Adaptation to Climate Change Impact in China

- A Case Study on Flood Damage for Investment Decision-making

March 2001

- Introduction
- Objectives
- Model Structure
- Scenarios
- Analysis
- Conclusion

INTRODUCTION

- *Change in flood risk is frequently cited as one of the potential effects of climate change. However, there have still been relatively few studies on that topic, though there are indications that the frequency of heavy rainfall events is generally likely to increase in some regions with global warming.*

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- *Attempts have been made to quantify changes in flood occurrence over small areas or from catchment basins. General conclusions are that both the frequency and intensity of floods may increase under changing climate in some seasons from some GCM output and that flood occurrence probability may double by the end of the next century.*

Continued...

- *The efficiency of each adaptation strategy has not been sufficiently analyzed quantitatively to propose a detailed action plan, main limitations are derived from the following features of climate change impact and adaptation studies:*

- *Mechanisms of adaptation are too complex to be evaluated.*
- *Climate change impact is still uncertain, and most impacts, even if they occur, will not be significant before the end of the 21st century;*

OBJECTIVE

- *Introduce a model that adopts the standard approach of modern optimal economic growth theory and includes two discount factors from the climate sector, i.e., flood damages from climate variability and climate change.*
- *Use this model to evaluate the benefits from investment as a robust adaptation strategy in flood prevention infrastructure to adapt to projected climate change impact in China.*

MODEL STRUCTURE

- **Objective Function**

$$Max\ \ U = \sum_{t} \left(\left(\prod_{i} C_i(t)^{v_i} \right) \times (1+\rho)^{-t} \right)$$

The fundamental assumption is that policies should be designed to maximize the generalized level of consumption now and in the future.

U is the flow of utility,
$C_i(t)$ is the flow of consumption per capita at year *t*,
ρ is the pure rate of social time preference,
i is economic sectors,
ν is consumption share of each sector product.

Production Function

$$Ya(t) = \min\left(\frac{Maa(t)}{a2a}, \frac{Mna(t)}{n2a}, \frac{YGDPa(t)}{a2ao}\right)$$

$$Yn(t) = \min\left(\frac{Mnn(t)}{n2n}, \frac{Man(t)}{a2n}, \frac{YGDPn(t)}{n2no}\right)$$

$Ya(t)$ and $Yn(t)$: the gross outputs of the agricultural and the non-agricultural sectors, respectively;

$Maa(t)$ and $Man(t)$: intermediate inputs from the agricultural sector to both the agricultural and the non-agricultural sectors, respectively;

$Mnn(t)$ and $Mna(t)$ are intermediate inputs from the non-agricultural sector to both the non-agricultural and the agricultural sectors, respectively.

$YGDPa(t)$ and $YGDPn(t)$ are the productions of the agricultural and non-agricultural sectors.

$a2a$, $n2a$, $n2n$, and $a2n$ are input coefficients, and $a2ao$ and $n2no$ are production factors.

Continued...

$$YGDPa(t) = Aa(t) \times Ka(t)^{\beta} \times La(t)^{\gamma} \times F(t)\lambda$$

Aa(t)	: *total factor of productivity in agricultural sector at year t,*
Ka(t)	: *capital input to agricultural sector,*
La(t)	: *labor input to agricultural sector,*
F(t)	: *land input to agricultural sector,*
β	: *elasticity of capital input in agricultural sector,*
γ	: *elasticity of labor in agricultural sector,*
λ	: *elasticity of farmland in agricultural sector.*

Continued...

$$YGDPn(t) = An(t) \times Kn(t)^{1-\alpha} \times Ln(t)^{\alpha}$$

α : *elasticity of output with respect to capital,*
$An(t)$: *total factor of productivity in non-agricultural sector,*
$Kn(t)$: *capital input at year t to agricultural sector,*
$Ln(t)$: *labor input at year t to agricultural sector.*

Material Balance Constraint

$$Ya(t) = Ca(t) + Ia(t) + IAa(t) + IADa(t) + Maa(t) + Man(t)$$

$$Yn(t) = Cn(t) + In(t) + IAn(t) + IADn(t) + Mnn(t) + Mna(t)$$

$$+ Iex(t) + IAex(t) + IADex(t)$$

Ia(*t*), *IAa*(*t*) and *IADa*(*t*) are contributions of the agricultural sector to capital stock, investment for flood control, and extra investment for projected flood damage from climate change at year *t*.

In(*t*), *IAn*(*t*) and *IADn*(*t*) are contributions of the non-agricultural sector to capital stock, investment for flood control, and extra investment for projected flood damage from climate change at year *t*.

Iex(*t*), *IAex*(*t*) and *IADex*(*t*) are contributions of the non-agricultural sector to agricultural sector in capital stock, investment for flood control, and extra investment for projected flood damage from climate change at year *t*.

Ca(*t*) and *Cn*(*t*) are the consumptions of agricultural and non-agricultural goods, respectively.

Capital Constraints

$$Ka(t) = (1-\delta)Ka(t-1) + Ia(t-1) + Iex(t-1)$$

$$Kn(t) = (1-\delta)Kn(t-1) + In(t-1)$$

$$INR(t) = INR(t-t') + IAa(t-t') + IAn(t-t') + IAex(t-t')$$

$$INRA(t) = INRA(t-t') + IADa(t-t') + IADn(t-t') + IADex(t-t')$$

δ is the depreciation rate;

$Ka(t)$ and $Kn(t)$ are capital stocks of the agricultural and the non-agricultural sectors, respectively, at year t;

$INR(t)$, $INRA(t)$ are investments to infrastructure which prevent flooding from current climate variability and projected climate change at year t.

t' is the time lag of investment taking effect.

Damage Function-Climate Variability

$$DAMak(t) = 10^{a1}\left[INR(t)/P(t-t')\right]^{b1}$$

$$DAMal(t) = 10^{a2}\left[INR(t)/P(t-t')\right]^{b2}$$

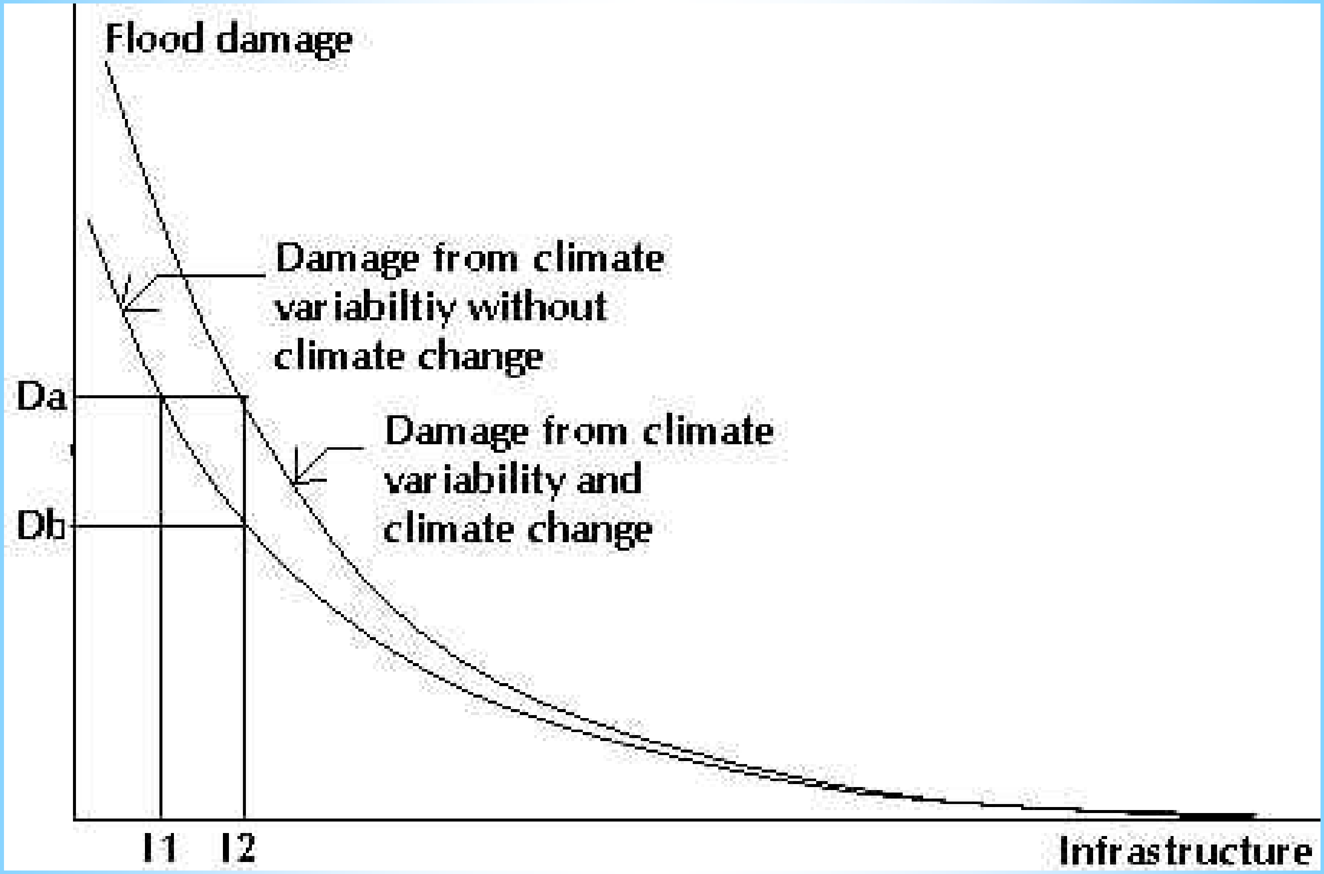
$$DAMn(t) = 10^{a3}\left[INR(t)/P(t-t')\right]^{b3}$$

$DAMn(t)$, $DAMak(t)$, $DAMal(t)$ are damages to capital stocks of the non-agricultural and agricultural sectors, and land at year t, respectively.

$P(t)$ is population at year t.

a1, a2, a3, b1, b2, b3 are constants that are equivalent to 1.51273, 0.79413, 0.983978, -091843, -077078, -0.35482, respectively.

Damage Function - Climate Change



Damage Function - Climate Change

$$\mathrm{DAMalc(t)} = 10^{\mathrm{a1}}\left[INRA(t)/P(t-t') + \left(Dc(t)/10^{a1}\right)^{1/b1}\right]^{b1}$$

$$\mathrm{DAMakc(t)} = 10^{\mathrm{a2}}\left[INRA(t)/P(t-t') + \left(Dc(t)/10^{a2}\right)^{1/b2}\right]^{b2}$$

$$\mathrm{DAMnc(t)} = 10^{\mathrm{a3}}\left[INRA(t)/P(t-t') + \left(Dc(t)/10^{a3}\right)^{1/b3}\right]^{b3}$$

$DAMnc(t)$, $DAMakc(t)$, $DAMacl(t)$ are flood damages from climate change to capital stocks of the non-agricultural and the agricultural sectosr, and land at year t, respectively.

Annual climate change damage

$$Dc(t) = Dref \times Tc(t)^2 \big/ 6.25$$

$T(t)$ is the temperature increase in year t. Damage caused by flooding under the climate change of a 2.5°C temperature increase is assumed to be *Dref*, the quadratic term of temperature reflects the assumption that the damage is quadratic along with temperature increase.

Growth Rate of Technology and Total Productivity Factor

$$GTa(t) = GTa0 \times \left[1 + \varphi a(t)\right]^{-t}$$

$$GTn(t) = GTn0 \times \left[1 + \varphi n(t)\right]^{-t}$$

$$ALa(t) = ALa0 \times \exp\left[GTa(t)\right]$$

$$ALn(t) = ALn0 \times \exp\left[GTn(t)\right]$$

$\varphi a(t)$ and $\varphi n(t)$ are the change rates of technology growth for the agricultural and the non-agricultural sectors,
GTa(t), GTn(t), GTa0 and GTn0 are the growth rates of technolgoy of both sectors at year t and the initial year.
ALa(t), ALn(t), ALa0, ALn0 are total productivity factors of agricultural and non-agricultural sector at year t and initial year

SCENARIOS
- Climate Change And Investment

		Climate Change	
		No	Yes
Investment	No	*CnAn*	*CyAn*
	Yes	*CnAy*	*CyAy*

SCENARIOS
- Population Growth In China

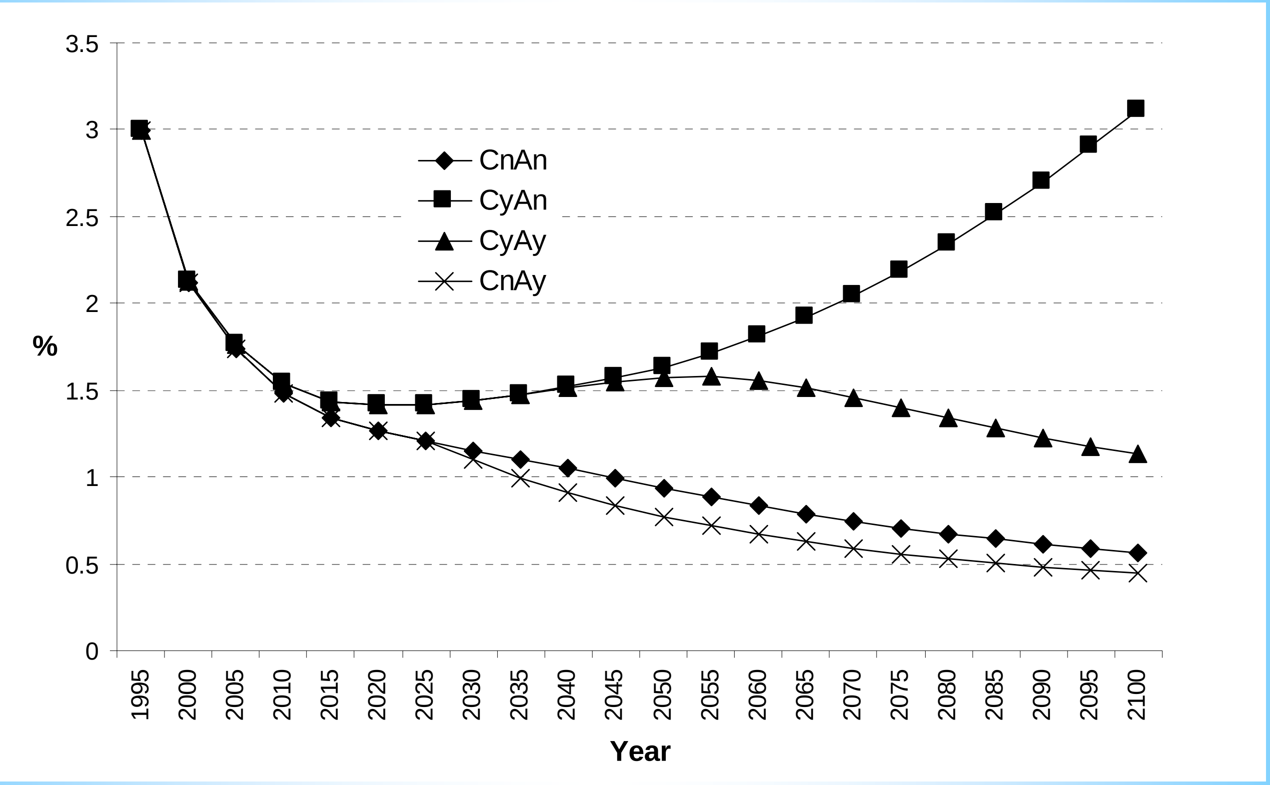
	Fertility rate (‰)	Population in 2000 (billion)	Population in 2100 (billion)
Low scenario	1.62	1.26	0.8
Medium scenario	1.8	1.26	1.033
High scenario	2.1	1.26	1.5

SCENARIOS
- Labor Employment In Different Sectors

Scenario	*I*		*II*	
Year	2050	2100	2050	2100
Agri. Sector	20%	10%	30%	20%
Non-Agri. Sector	80%	90%	70%	80%
Labor move rate (%)	0.585 (1995-2050)	0.2 (2051-2100)	0.404 (1995-2050)	0.2 (2051-2100)

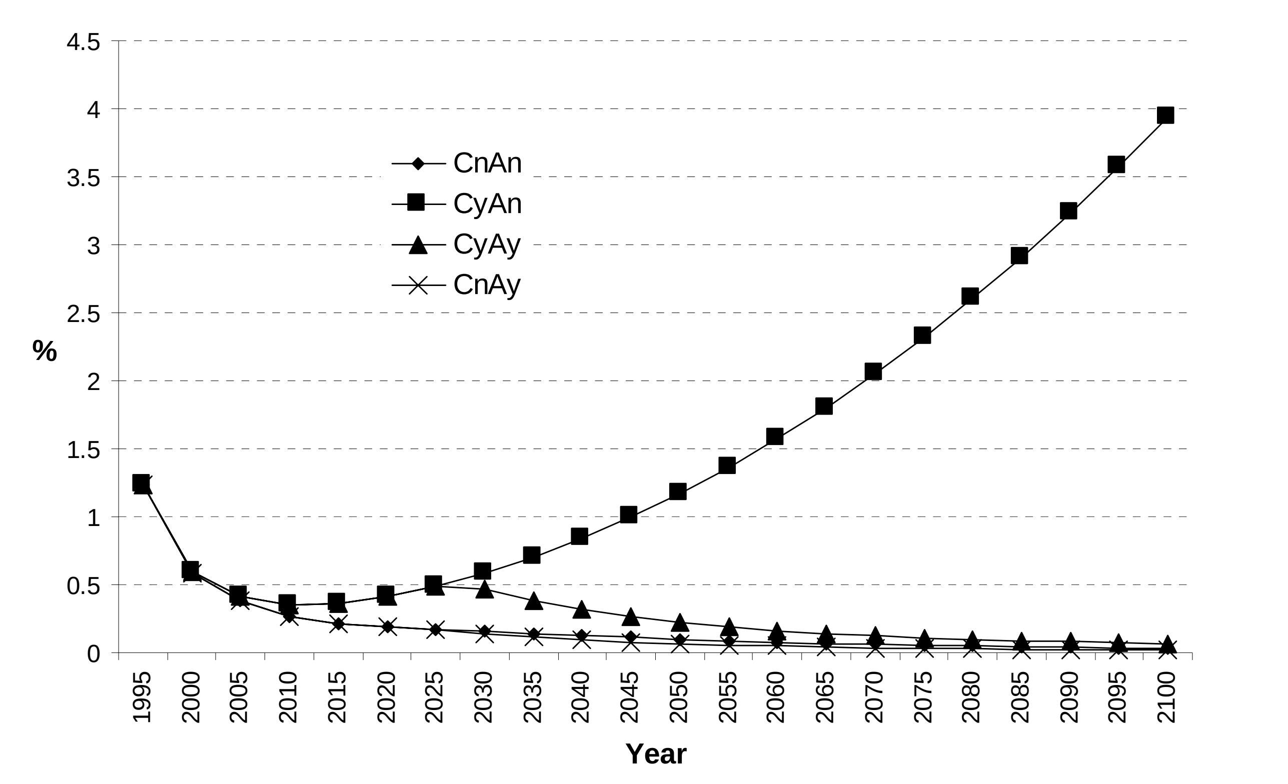
BENEFIT ANALYSIS

Flood damage to cultivated land



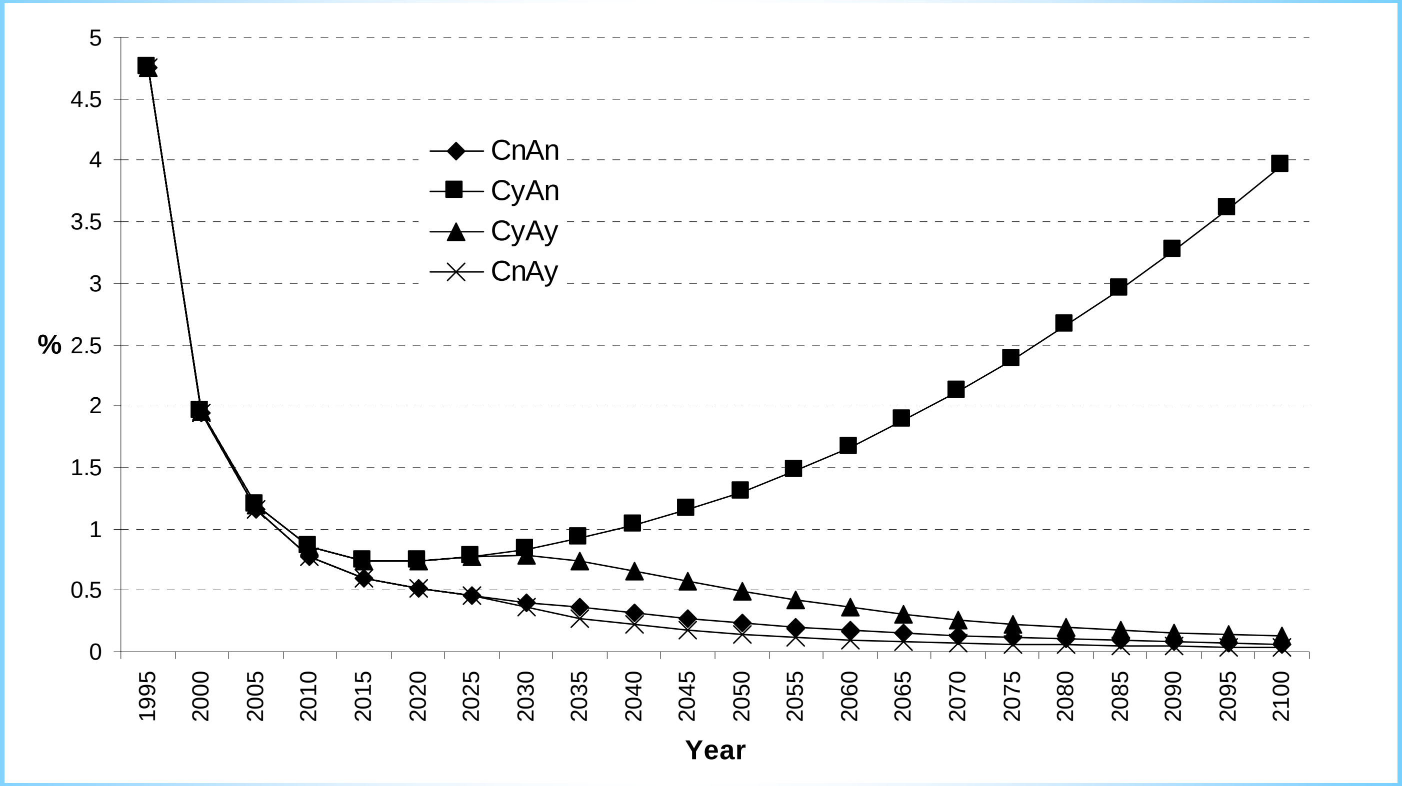
BENEFIT ANALYSIS

Flood Damage to capital stock of agricultural sector



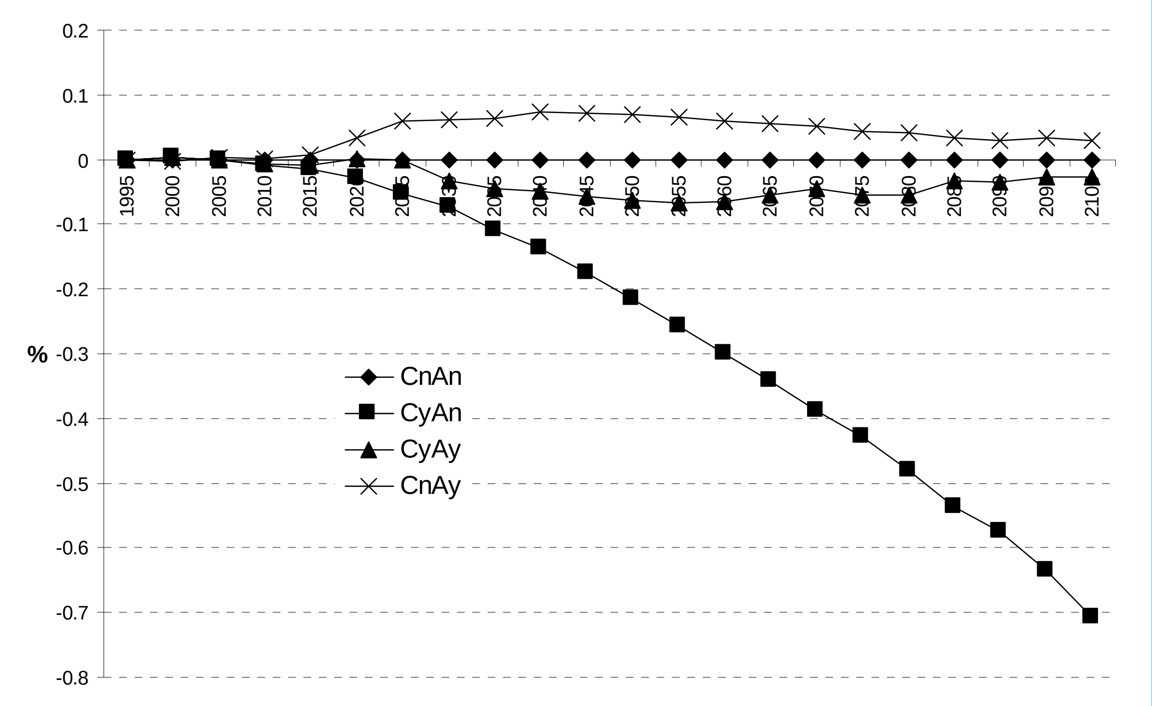
BENEFIT ANALYSIS

Damage to capital stock of non-agricultural sector



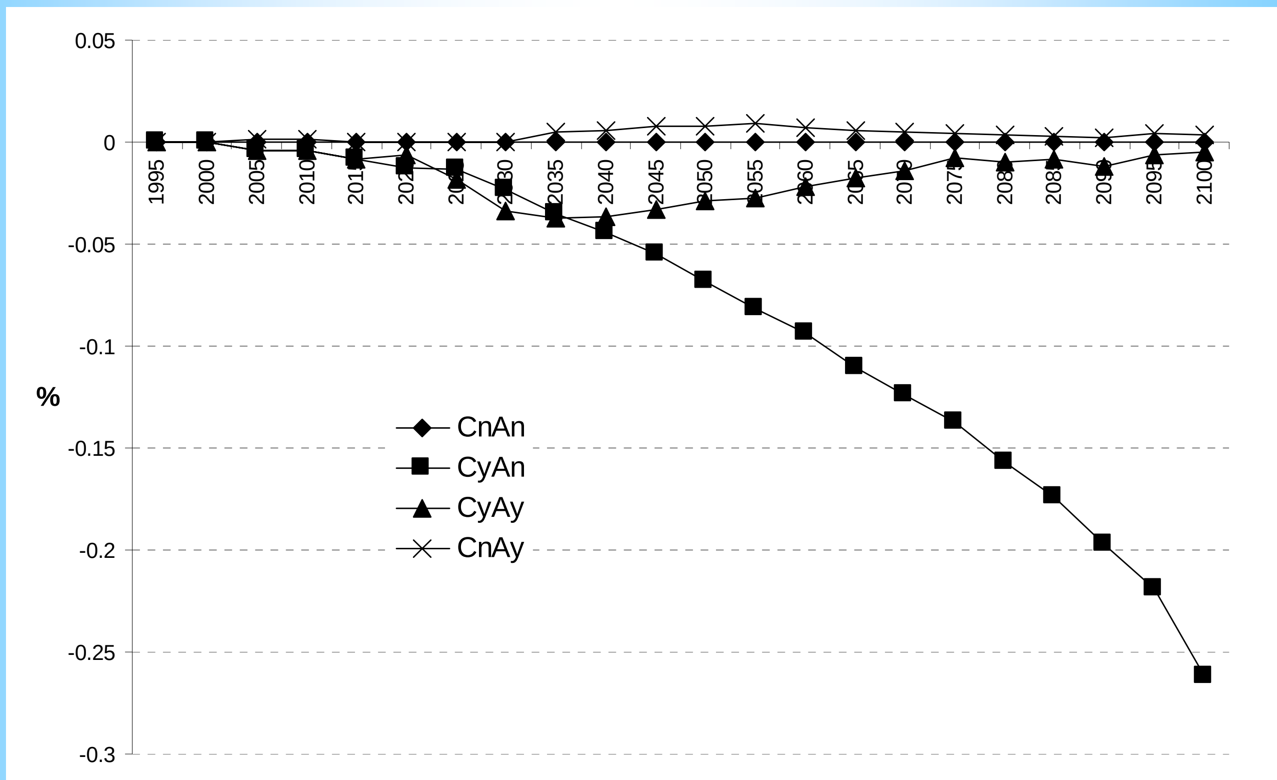
BENEFIT ANALYSIS

GDP gain of agricultural sector



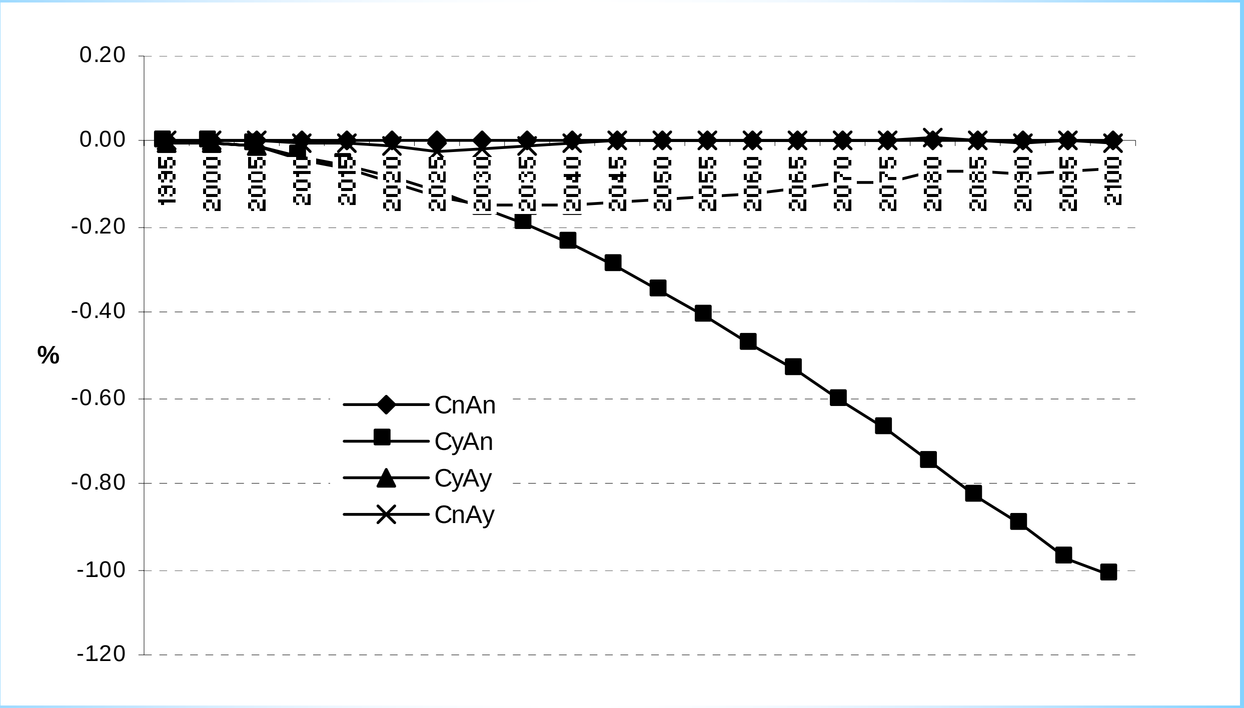
BENEFIT ANALYSIS

GDP Gain of non-agricultural sector



BENEFIT ANALYSIS

Consumption per capita



ANALYSIS

Decision making analyses based on consumption change following maximin and maximax principles

Time span	Adaptation option	Climate change occurrence	No climate Change occurrence	Minimum benefit	Maximum of minimum benefit	Best option	Maximum benefit	Maximum of maximum benefit	Best option
1995-2100	Investment	-13700.7	422.2	-13700.7	-13700.7	v	422.2	422.2	v
	No investment	-129402.0	0	-129402.0			0		
1995-2080	Investment	-6855.3	178.7	-6855.3	-6855.3	v	178.7	178.7	v
	No investment	-34668.6	0	-34668.6			0		
1995-2050	Investment	-1534.5	-51.7	-1534.5	-1534.5	v	-51.7	0	
	No investment	-2620.8	0	-2620.8			0		**v**

Decision making analyses based on consumption change following minimax regret principles

	Time span	Adaptation option	Regret value		Maximum regret value	Minimum of maximum regret value	Best option
			Climate change occurrence	No climate change occurrence			
Consumption	1995-2100	Investment	0	0	0	0	v
		No investment	115701.3	422.2	115701.3		
	1995-2080	Investment	0	0	0	0	v
		No investment	27813.3	178.7	27813.3		
	1995-2050	Investment	0	51.7	51.7	51.7	v
		No investment	1086.3	0	1086.3		

Conclusion

- *Investments optimized ignoring climate change will cause severe damage starting about 2020 when climate change happens. Flood damage from climate change can be effectively mitigated by optimizing investment considering both climate variability and climate change.*

- *GDP of the agricultural and non-agricultural sectors gains in scenario CnAy when investment considers both climate change and climate variability, even if climate change does not occur*

- *The results show that investment against projected climate change is the best option, whether climate change occurs or not. Uncertainty about climate change should not be an obstacle to formulating an adaptation policy to offset the negative impact of climate change, i.e., floods in this paper. Investment in social infrastructure not only adds adaptive capacity against the impact of future climate change but also improves current society.*

- *The model also is run to test its validity under various combinations of different scenarios of population growth, labor employment in both sectors, and marginal adaptation costs to climate change (increased by 10%, 20% and 30% compared with that to climate variability). The same conclusions can be reached for changes in patterns of GDP and consumption. Investment to mitigate projected climate change is still the best option whether climate change occurs or not.*

Safety Status of Main Rivers/Watershed in China

River/watershed	Location	Guaranteed Safety
Yellow River		1/60
Huaihe River	Main streams in middle reaches	1/40
	Lower reaches	1/50
	Main branches	1/10-1/20
Haihe River & Luanhe River		1/20
Yangtze River	Main streams and lakes in middle and lower reaches	1/10-1/20
Taihu Lake & its Surrounding area		1/20
Pearl River	Important economic areas	1/50
	Other areas	1/10-1/20
	Dikes of main streams in Xijiang	1/10-1/20
Liaohe River	Dikes of main streams	1/20
	Branches	1/10-1/20
	Shenyang, Liaoyang, Fushun	1/100
	Benxi	<1/20
Songhuajiang River	Farmland	1/20
	Harbin, Qiqihaer, Jiamusi	1/40

Data sources: (1) Liu, 1993, (2) China Agricultural Encyclopedia - Water Conservancy (A). Agricultural Publishing House, 1987, pp 151

Safety standards of infrastructure against flooding area expressed in terms of the frequency of overtopping the flood prevention system.

National Safety Standards of Flood Prevention Infrastructure in China

Standards of flood prevention	Cities (Non-agri. pop.: 1000 persons)	Mineral Area	Cultivated area (1000 ha.)
<= 1/200	>= 1500	Very Important	> 333.3
1/100~1/200	500~1500	Important	333.3~6.67
1/50~1/100	200~500	Medium	2~6.67
1/20~1/50	<= 200	Less	<2

Data source: (1) China Agricultural Encyclopedia - Water Conservancy (A). Agricultural Publishing House, 1987, pp 152; (2) Li, 1997

Flood Damage in China

Year	Total damage from natural disasters (billion Yuan)	Flood damage (billion Yuan)	Flood damage to total damage (%)	Percentage equivalent to GDP
1990	61.6	24.0	39.0	1.3
1991	121.6	77.9	64.1	3.6
1992	85.4	41.3	48.4	1.5
1993	99.3	64.2	64.7	1.9
1994	187.6	179.7	95.8	3.9
1995	186.3	165.3	88.7	2.9
1996	288.2	220.8	76.6	3.3
1997	197.5	93	47.1	1.3
1998	307.2	225.1	73.3	2.9
Mean			66.4	2.5

Data source: (1) Outline on water resources statistics (1949-1998). Dept. of Planning and Programming, Ministry of Water Resources, PRC. Internal Report. (2) Zhang *et al.*, 2000, pp 79. (3) *China Disaster Reduction*, (1991~1999).