Energy and Green House Gas Mitigation Technologies

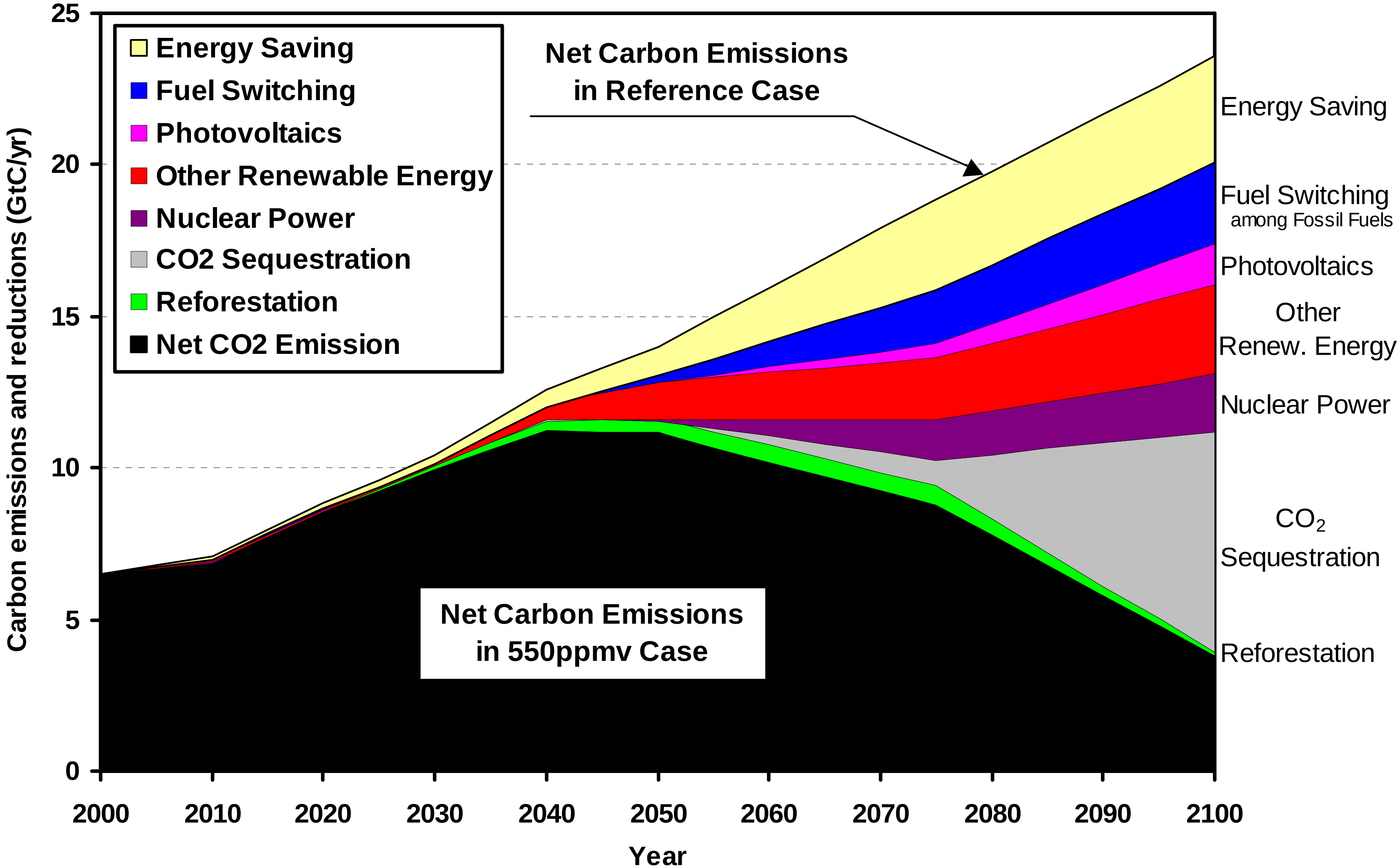
Japan Society for the Promotion of Science-Imperial College London-University of Tokyo Symposium on Climate Change

Thursday 28th and Friday 29th September 2006

Imperial College London, South Kensington Campus, London SW7 2AZ

CO_2 Capture and Afforestation to Mitigate Global Warming

Koichi Yamada



Technological Options for 550 ppmv Stabilization

Cost Estimation of Geological CO_2 Sequestration

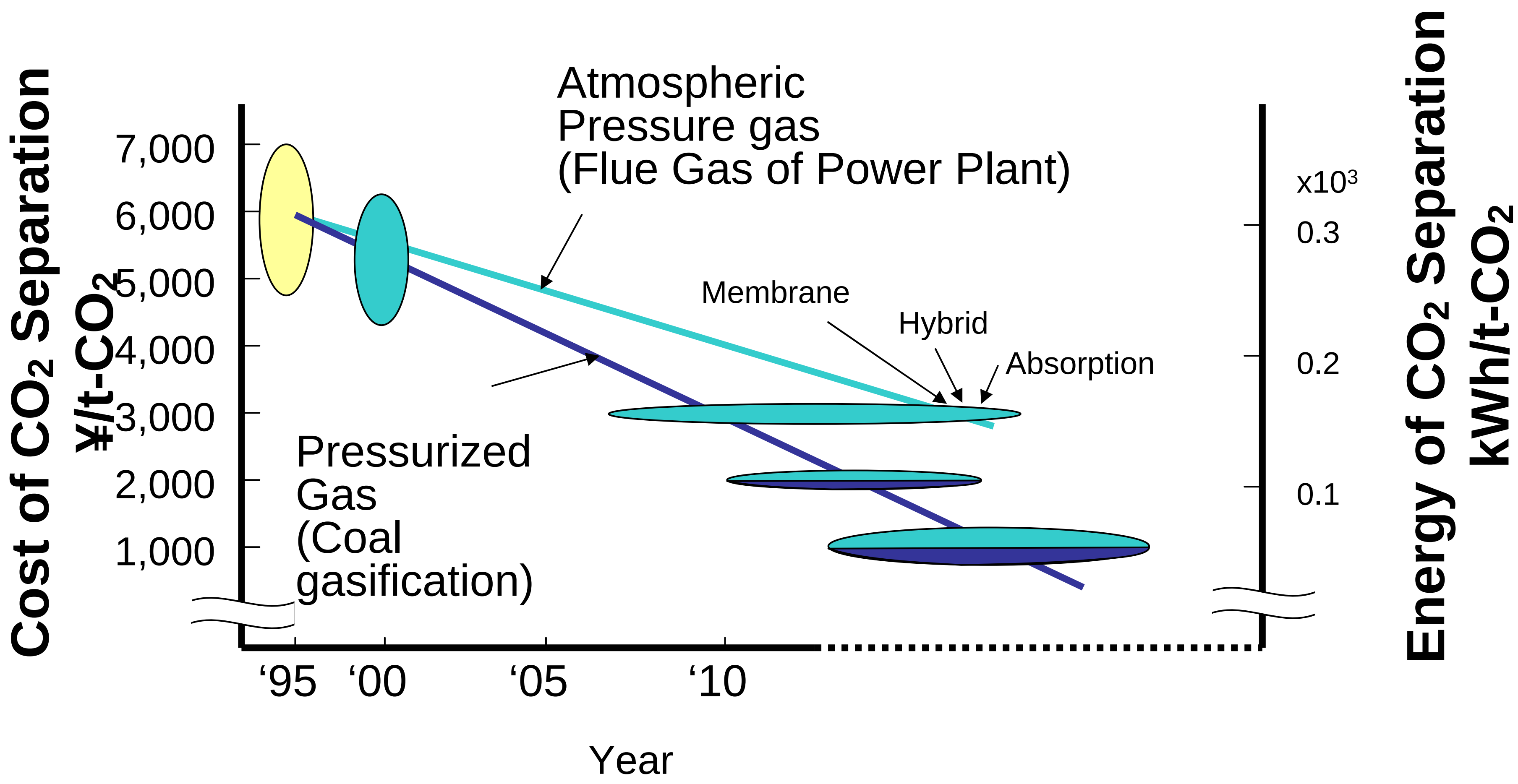
NEDO Report (Example in Japan)

		Percentage
CO_2 Capture	45 \$/t-CO_2	70%
Total	62 - 67 \$/t-CO_2	

IEA Report (presented at 1st CSLF)

		Percentage
CO_2 Capture	15 – 40 \$/t-CO_2	90%
Total	17 – 45 \$/t-CO_2	

Prospective cost of CO_2 Separation & Capture



CO_2 Capture Costs by Different Methods

Chemical absorption			PTSA	Membrane separation
MEA	KS-1	NewKS-1		
1	0.82	0.78	2.4	1.2

By N.Imai(GHGT-7)

Cost Estimation of Chemical Absorption Processes

	1	2	3	4
Phase	Present	←	←	Future
Place	Japan	←	Norway	←
Source	Coal P.P.	Blast fur. (3Mt-Fe/y)	NG	←
Capacity (Mt-CO2/y)	1.0	1.0	1.3	1.3
Initial CO_2 (%)	14	23	8.5	8.5
Cost (¥/t-CO_2)				
Fixed at 10%/y	1,000	1,000		
Variable	3,070	5,870		
Total	4,070	6,870	6,510	2,960

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CO_2 chemical absorption and compression Energy (Coal fired power plant)

1. Present energy consumption (GJ/t-C)

Pressure loss of absorbent

Heating of absorbent 2.6 (23%)

CO_2 desorption reaction 6.7 (58%)

0.5 (4%)

CO_2 compression 1.7 (15%)

- Present separation & compression energy = 11.5 GJ/t-C

2. Consumption Energy

- Energy of Coal = 41 GJ/t-C, Now 28% $\left(\frac{11.5}{41.0}\right)$

3. Energy efficiency

- Theoretical separation energy = 0.7 GJ/t-C
- Present separation energy = 9.8 GJ/t-C

$$\frac{0.7}{9.8} = 7\%$$

Reduction of reaction energy is a key issue of success in carbon sequestration !

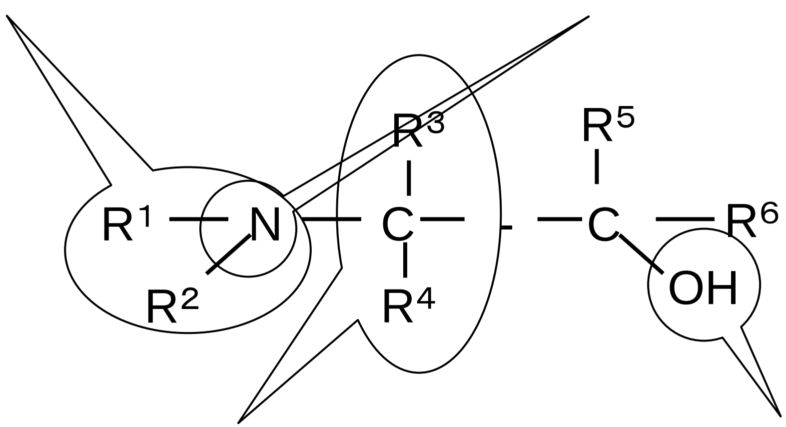
Concepts of New Solvent

Desirable characteristics of absorbents:

1. Regeneration with low energy use
2. High absorption/desorption rate
   and regeneration under low temperature
3. High loading rate of CO2
4. Low volatility, viscosity and high stability

(1) Secondary/Tertiary amine

(3) High density of amino group

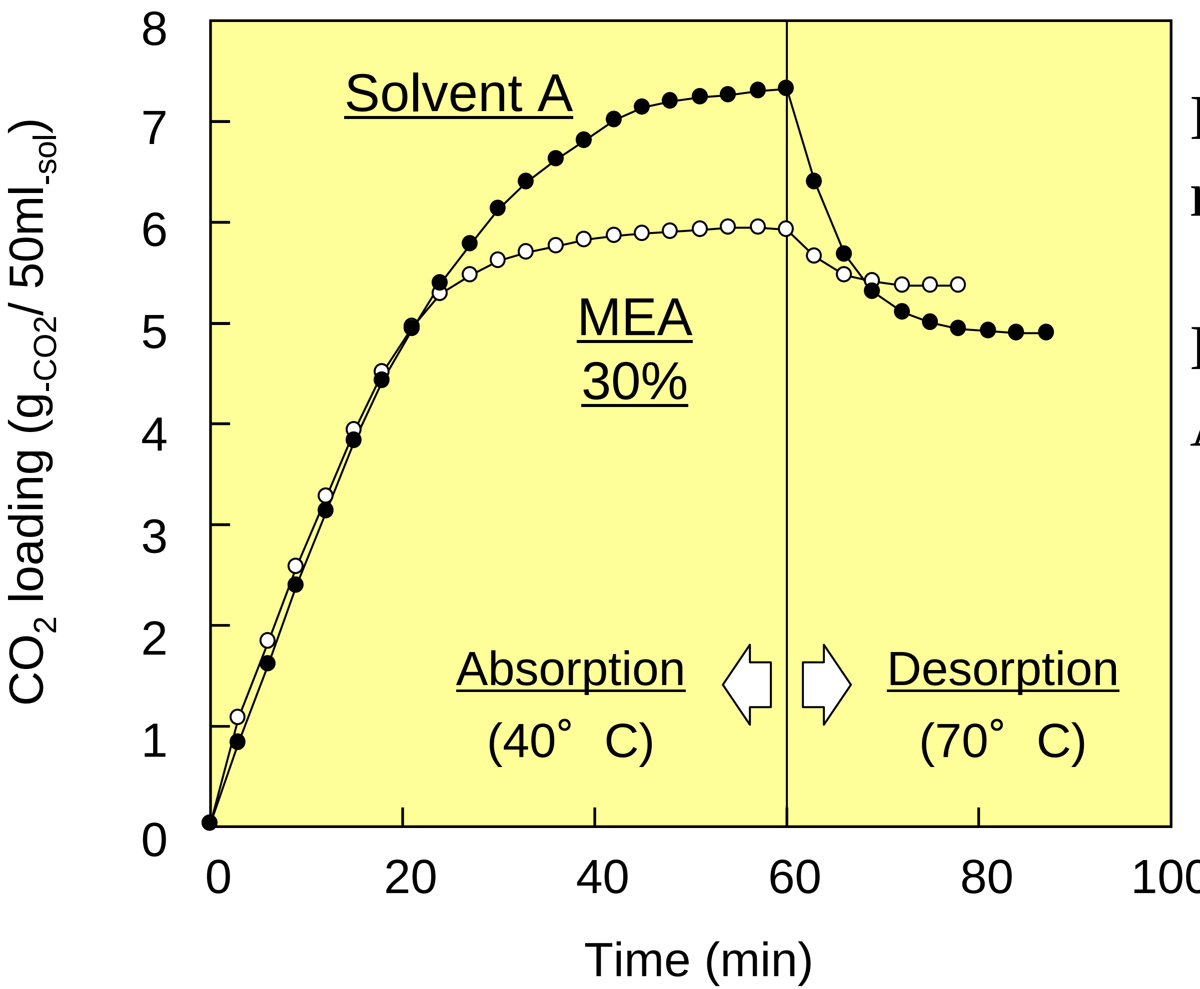


(2) Effect of steric hindrance

(4) Position and number of OH-

Capacity of CO_2 Capture

Solvent A : Newly-developed absorbent in 2004

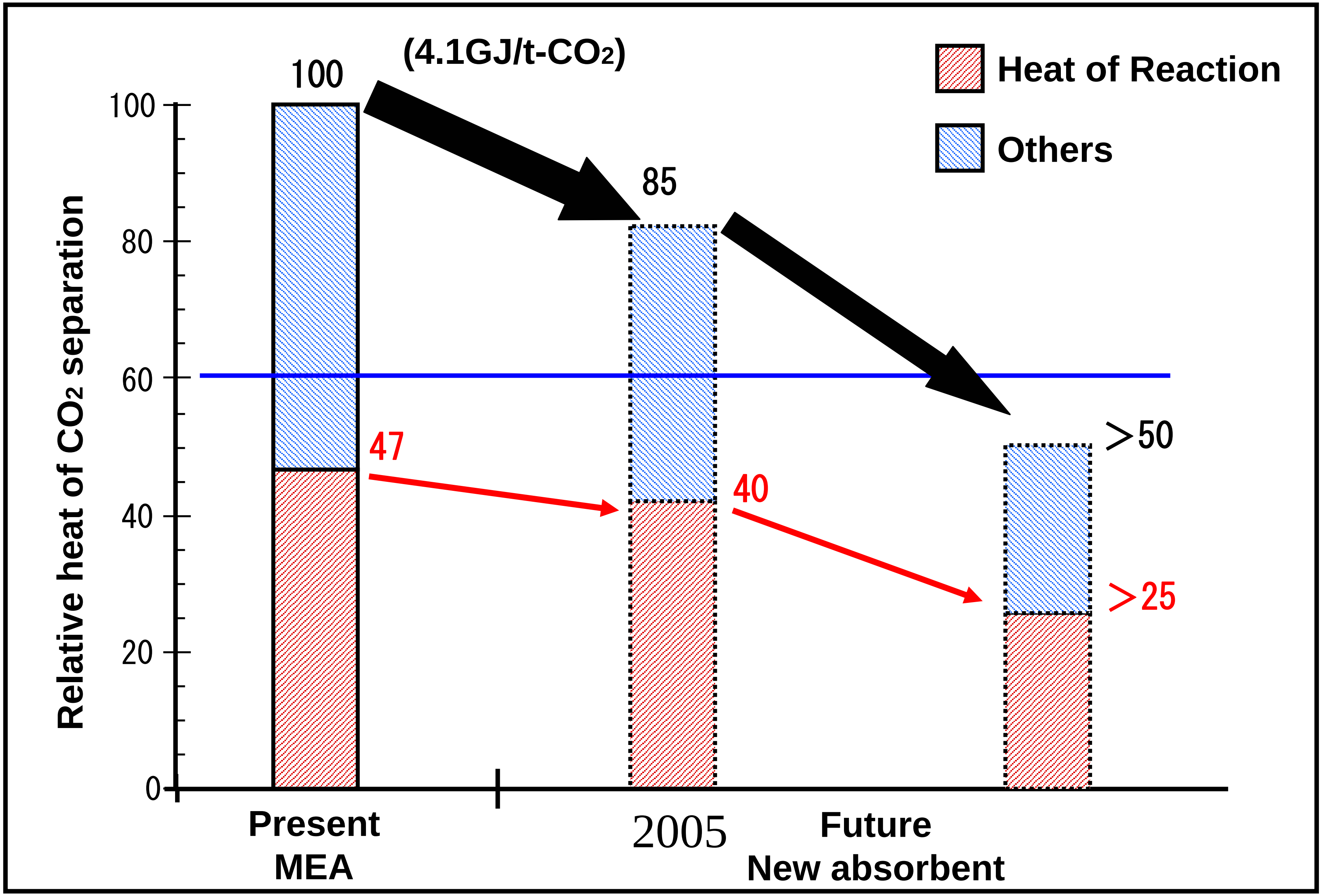


Heat of reaction kJ/mol

MEA: 85

A : 74

Development Step of New Absorbent



Prospect for CO_2 Separation Cost of Membrane Separation

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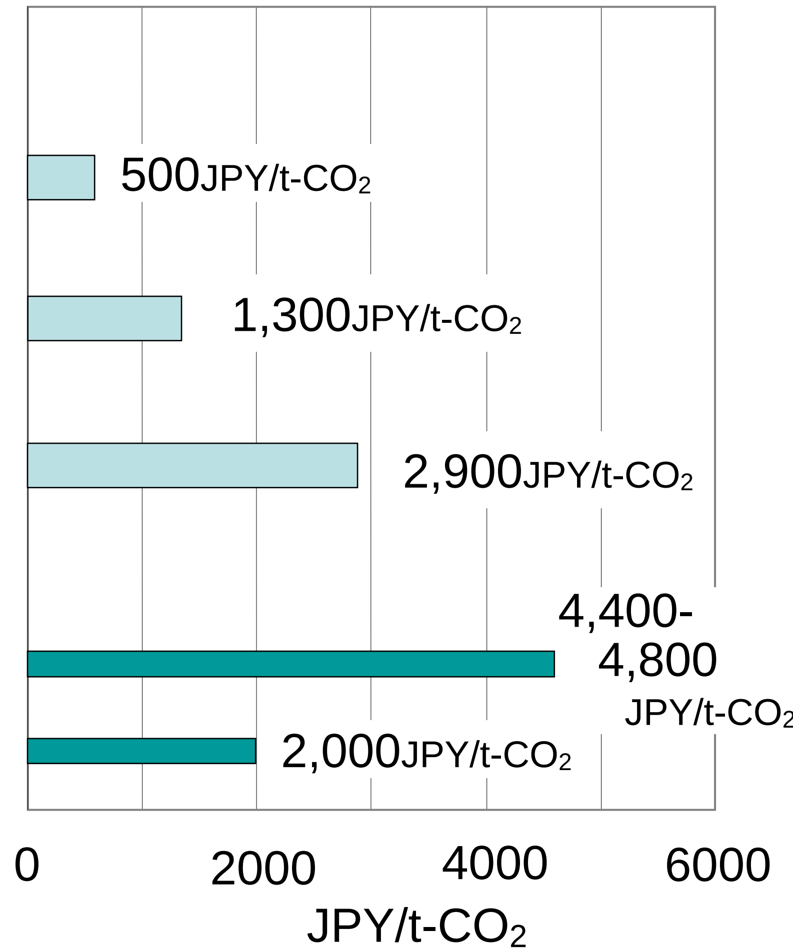
CO_2 Source	Gas Pres.	Gas Comp.	Membrane Performance (Target)
H_2 Prod. Plant	4MPa	CO_2:40% H_2, H_2O	QCO_2 :1×10^{-9} ($m^3\ m^{-2}\ s^{-1}\ Pa^{-1}$) $\alpha CO_2/H_2$: 500 (2016FY)
Steel Works	0.1MPa	CO_2:27% N_2, H_2O	QCO_2 * :5×10^{-8} ($m^3\ m^{-2}\ s^{-1}\ Pa^{-1}$) $\alpha CO_2/N_2$ * : 3000
Coal Fired Power St.	0.1MPa	CO_2:14% N_2, H_2O	
Chemical Absorption		Current(MEA)	
		2013 Target(New Solvent)	



Conditions: Membrane Cost: 10,000JPY/m^2

QCO2 *:5 times higher than a present value

CO_2 Molecular Gate Membrane

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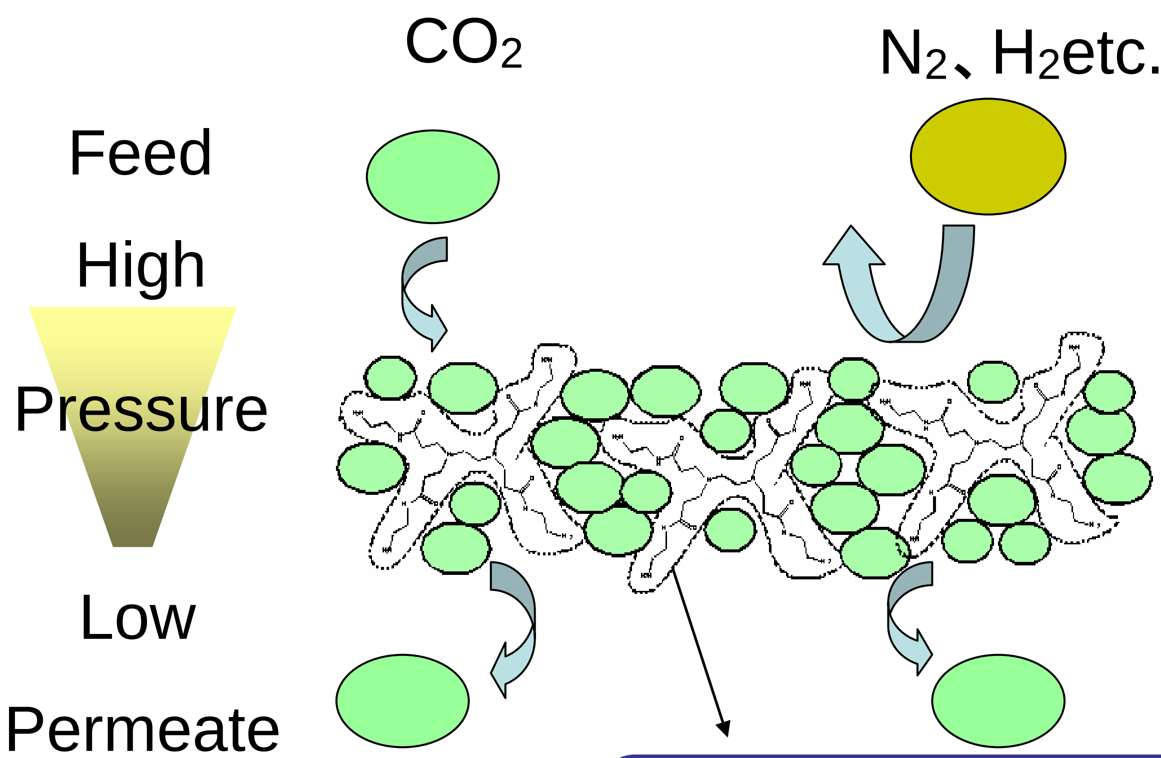
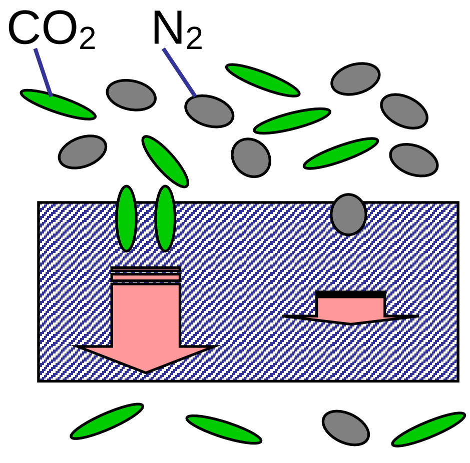


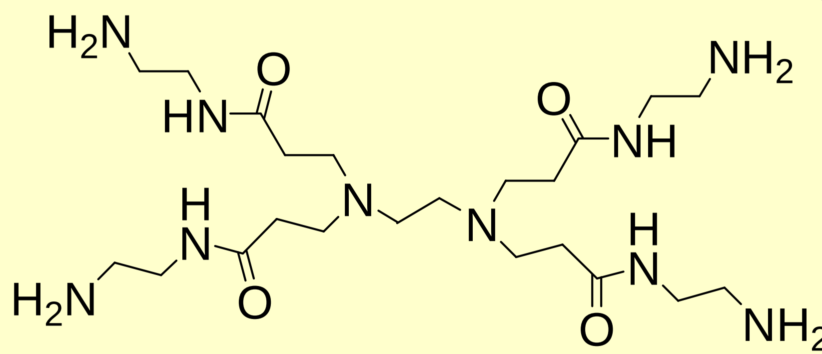
Conventional Polymeric Membrane:



CO_2/N_2 Selectivity: 40

Dendrimer

400



Synthesis and Chemical Structure of Hydroxyl PAMAM Dendrimer

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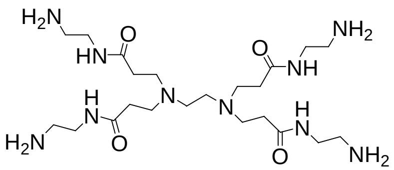
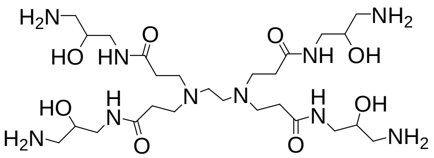
	 Conventional Polyamidoamine(PAMAM) Dendrimer	 Novel hydroxyl modified Polyamidoamine(PAMAM) Dendrimer
CO_2 Permeability [ml cm/cm^2 s cmHg]	3×10^{-9}	7×10^{-8}
CO_2/N_2 Selectivity	400	4000
CO_2/H_2 Selectivity	-	400

R&D Subjects for Cost Reduction

1 Chemical absorption

・New absorbent

(low reaction heat, high loading,

high stability, low viscosity)

・Reduction of equipment size

2 Membrane separation

・High performance membrane

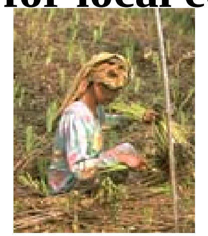
(high permeability , high selectivity ,

high stability)

Development of Greenhouse-gas Sink/Source Control Technologies through Conservation and Efficient Management of Terrestrial Ecosystems

Source control

Land resources management and the empowerment for local community



Mitigation of CH_4, N_2O emission

Afforestation in tropical forest

Construction of integrated platform and common information system for promoting the research project


Sink/Source control in tropical peat swamp

Ecosystem management in shifting-cultivation region

Afforestation in arid land

Sink enhancement

Budget；¥1,3B (2003～2007)

Project Leader
K. YAMADA

Development of Greenhouse-gas Sink/Source Control Technologies through Conservation and Efficient Management of Terrestrial Ecosystems

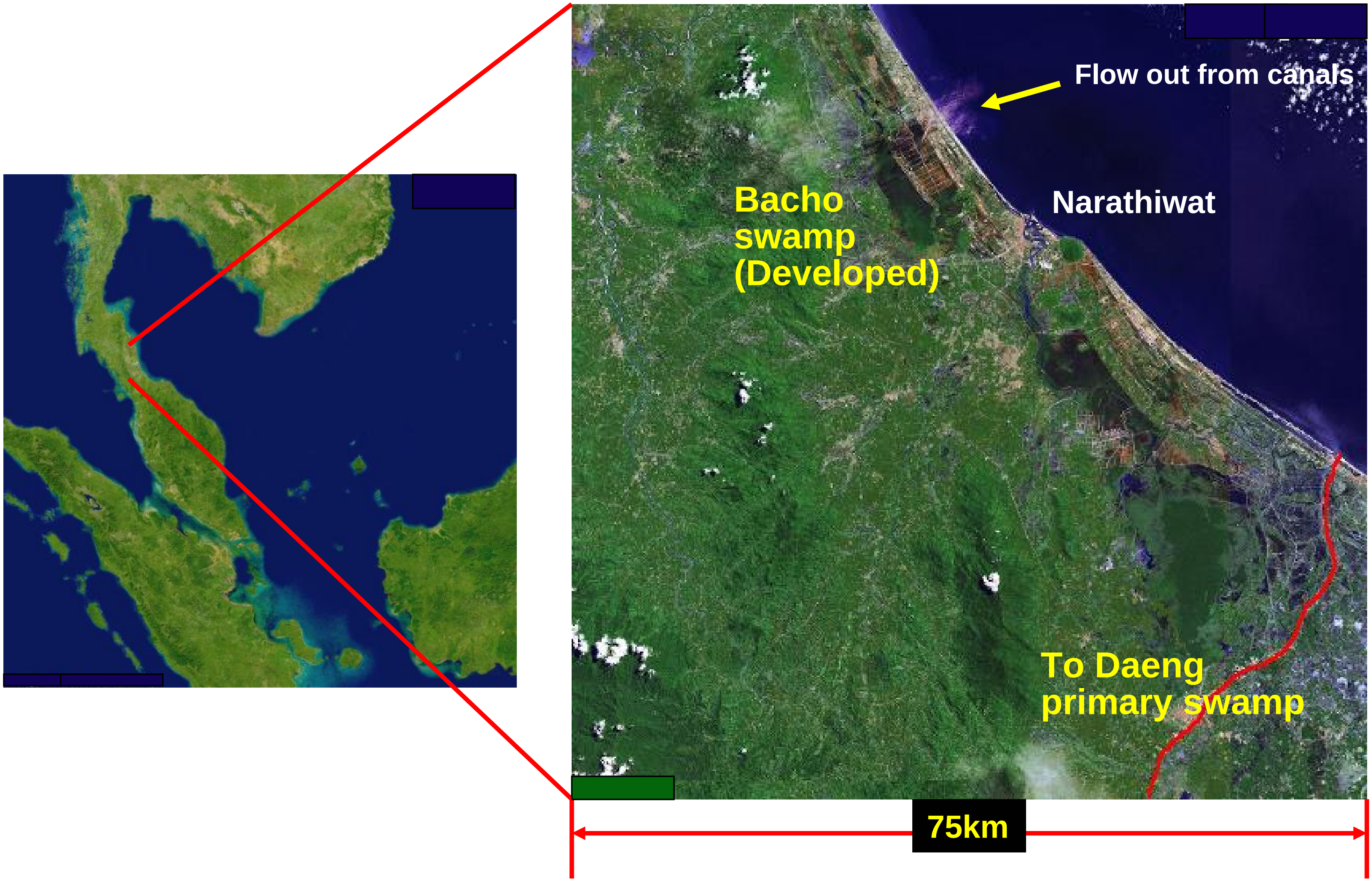
Objectives

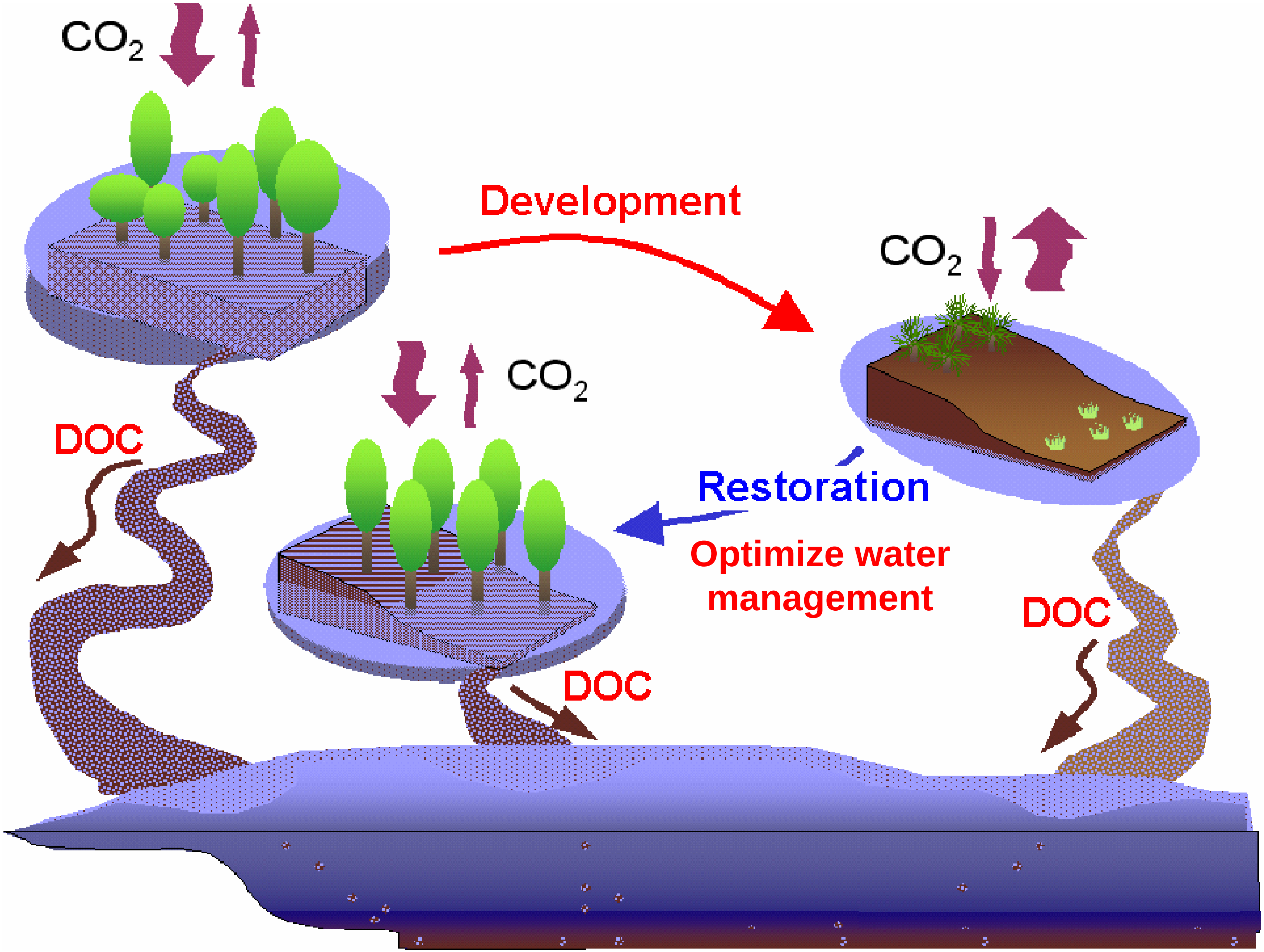
Establishment of GHG sink/source control Technologies in Terrestrial ecosystems.

These technologies should connect with concrete options for policy maker after 2nd period of Kyoto Protocol (2013～).

Distribution of tropical peat swamp 20Mha,bare land-25% in SE Asia

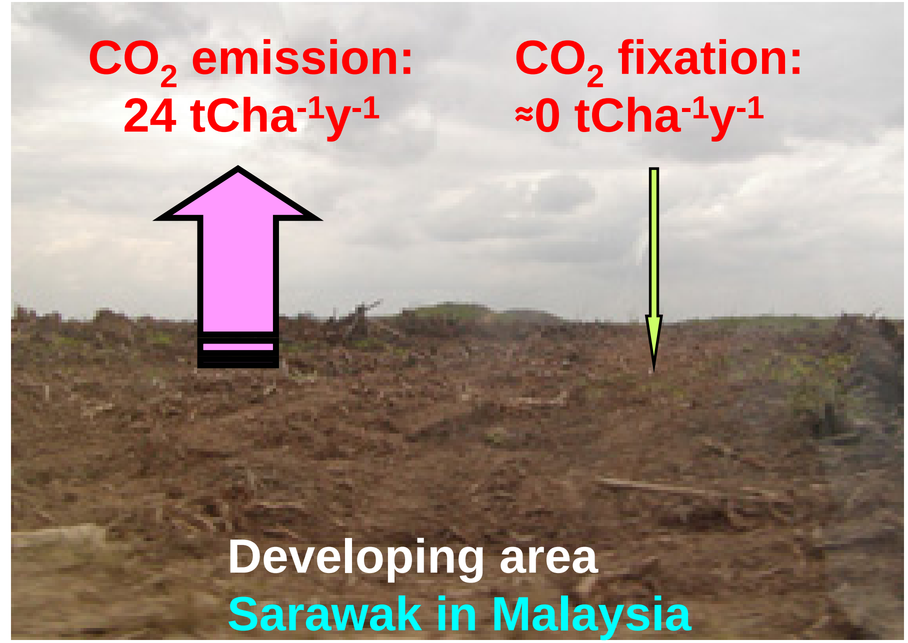
Tropical peat swamp at southern Thailand

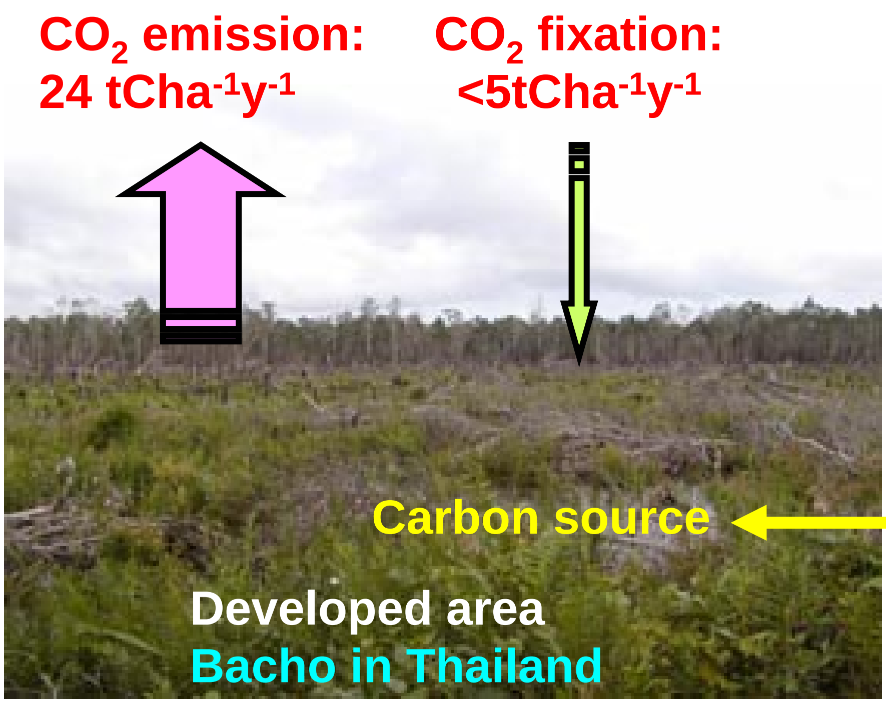


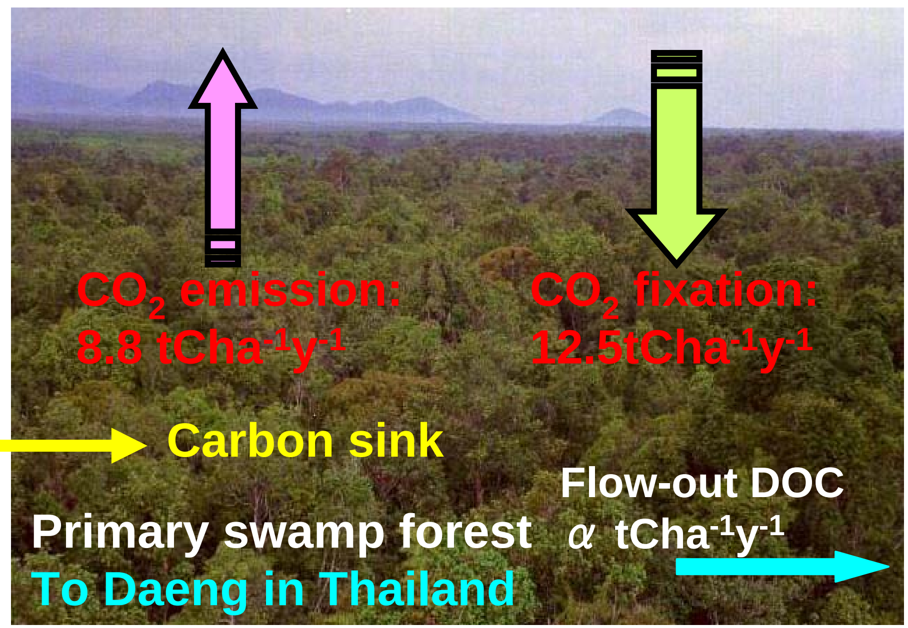


CO_2
Development
CO_2
CO_2
DOC
Restoration
Optimize water management
DOC
DOC

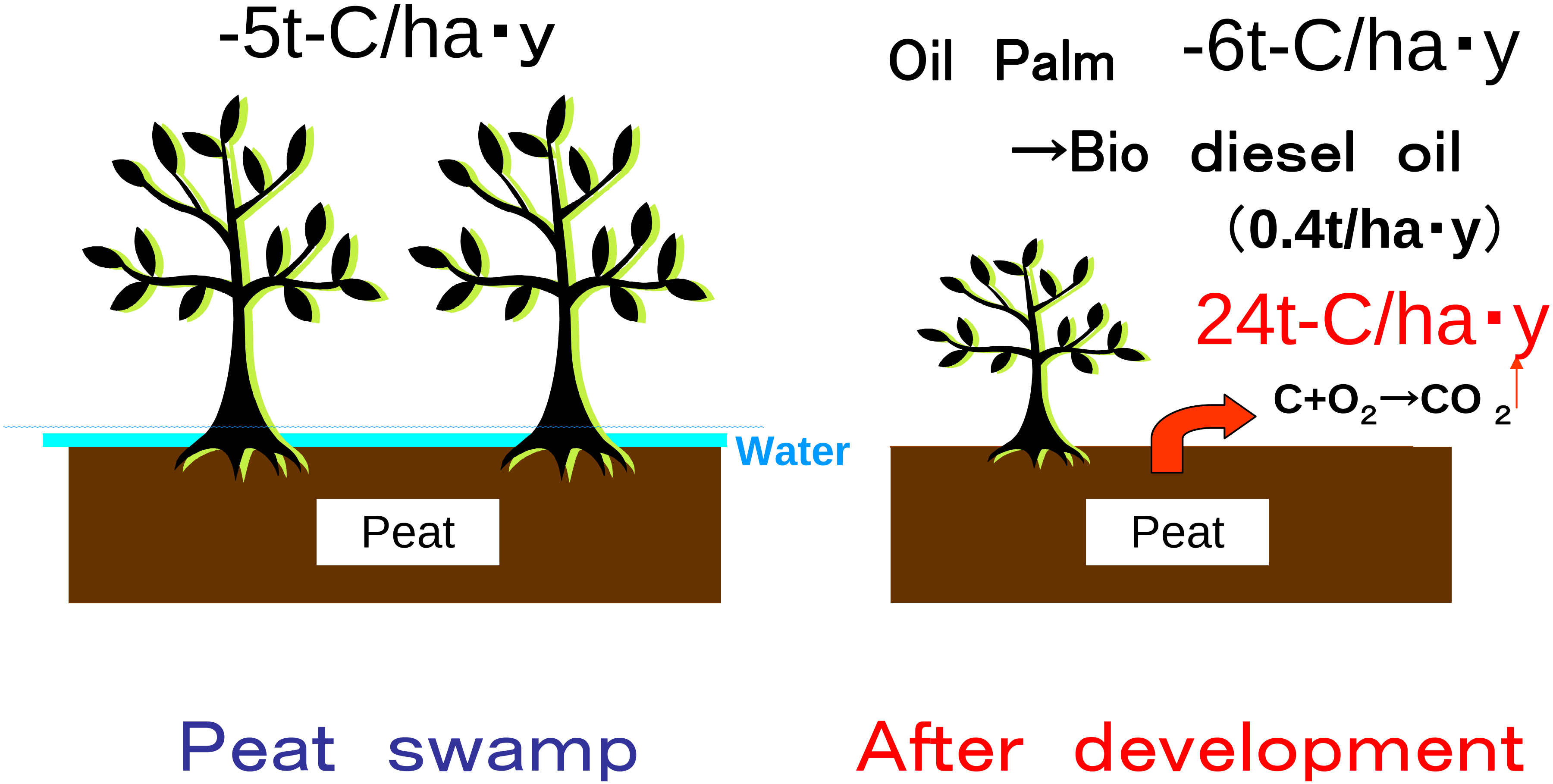
CO_2 fixation and emission from primary swamp forest and developed area







$\{(12.5-8.8)+(24-2)\} \times 5.14 \times 10^6 + \alpha$ (Palm oil plantation) $= (132 + \alpha) \times 10^6$ tC



-5t-C/ha・y
Oil Palm -6t-C/ha・y
→Bio diesel oil
(0.4t/ha・y)
24t-C/ha・y
C+O2→CO 2
Water
Peat
Peat
Peat swamp
After development

CO_2 reduction by changing from developed tropical peat swamp to natural peat swamp

CO_2 emission	24 t-C/ha･y
Oil palm	－6
Natural swamp	－5
CO_2 reduction	
（24－6＋5）	

23 (84t-CO2/ha･y)

Reduction potential:１００Mt-C/Y (5Mha)

CO_2 reduction cost using developed tropical peat swamp

1.	Land rental (20years)	100,000¥/ha
2.	Land preparation	130,000¥/ha
3.	Seedling, plantation	40,000¥/ha
4.	Others	100,000¥/ha
Total		370,000¥/ha

・compensation of palm oil income ＝200,000¥/ha

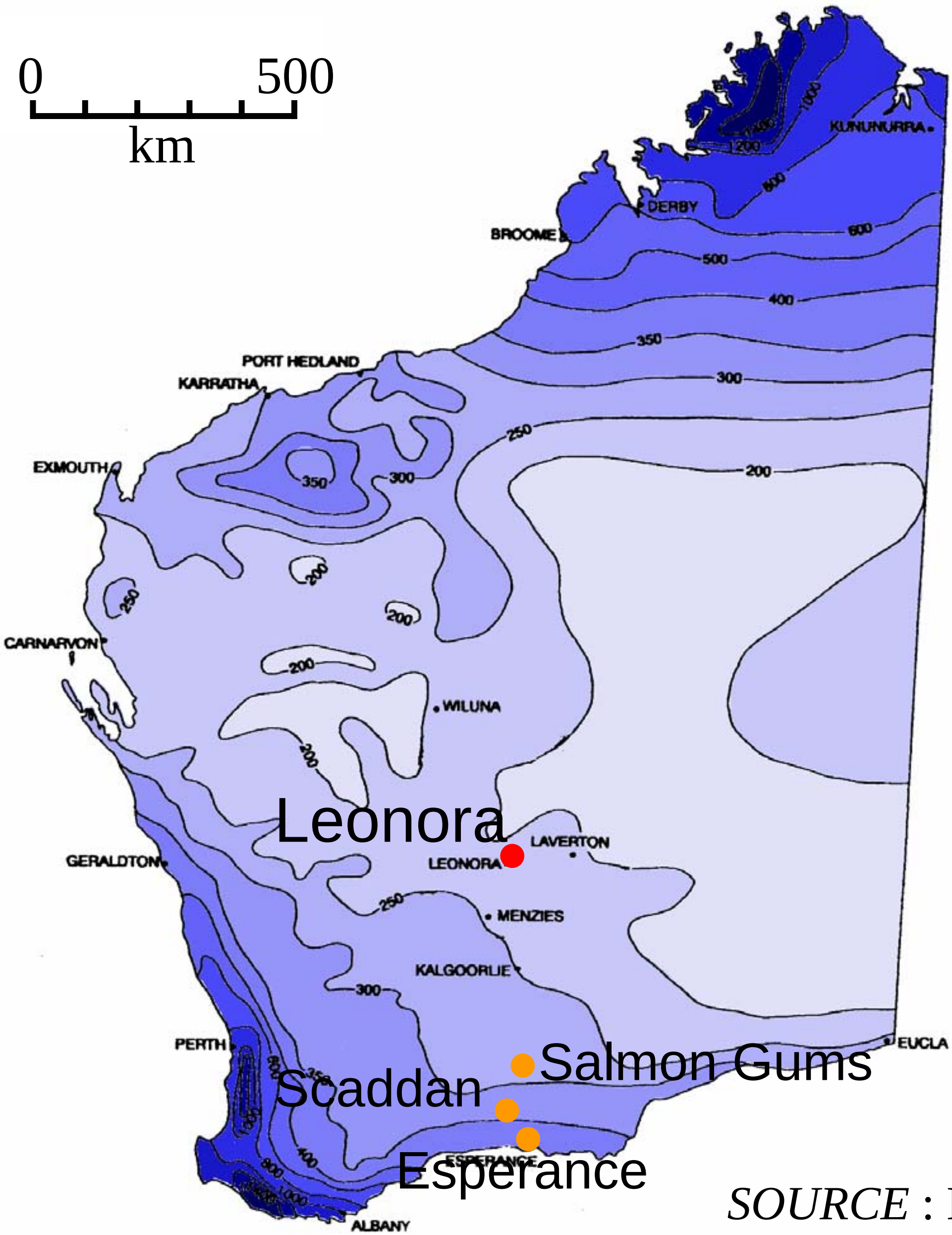
CO_2 reduction cost

$$\frac{370{,}000+200{,}000}{23\times 20}$$

＝1,240¥/t-C

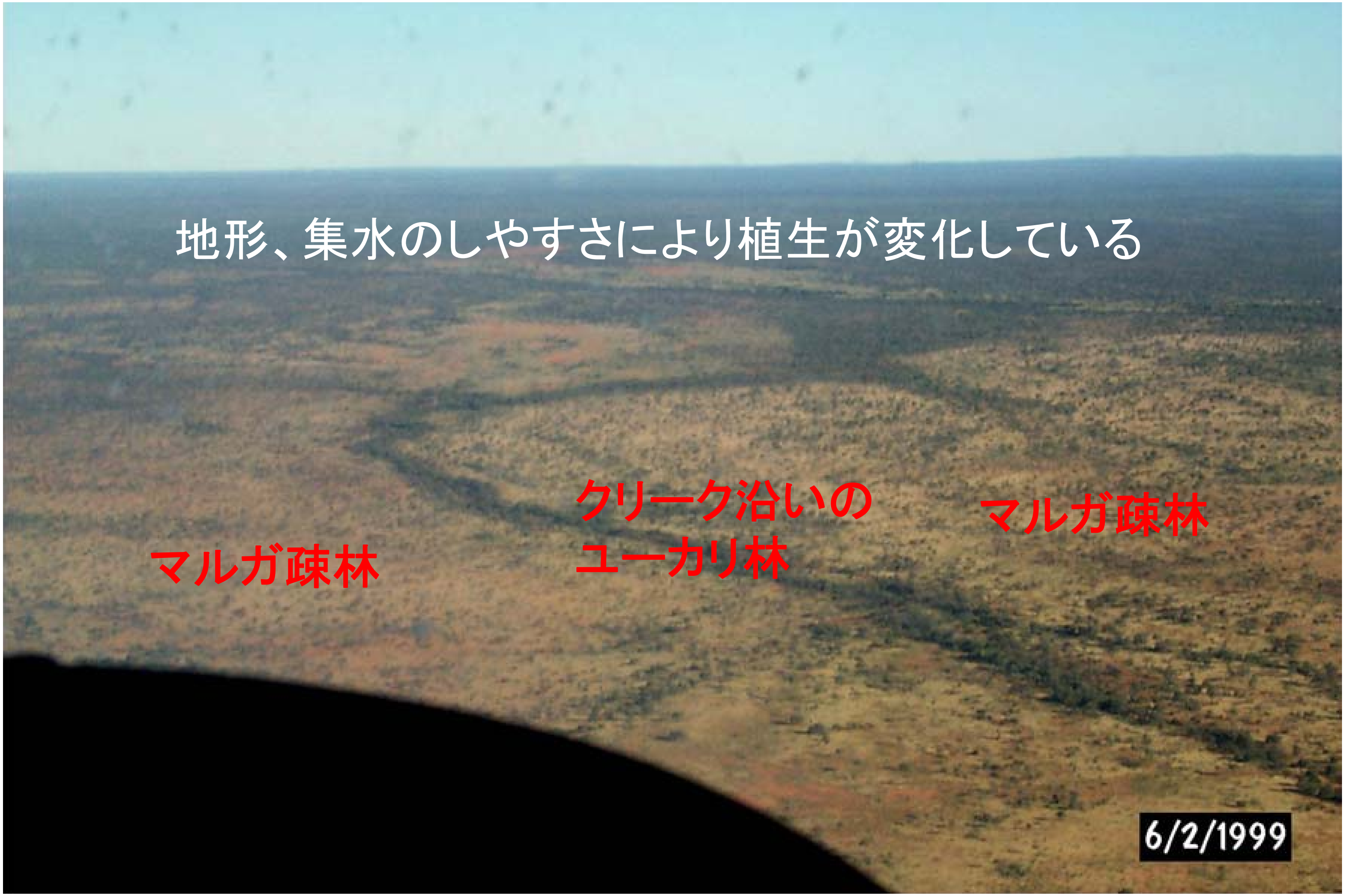
(＝ 340¥/t-CO2)

Research areas in Western Australia

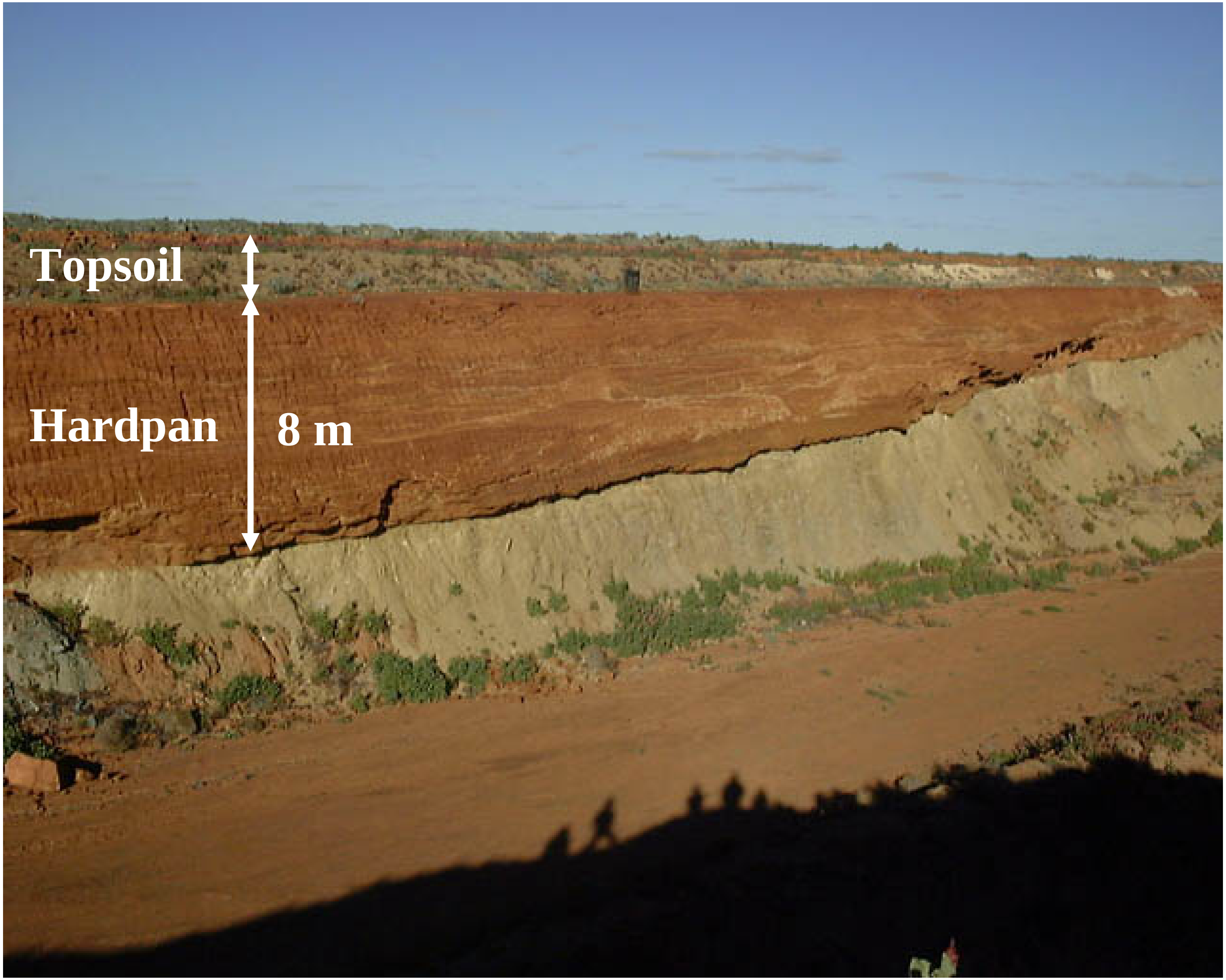


Annual rainfall [mm]	Area [km^2]
～200	594,060
200～250	751,087
250～300	367,124
300～350	267,372
350～400	153,694
400～600	129,410
600～800	106,600
800～1000	67,016
1000～1200	26,998
1200～1400	23,351
1400～	10,214
Total area	2,496,925

SOURCE : BUREAU OF METEOROLOGY 1990



主調査地域（STM）の植生分布



Soil profile (Hardpan)

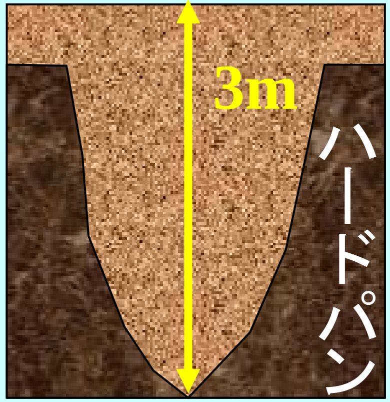
Blasting of Hardpan

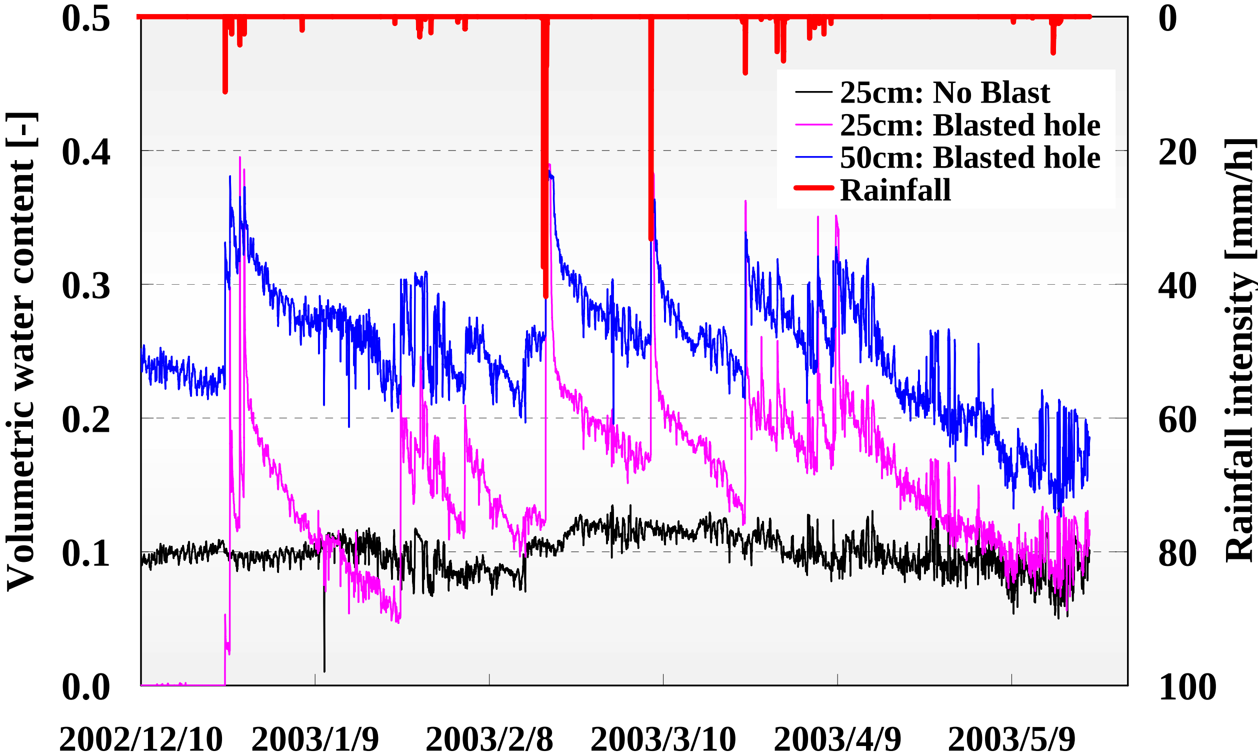
ANFO爆薬によるハードパン破砕

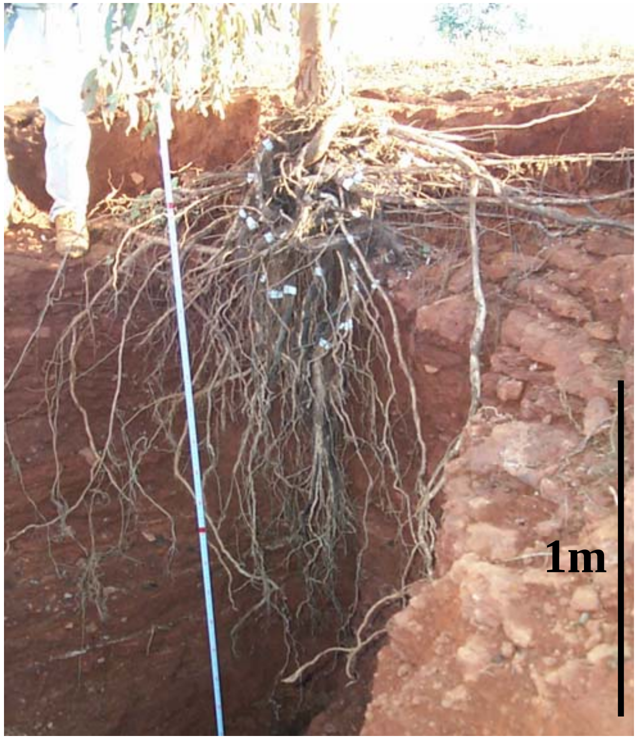
要素技術（土壌S-1土壌構造改良技術，ハードパン破砕）

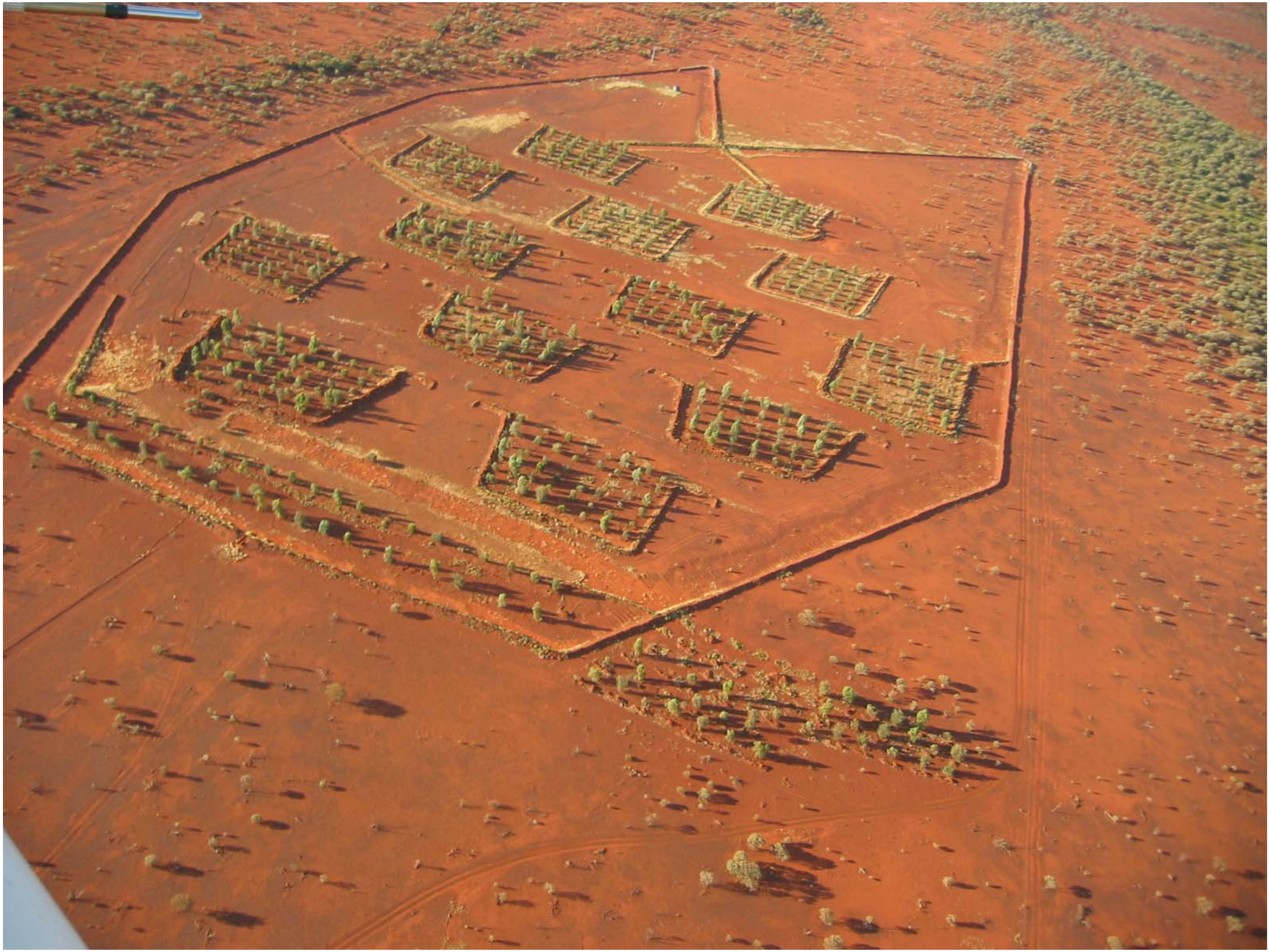
ハードパン破砕

- 根域拡大
- 蒸発抑制
- 水分保持









Site C, May 2003

要素技術（土壌S-1土壌構造改良技術，有効土層拡大）

Site E 全景

CO_2 fixation efficiencies and costs

	Site C (blasting)			Site E (soil-piling)		
Area(m^2)	140,000			15,000		
Tree No.	7,000			750		
Fixed CO_2(t-C)	1,050			113		
CO_2 emission & cost						
	consumption	CO_2 emissions (t-C)	cost (k Yen)	consumption	CO_2 emissions (t-C)	cost (k Yen)
Dieseloil	11[kl]	8.2	550	1.2[kl]	0.92	60
Explosives	25[t]	5.8	800	0		
Steel fence	3.5[t]	1.2	350	1.9[t]	0.68	190
Seedlings	7,000		560	750		60
Equipment		0.8＊	2,400		0.1＊	540
Labor	4,000[man・h]		12,000	550[man・h]		1,650
Total		16.0	16,660		1.70	2,500
CO_2 efficiency (Fixed/Emitted)		66			66	
CO_2 fixation cost (Yen/t-C)		15,900			22,000	
(Yen/t-CO_2)		4,300			6,000	

＊10% of CO_2 emissions by dieseloil

CO_2 sequestration potential in Western Australia calculated by the experimental data

A. Arid land (Ann. rainfall: 200 ~ 300 mm)

Assumption: i) Available water – 0.3 × 200 mm = 6×10^4 t-water/km^2/y

ii) Growth rate – 0.5 kg-C/t-water at 1000 mm rainfall

<u>Calculation</u> $(2.5 \times 10^3\ km^2) \times (6 \times 10^4$ t-water/km^2/y$)$

$\times (0.5 \times 10^{-3}$ t-C/t-water$) \times (1.1 \times 10^6)/(2.5 \times 10^3) \times 20$ y

$= 6.6 \times 10^8$ t-C

B. Wheat belt (Ann. rainfall: 300 ~ 600 mm)

Assumption: i) Available water – 500 mm = 5×10^5 t-water/km^2/y

ii) Growth rate – 0.35 kg-C/t-water at 500 mm rainfall

<u>Calculation</u> $(0.2 \times 5.4 \times 10^5\ km^2) \times (5 \times 10^5$ t-water/km^2/y$)$

$\times (0.35 \times 10^{-3}$ t-C/t-water$) \times 30$ y

$= 5.7 \times 10^8$ t-C

Carbon sequestration potential in W.A. = 1.2 **G t-C/20y**

Conclusion

1. A present CO_2 capture cost (40$/t-$CO_2$) is comparable to CO_2 fixation cost by afforestation of arid land.
2. Future CO_2 capture cost can be reduced to less than 50% of a present one.
3. CO_2 reduction cost using developed tropical peat swamp is as low as 3$/t-$CO_2$.