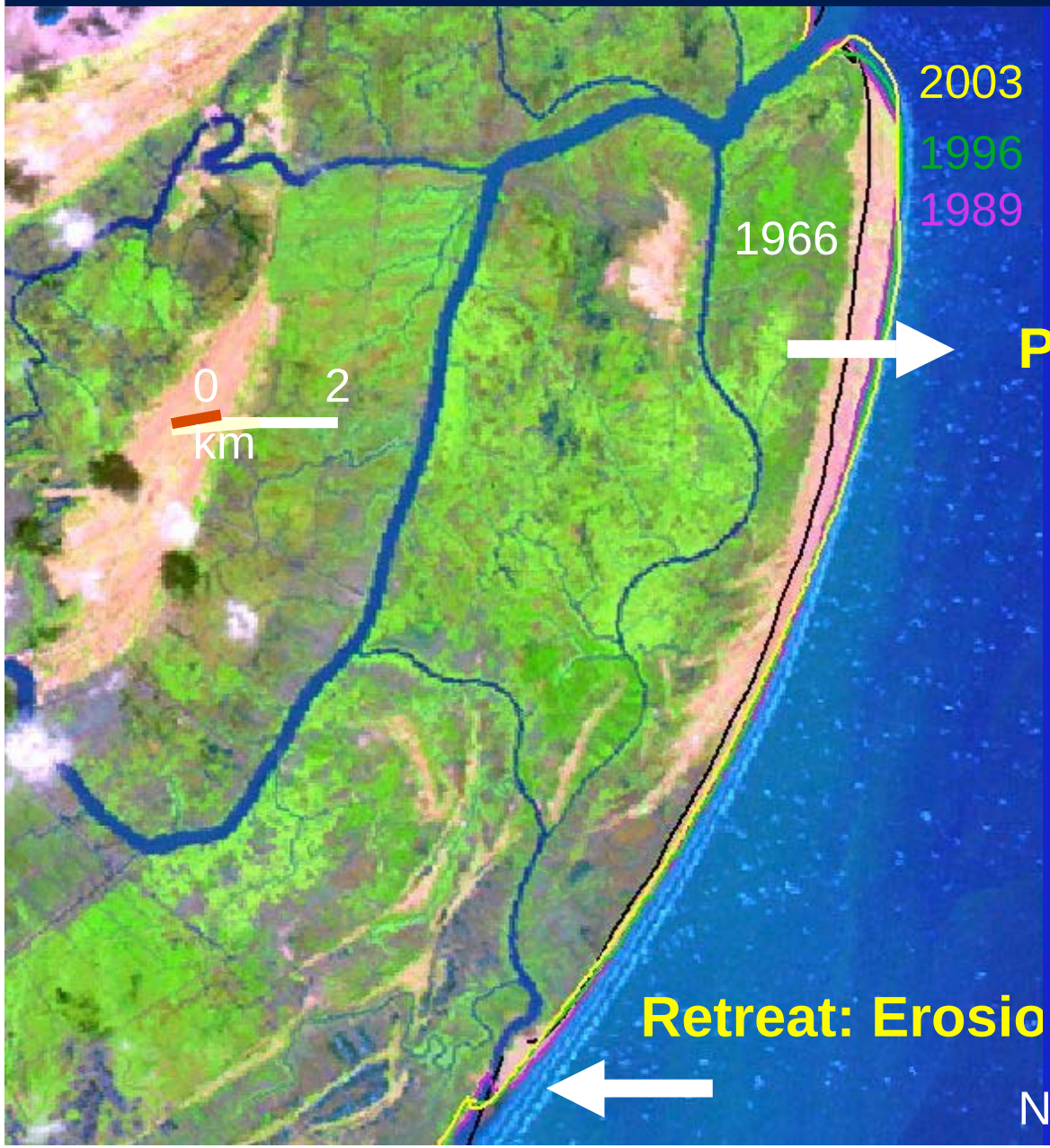


Catchment area: 795,000 km^2
Main stream length: 4,800 km
Mean flow: 14,500 m^3/s
Run off: 575 mm

Delta area: 62,520 km2
Mean tidal range: 2.5 m
Mean wave height: 0.9 m
Water discharge: 470 km3/y
Sediment discharge: 160 million t/y


Mekong Delta
Sediment reduction ~5 %
Sand mining :Unknown
More than 250 km Progradation For 6 ky
Tra Vinh
Camau

Shoreline changes in Tra Vinh area



1996-2003

Progradation: Deposition

Retreat: Erosio

NGUYEN Van Lap et al., 2006

Shrimp pond

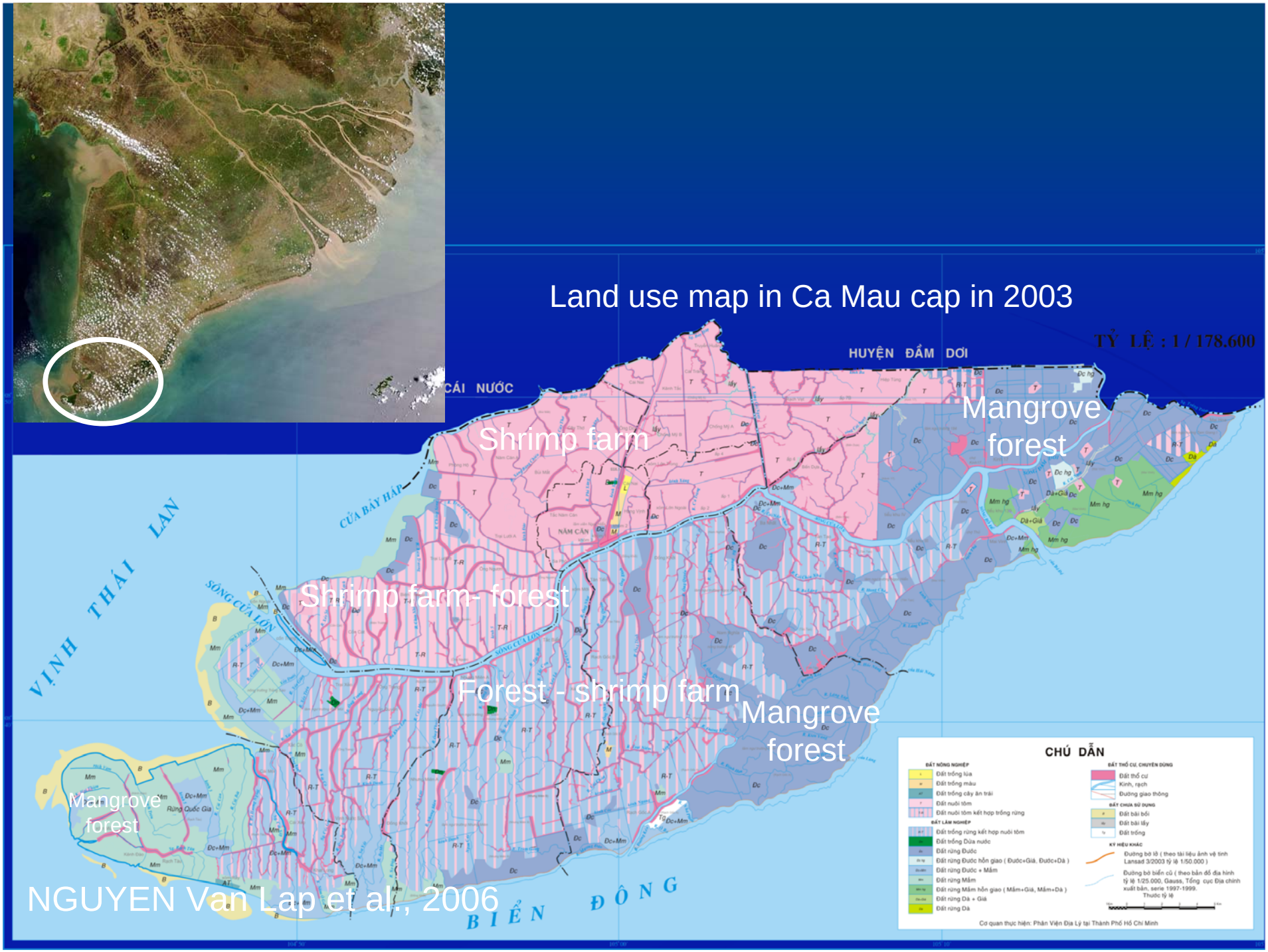
NGUYEN Van Lap et al., 2006

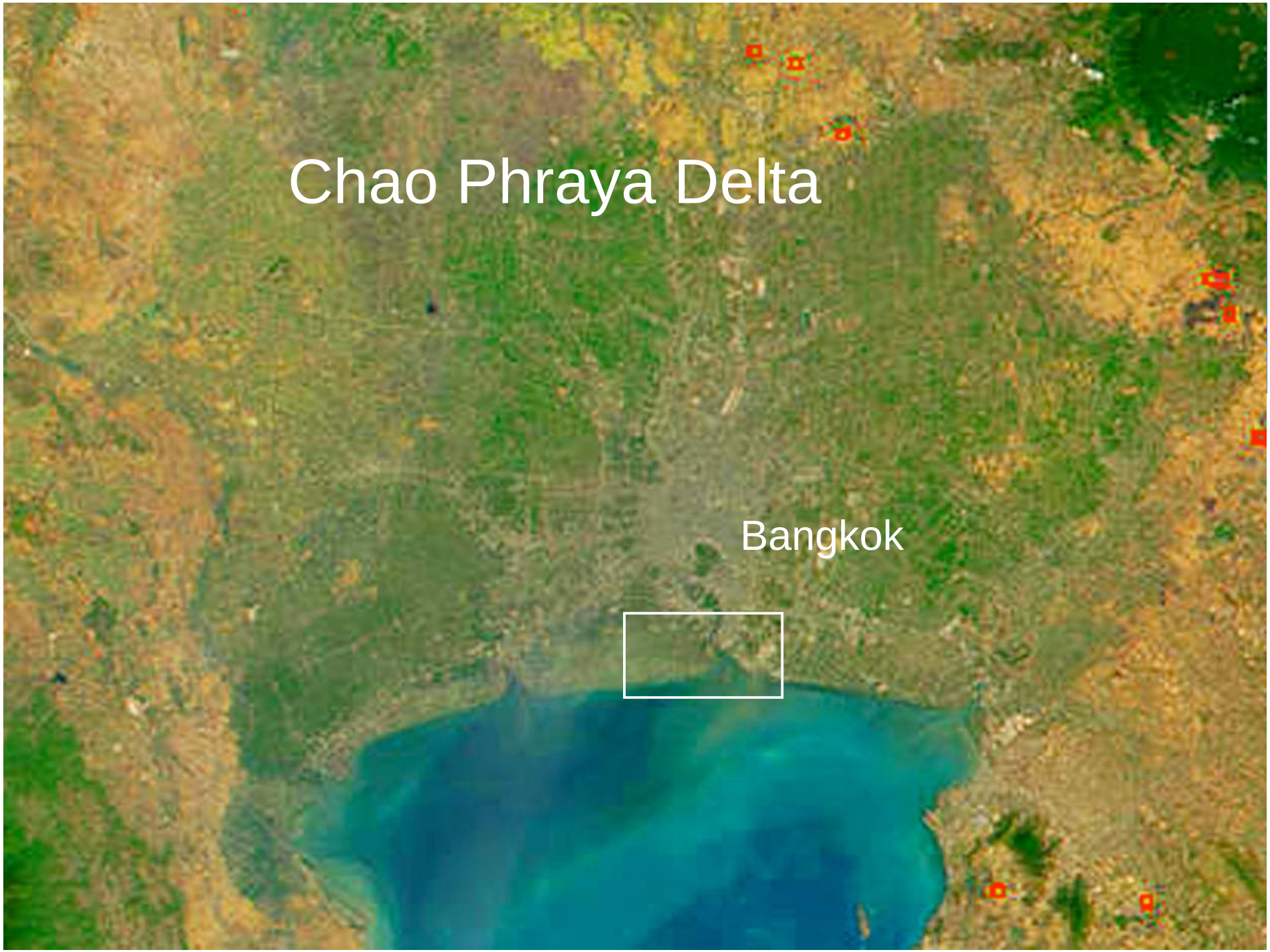

NGUYEN Van Lap et al., 2006

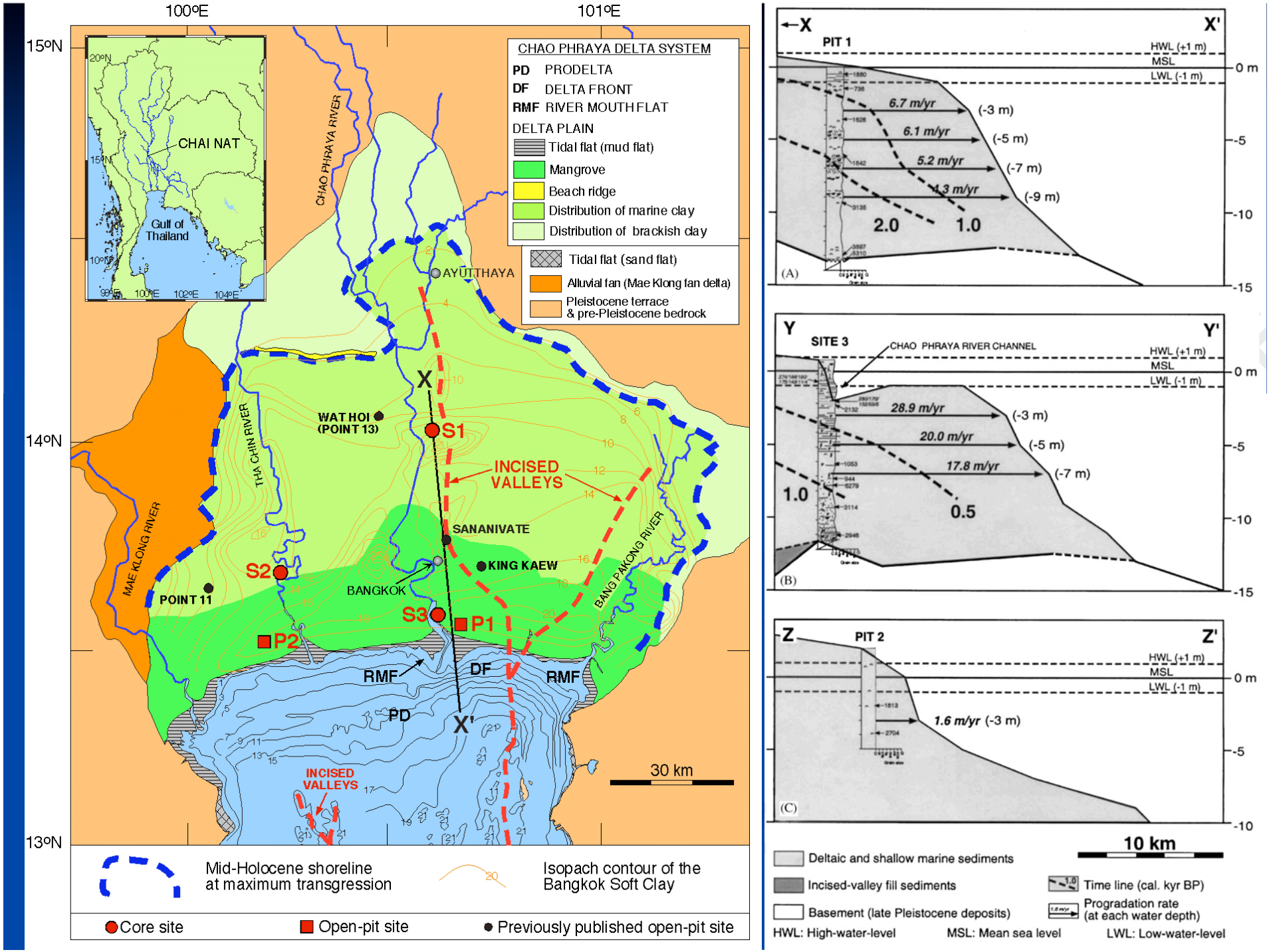
Area of mangrove forest in Tra Vinh coast (ha)

1960	1970	1980	1990	1992	1996	2005
40,000	16,300	12,400	5,924	3,725	1,384	6,218

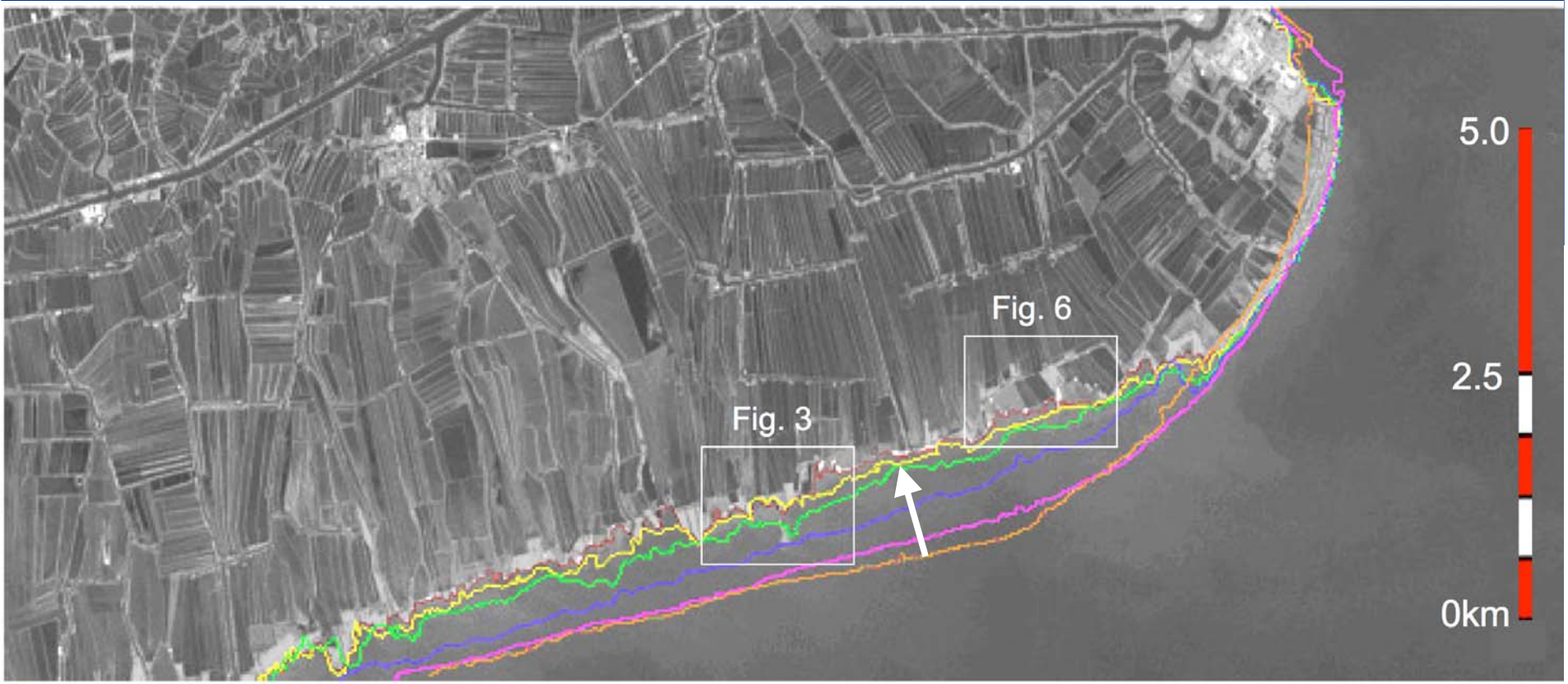
NGUYEN Van Lap et al., 2006


Land use map in Ca Mau cap in 2003
Shrimp farm
Mangrove forest
Shrimp farm- forest
Forest - shrimp farm
Mangrove forest
Mangrove forest
NGUYEN Van Lap et al., 2006
HUYỆN ĐẦM DƠI
TỶ LỆ : 1 / 178.600
CÁI NƯỚC
VỊNH THÁI LAN
BIỂN ĐÔNG
CHÚ DẪN


Chao Phraya Delta
Bangkok


100ºE
101ºE
15ºN
14ºN
13ºN
CHAO PHRAYA DELTA SYSTEM
PD PRODELTA
DF DELTA FRONT
RMF RIVER MOUTH FLAT
DELTA PLAIN
Tidal flat (mud flat)
Mangrove
Beach ridge
Distribution of marine clay
Distribution of brackish clay
Tidal flat (sand flat)
Alluvial fan (Mae Klong fan delta)
Pleistocene terrace
& pre-Pleistocene bedrock
CHAI NAT
Gulf of Thailand
CHAO PHRAYA RIVER
AYUTTHAYA
WAT HOI (POINT 13)
THA CHIN RIVER
MAE KLONG RIVER
BANG PAKONG RIVER
INCISED VALLEYS
SANANIVATE
KING KAEW
BANGKOK
POINT 11
S1
S2
S3
P1
P2
X
X'
RMF
DF
PD
INCISED VALLEYS
30 km
Mid-Holocene shoreline
at maximum transgression
Isopach contour of the
Bangkok Soft Clay
Core site
Open-pit site
Previously published open-pit site
X
X'
PIT 1
HWL (+1 m)
MSL
LWL (-1 m)
6.7 m/yr
(-3 m)
6.1 m/yr
(-5 m)
5.2 m/yr
(-7 m)
4.3 m/yr
(-9 m)
2.0
1.0
(A)
Y
Y'
SITE 3
CHAO PHRAYA RIVER CHANNEL
28.9 m/yr
(-3 m)
20.0 m/yr
(-5 m)
17.8 m/yr
(-7 m)
1.0
0.5
(B)
Z
Z'
PIT 2
1.6 m/yr (-3 m)
(C)
0 m
-5
-10
-15
10 km
Deltaic and shallow marine sediments
Incised-valley fill sediments
Basement (late Pleistocene deposits)
Time line (cal. kyr BP)
Progradation rate
(at each water depth)
HWL: High-water-level
MSL: Mean sea level
LWL: Low-water-level

1 km shoreline retreat at the river mouth of the Chao Phraya



Rokugawa et al., 2006; Saito et al., 2007

Chao Phraya delta

Marine Inundation

Sediment discharge of the Chao Phraya River

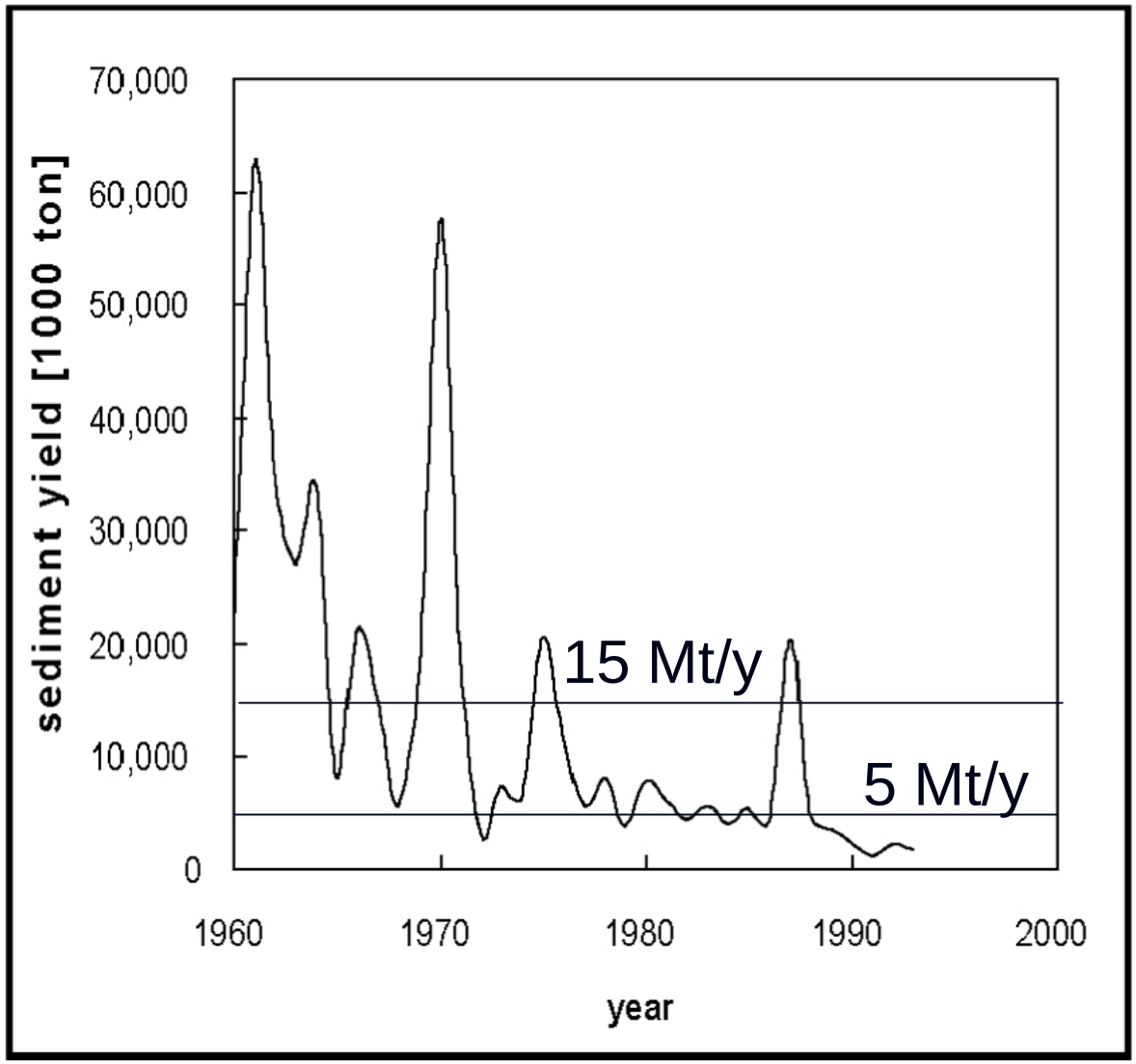
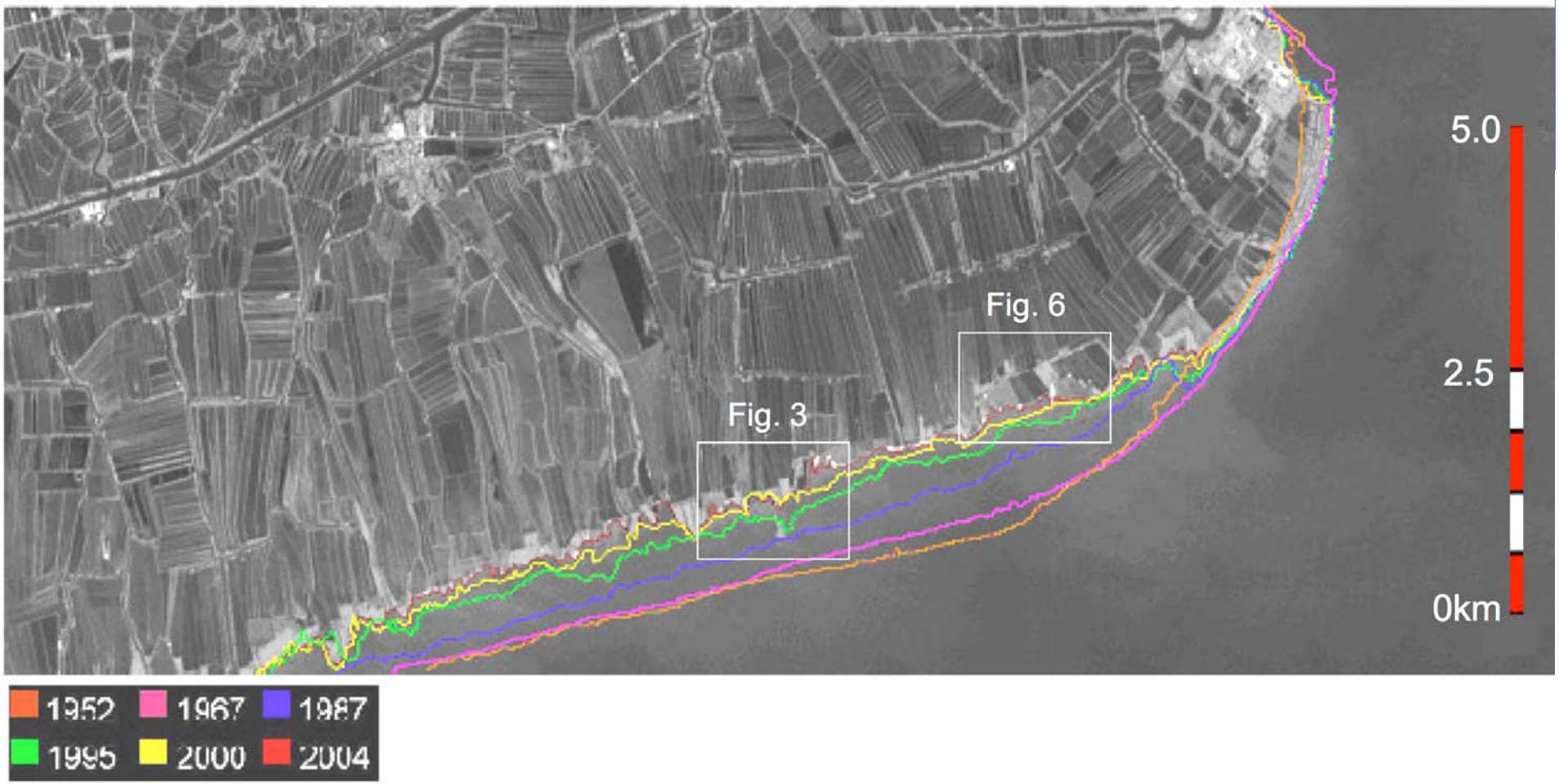


Figure 5. Sediment yield Chao Phraya River; the Bhumipol dam became in operation in 1965 and the Sirikit dam in 1972.

Winterwerp et al., 2005

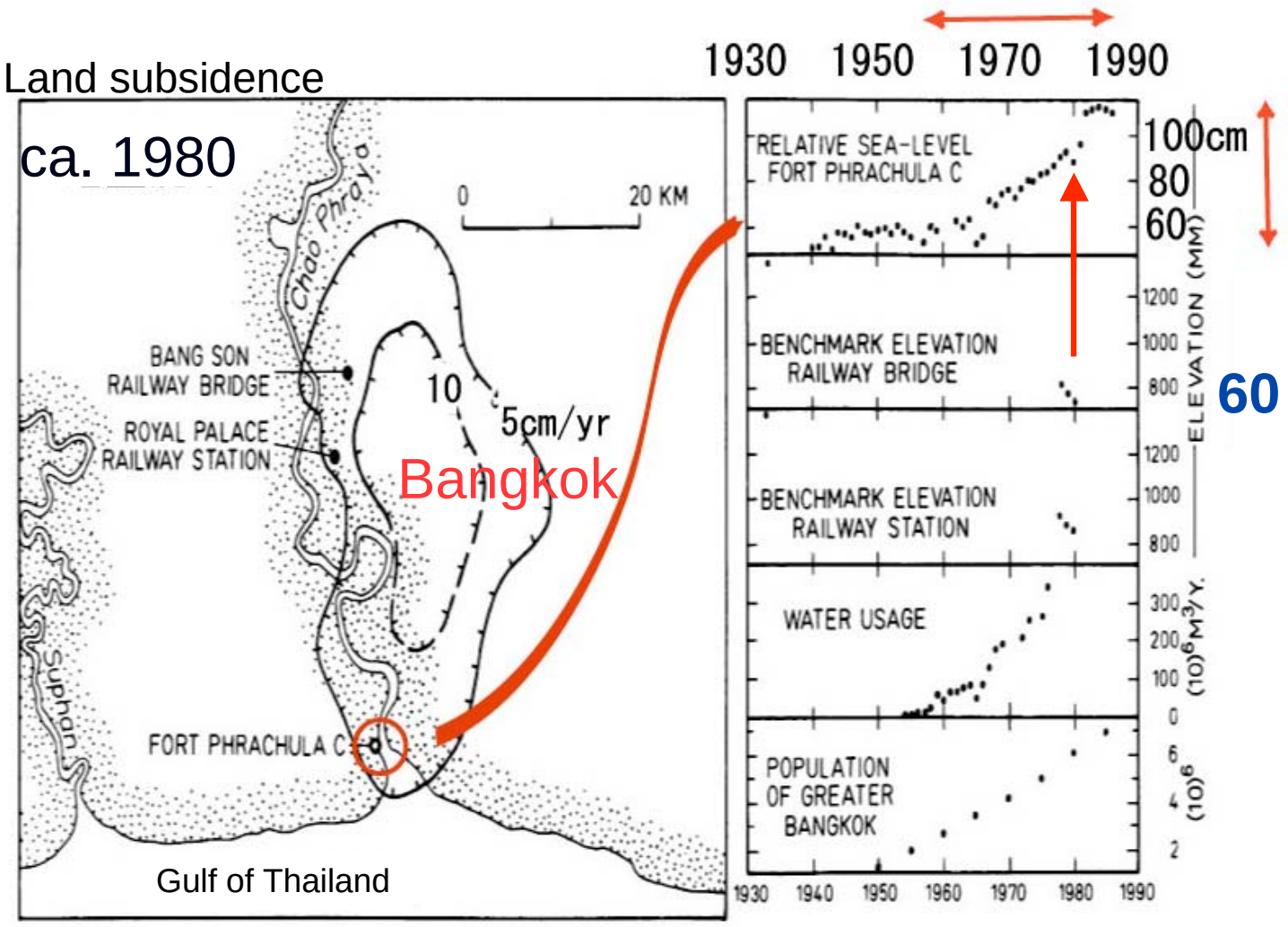
Upper Gulf of Thailand

During 1969–1976, accretion: 8.9 km^2, erosion: 4.5 km^2 net accretion rate: 0.62 km^2/y;
During 1976–1987, accretion 4.9 km^2, erosion 10.3 km^2, net accretion rate: –0.49 km^2/y
During 1987–1997, accretion 7.4 km^2 , erosion 4.5 km^2, net accretion rate 0.25 km^2/y



Saito et al., 2007

Relative sea-level rise due to subsidence



60 cm rise in SL 1960-1990

Haq, 1994

Land subsidence
During 1992-2000

>20 cm/ 8 years
2-3.5 cm/y: coast
(<4.5 cm/y inland)

More than 1m
Sea-level rise
For the last 50 y

Winterwerp
et al., 2005

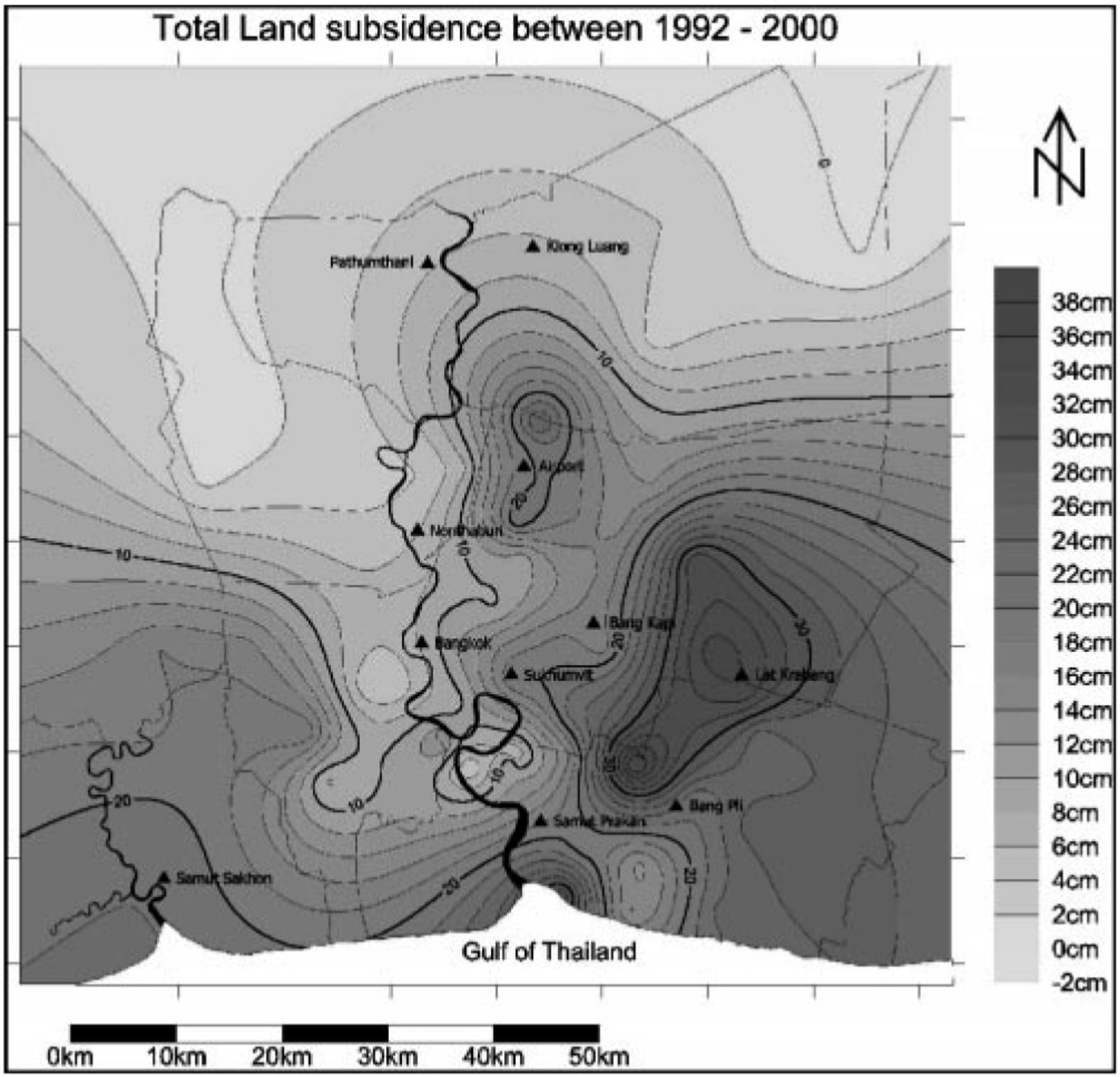
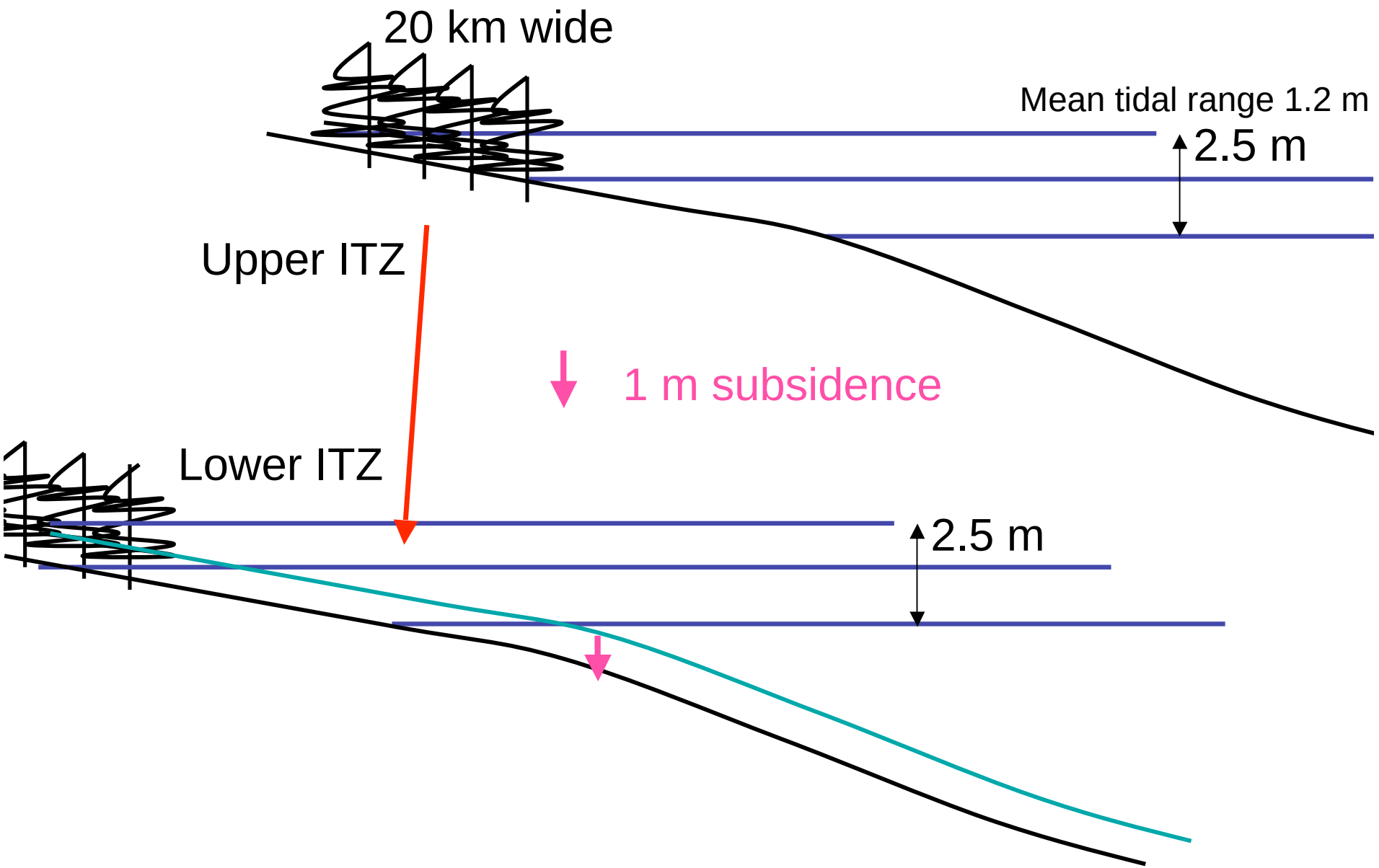
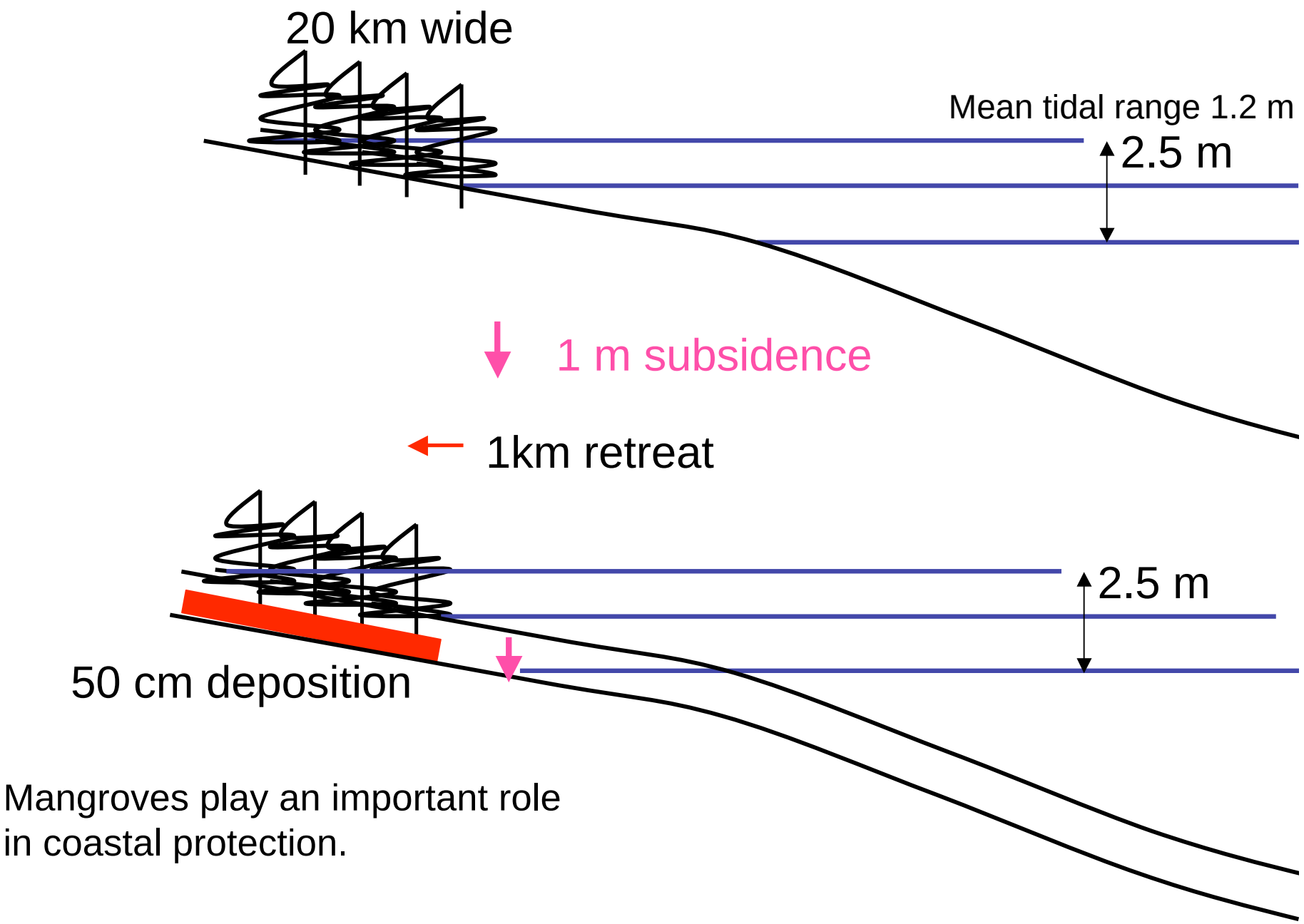


Figure 4. Measured land subsidence in the period 1992–2000.

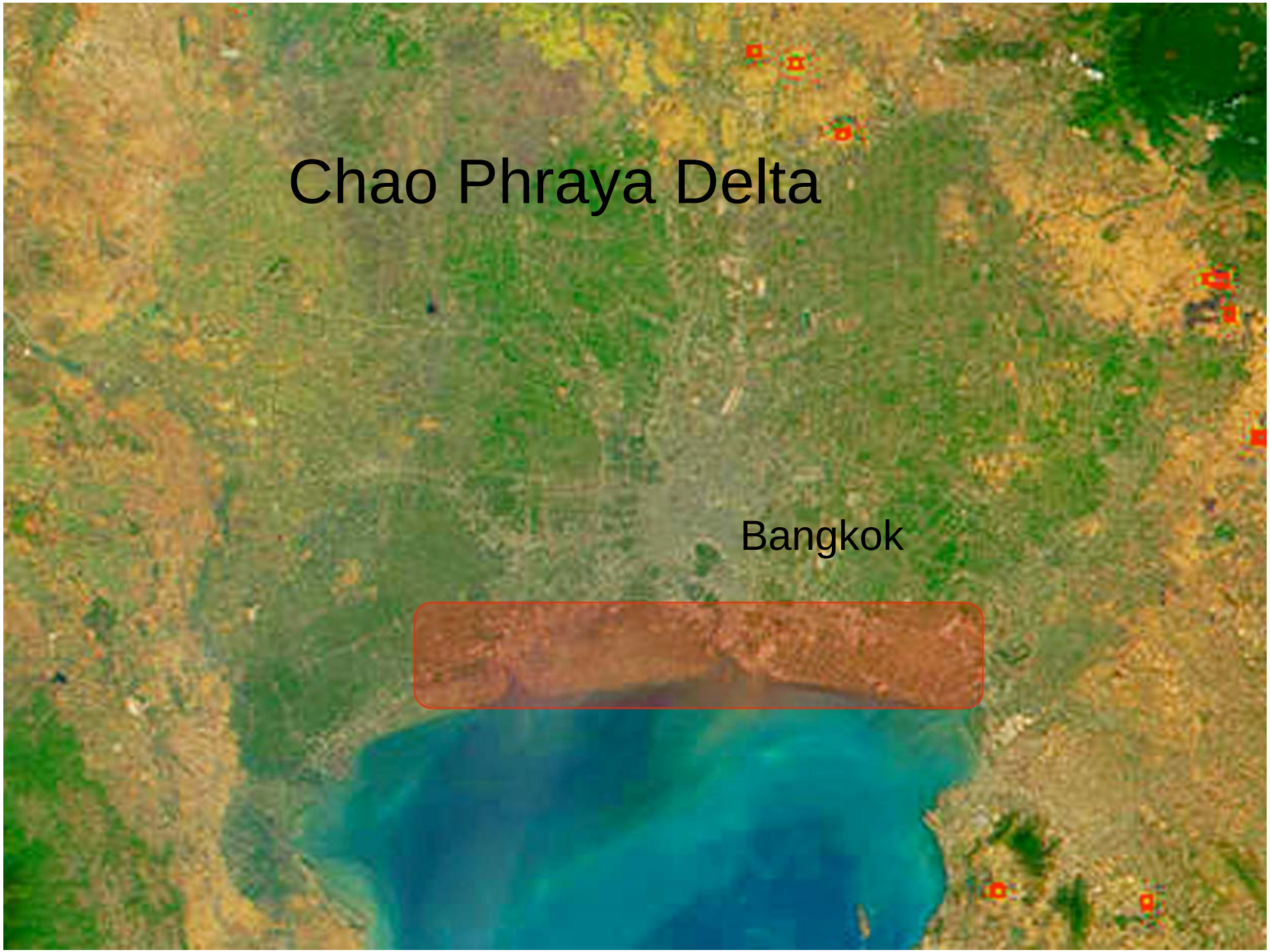
Rapid sediment deposition in the intertidal zone
(~50 cm thick sediment deposition during 1 m sea-level rise)

Saito et al., 2007


20 km wide
Mean tidal range 1.2 m
2.5 m
Upper ITZ
1 m subsidence
Lower ITZ
2.5 m



Mangroves play an important role in coastal protection.


Chao Phraya Delta
Bangkok

Zhujiang (Pearl River)

The Zhujiang shows a similar reduction of sediment delivery. The annual sediment discharge from the Zhujiang has declined from 80 Mt to 54 Mt on average since 1995. As a result of the steady decline since the early 1990s, in 2004 the annual sediment discharge was about one-third the mean pre-1990s discharge (Zhang et al., 2007).

Pearl River (Zhujiang) example

Luo et al., 2007

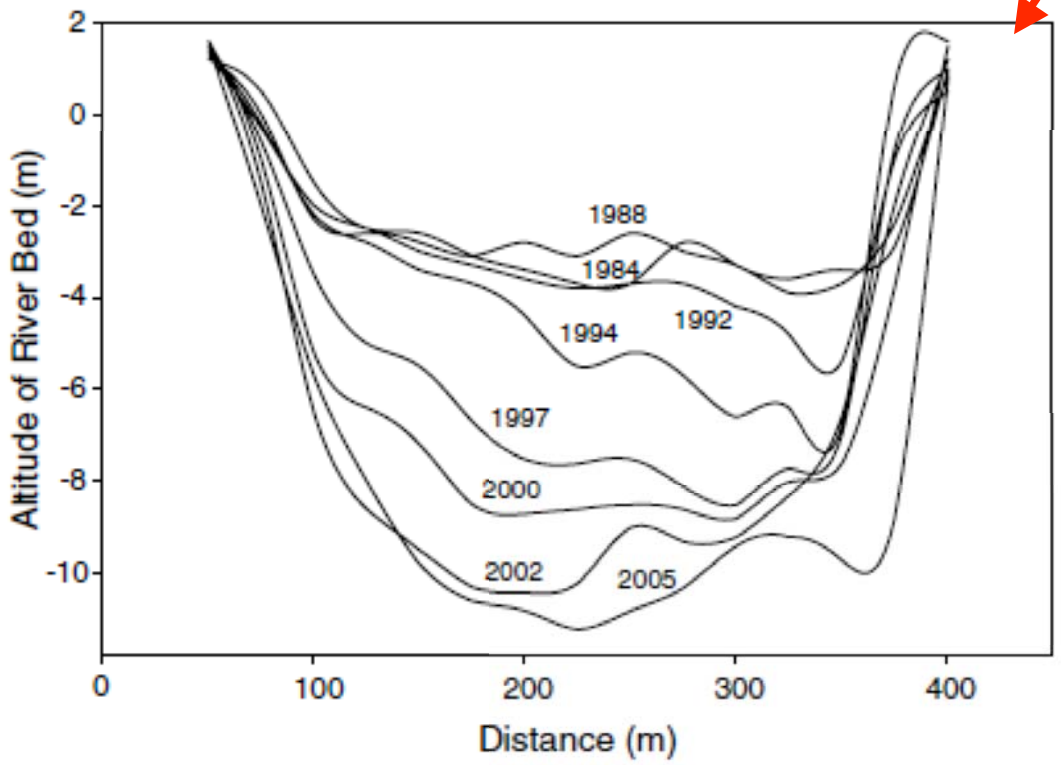
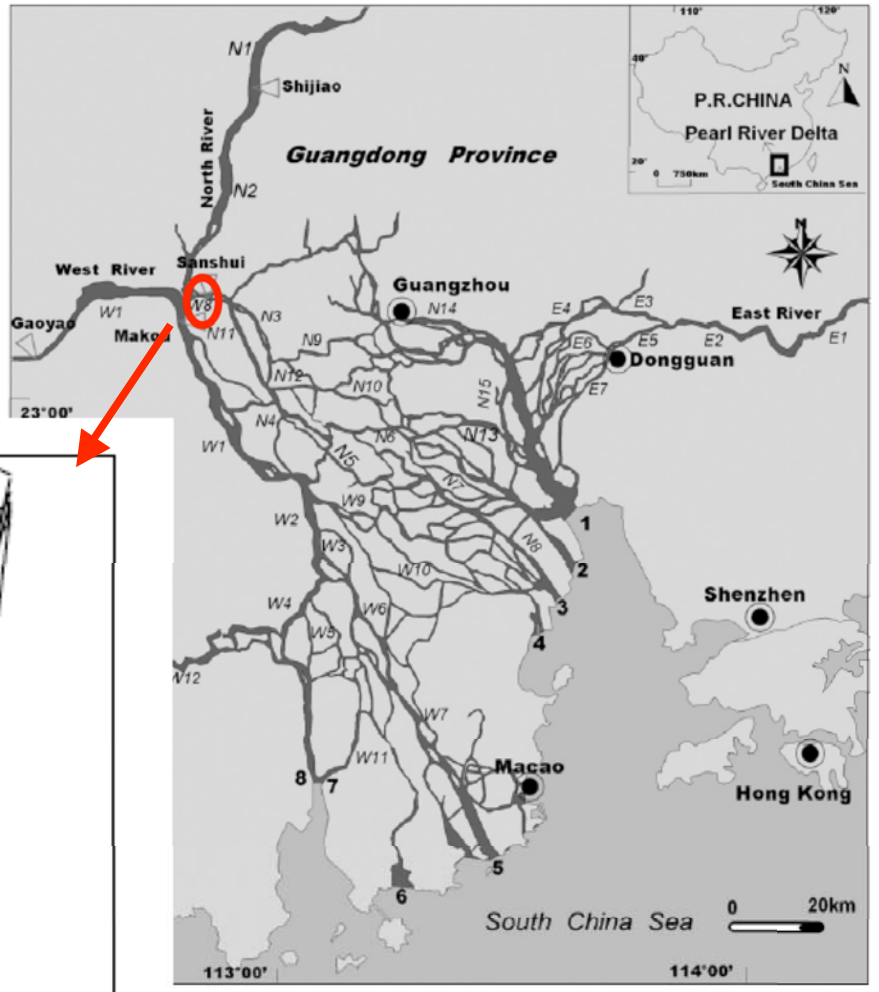


Figure 4 Temporal changes of the cross section at the Sanshui station (Fig. 1). The data in the figure were provided by the Sanshui Hydrologic State.



and its river network. N1–N15, W1–W12, and E1–E7 are the cha
, and East River network, respectively; Numbers 1–8 indicate the e
South China Sea, include Humen, Jiaomen, Hongqimen, Hengme
to west. The triangle symbols represent the locations of the hydro

>8.7x108 m3 sand/22 years
>4 x 107 m3 sand/year
8 x 107 t/y (ss): 1 x 107 m3 sand

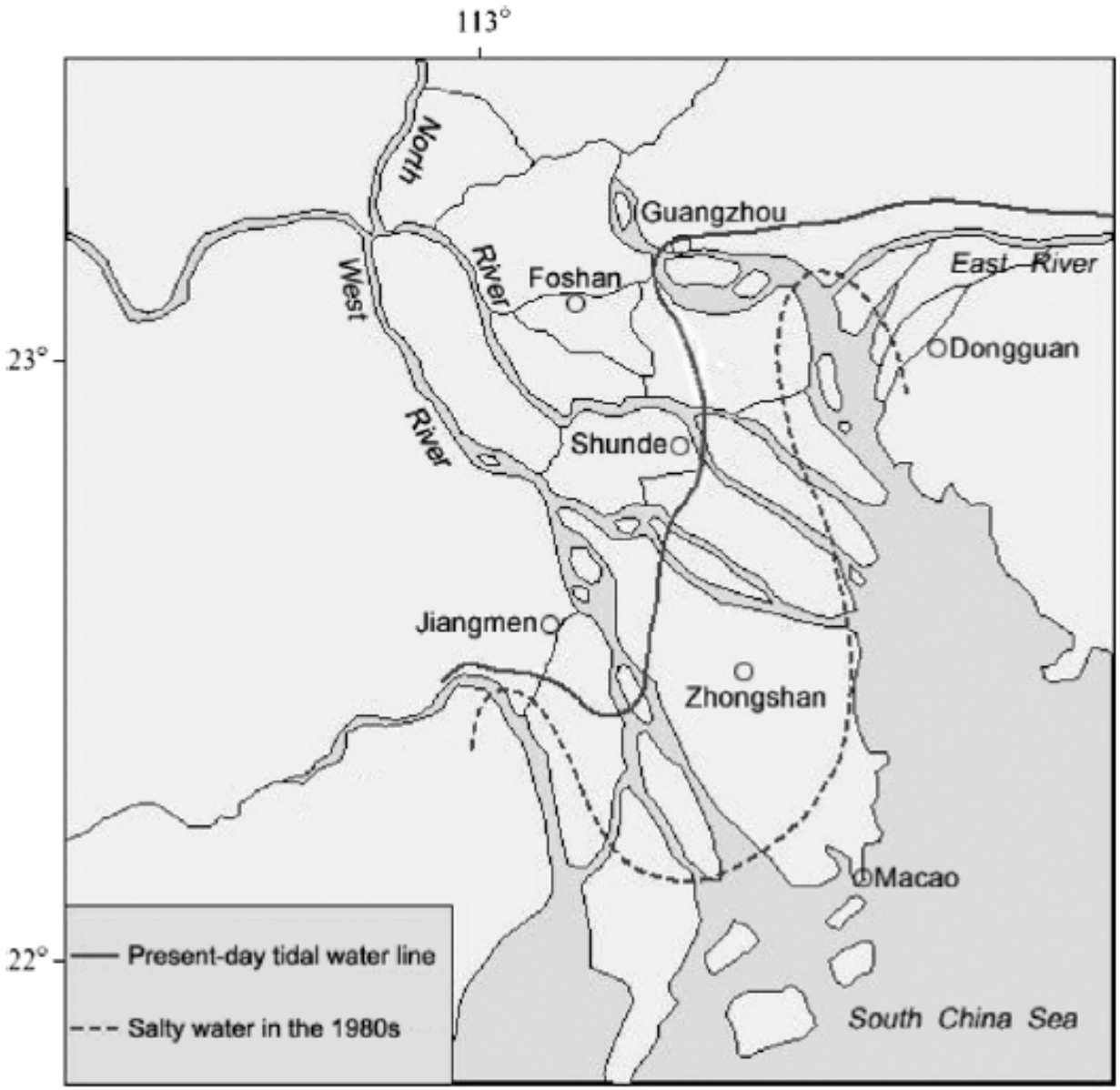


Figure 7 Brackish-water intrusion ranges in the 1980s and the present days within the Pearl River Delta.

Luo et al.,2007


Invitation to
IGCP-475: Deltas in the
Monsoon Asia-Pacific region
International Conference on Deltas (Bangladesh):
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Shanghai subsidence