Dept. of Forest Economics

Seminar

Peter Lohmander

Dept. of Forest Economics
SLU Umeå, Sweden

is giving a seminar on

Principles of optimal forest utilization and the global warming problem

Thursday December 10, 2009,
1400 HRS

SLU

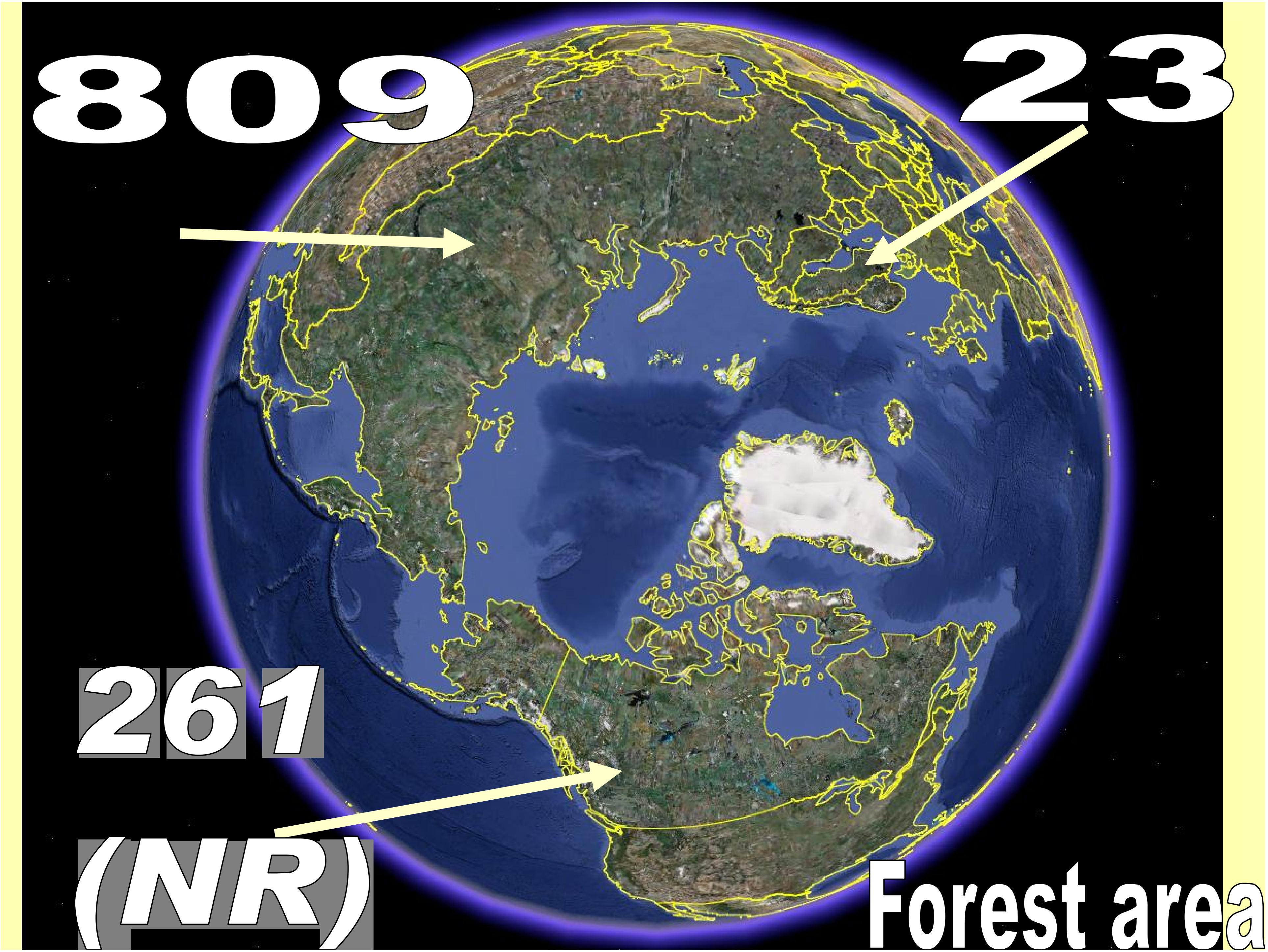
Principles of optimal forest utilization and the global warming problem

- Observations of the state of the global forest
- Briefing on recent ideas
- Comments on the recent ideas
- Principles of optimal forest utilization and the global warming problem from different perspectives

Observations of the state of the global forest

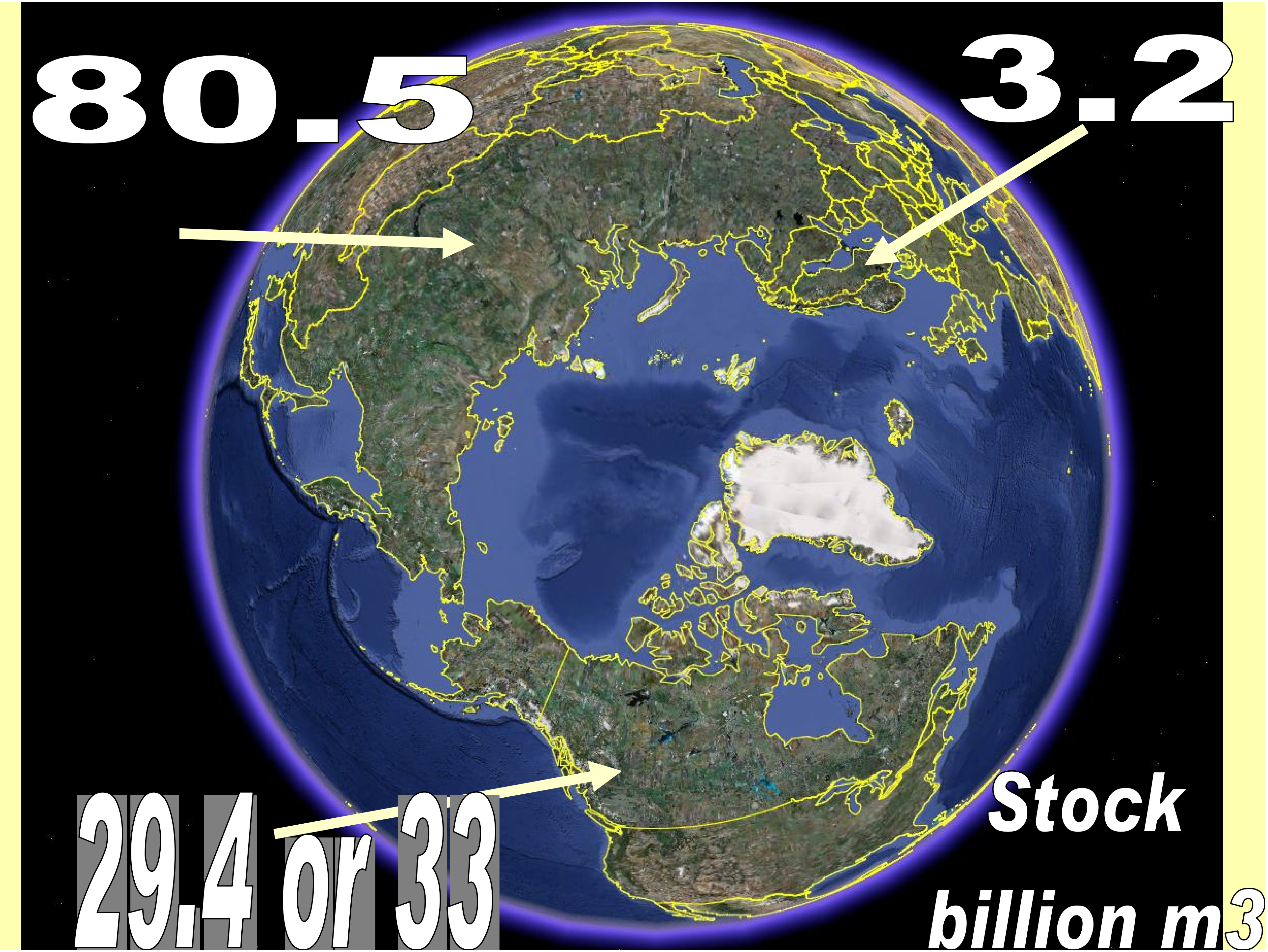

MONGOLIA
CHINA
RUSSIA
FINLAND
SWEDEN
NORWAY
Arctic Ocean
The Circumpolar Extent of the Boreal Forest
Boreal Forest
International Boundaries
U.S.A.
(ALASKA)
ARCTIC CIRCLE
Atlantic Ocean
Pacific Ocean
CANADA
0 500 1000 1500 km


Russian Fed.
Sweden
Canada


809
23
261
(NR)
Forest area

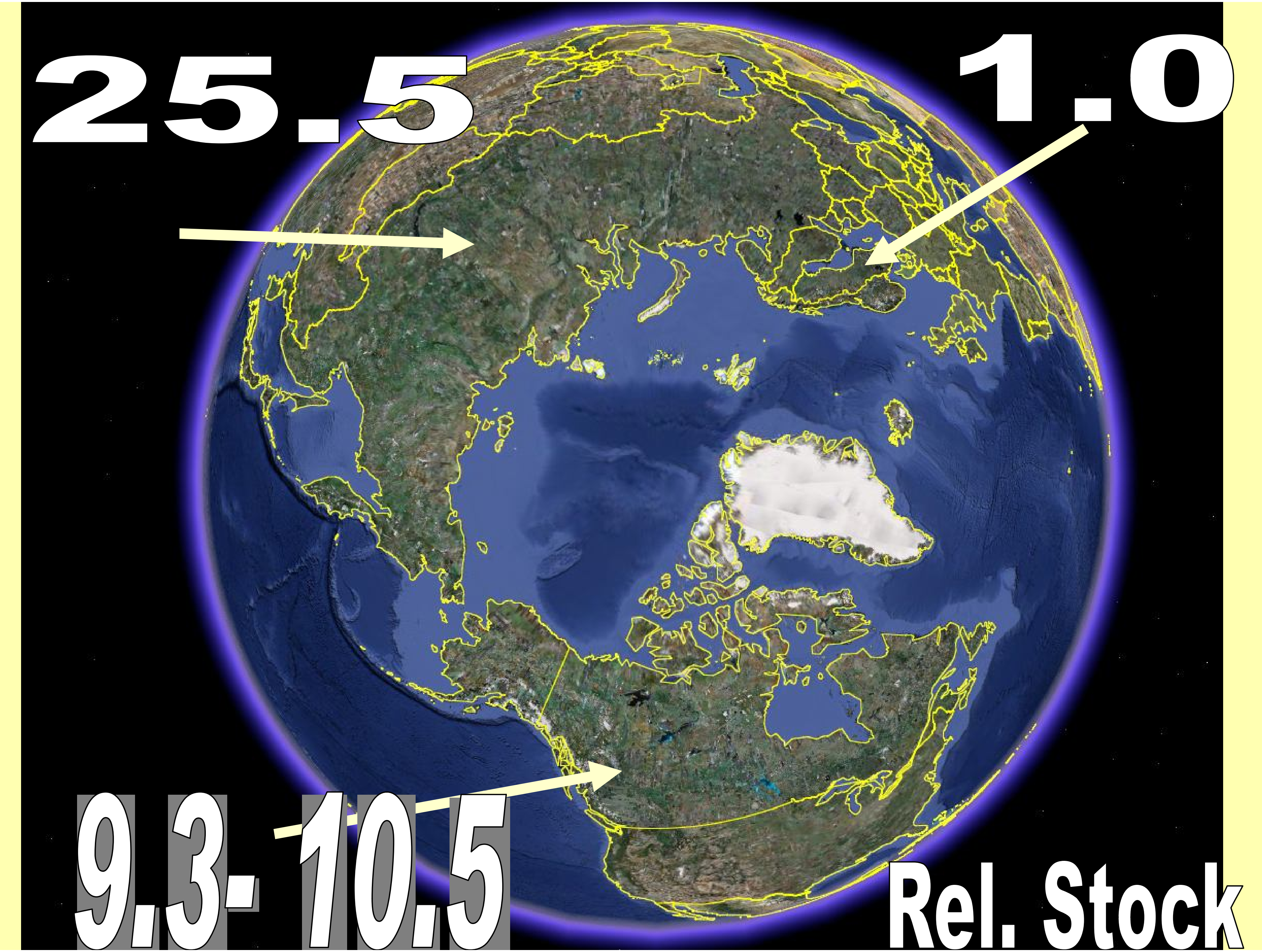
Forest area (million hectares):

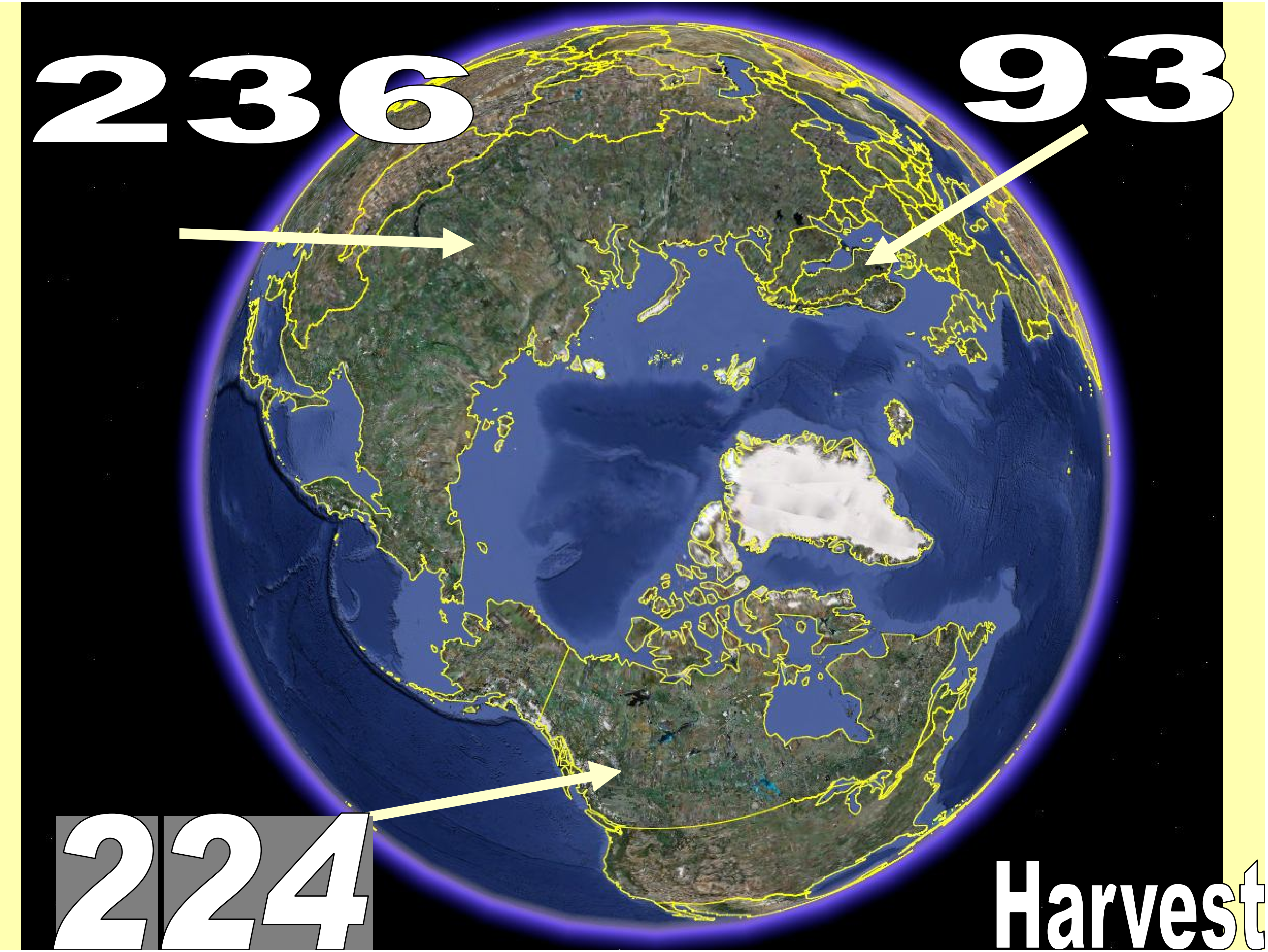
- Sweden: 23.000 (SVO, 2009)
- Russian Federation: 808.790 (FAO, 2005)
- Canada: non res. = 260.643. (Canfi 2001)


80.5
3.2
29.4 or 33
Stock
billion m3

Forest stock (million cubic metres):

Sweden:	**3 155**	**(SVO, 2008)**
Russian Federation:	**80 479**	**(FAO, 2005)**
Canada:	**29 384**	**(Canfi 2001)**
Canada	**32 983**	**(FAO 2005)**


25.5
1.0
9.3- 10.5
Rel. Stock


236
93
224
Harvest

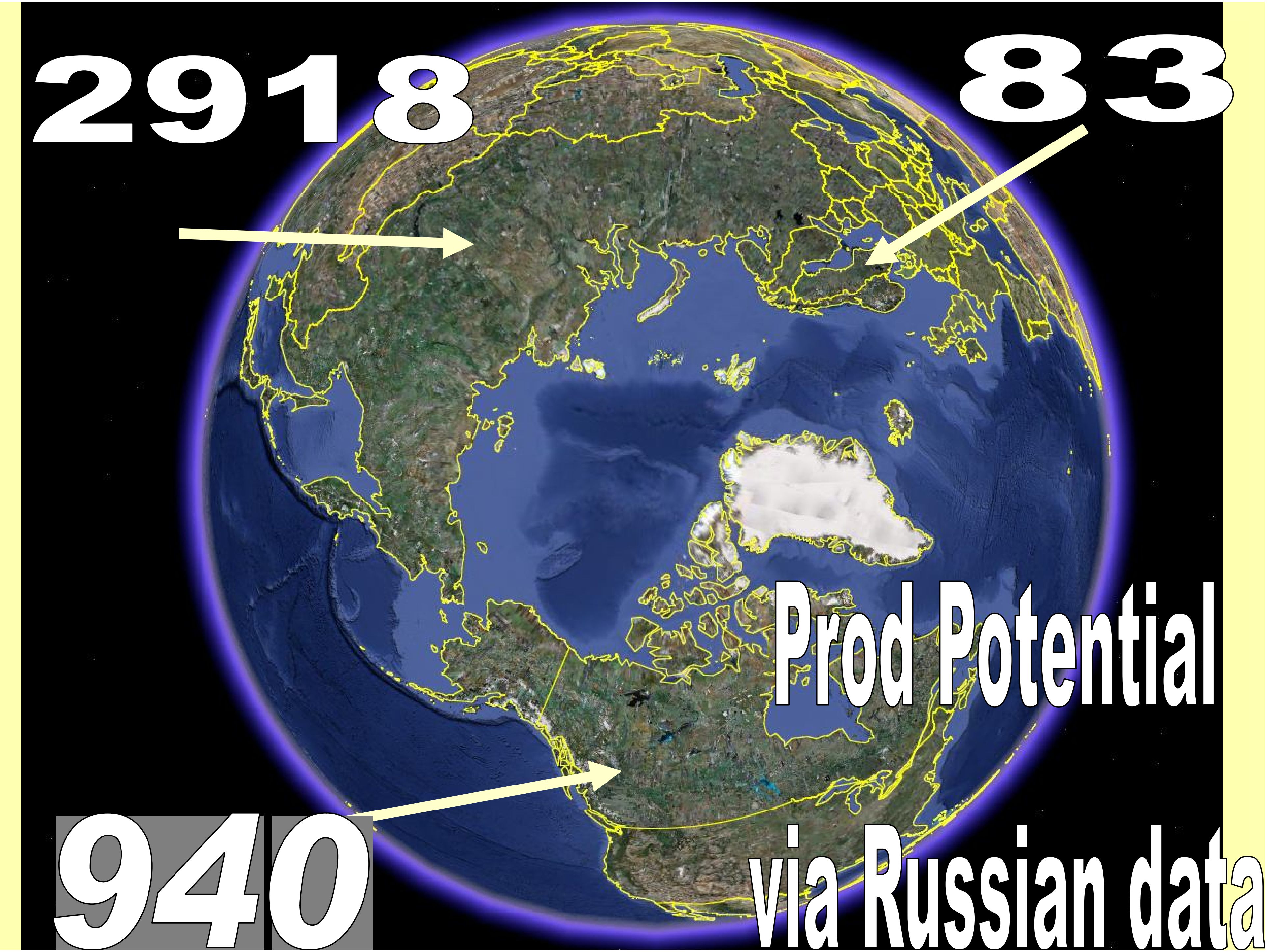
Forest harvest *(million cubic metres) (FAO, 2005):*

- Sweden: 92.8 (Roundwood + pulpwood)
- Russian Federation: 236 (Roundwood + pulpwood)
- Canada: 223.5 (Industrial roundwood 219.5 + woodfuel 4)

Russian site index tables give:

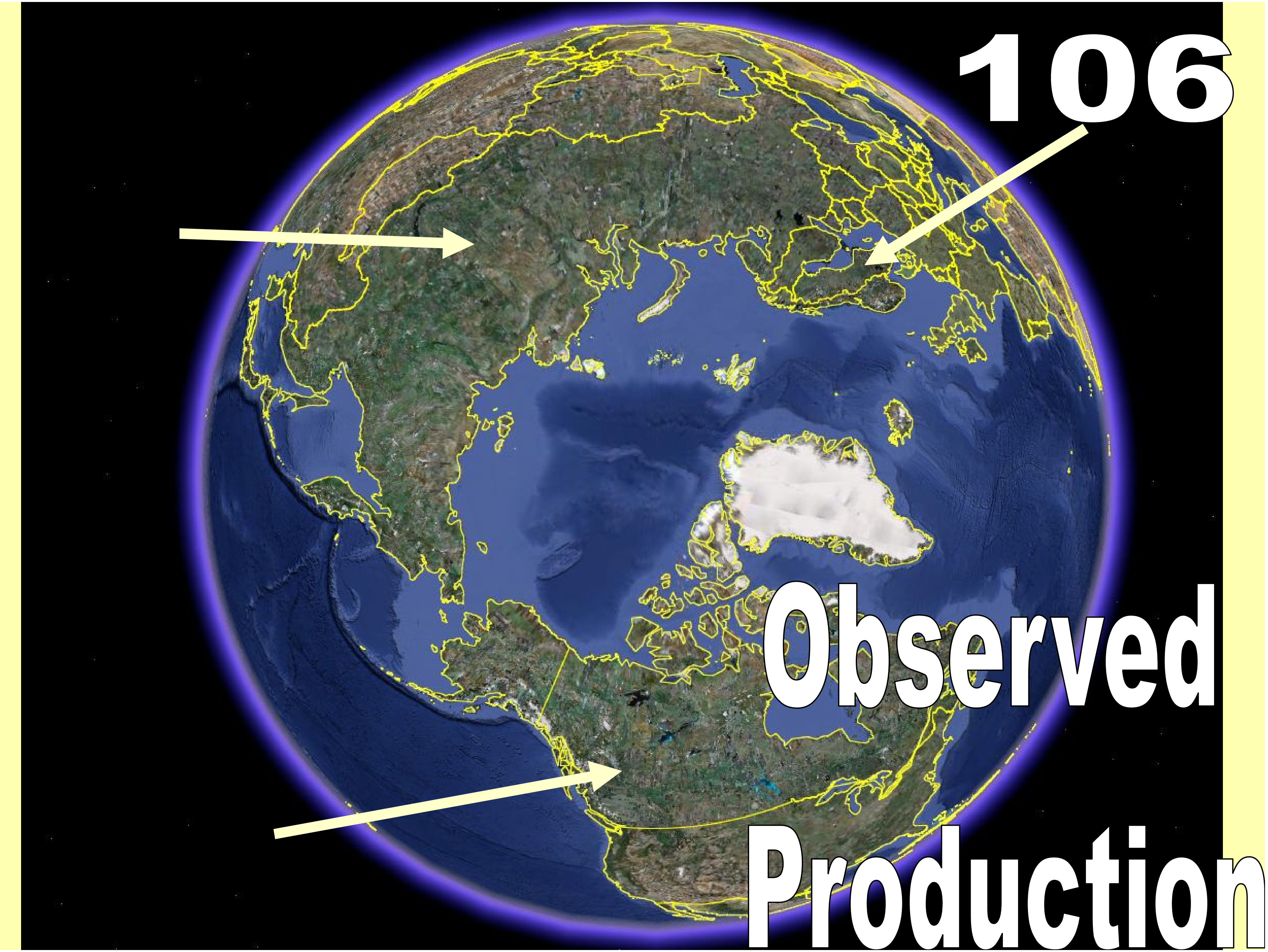
- *Total growth 2919 million cubic metres on 645 million hectares (the best soils) gives 4.53 m3/ha.*
- *Total growth 2919 million cubic metres per 809 million hectares (total forest area) gives 3.608 m3/ha.*

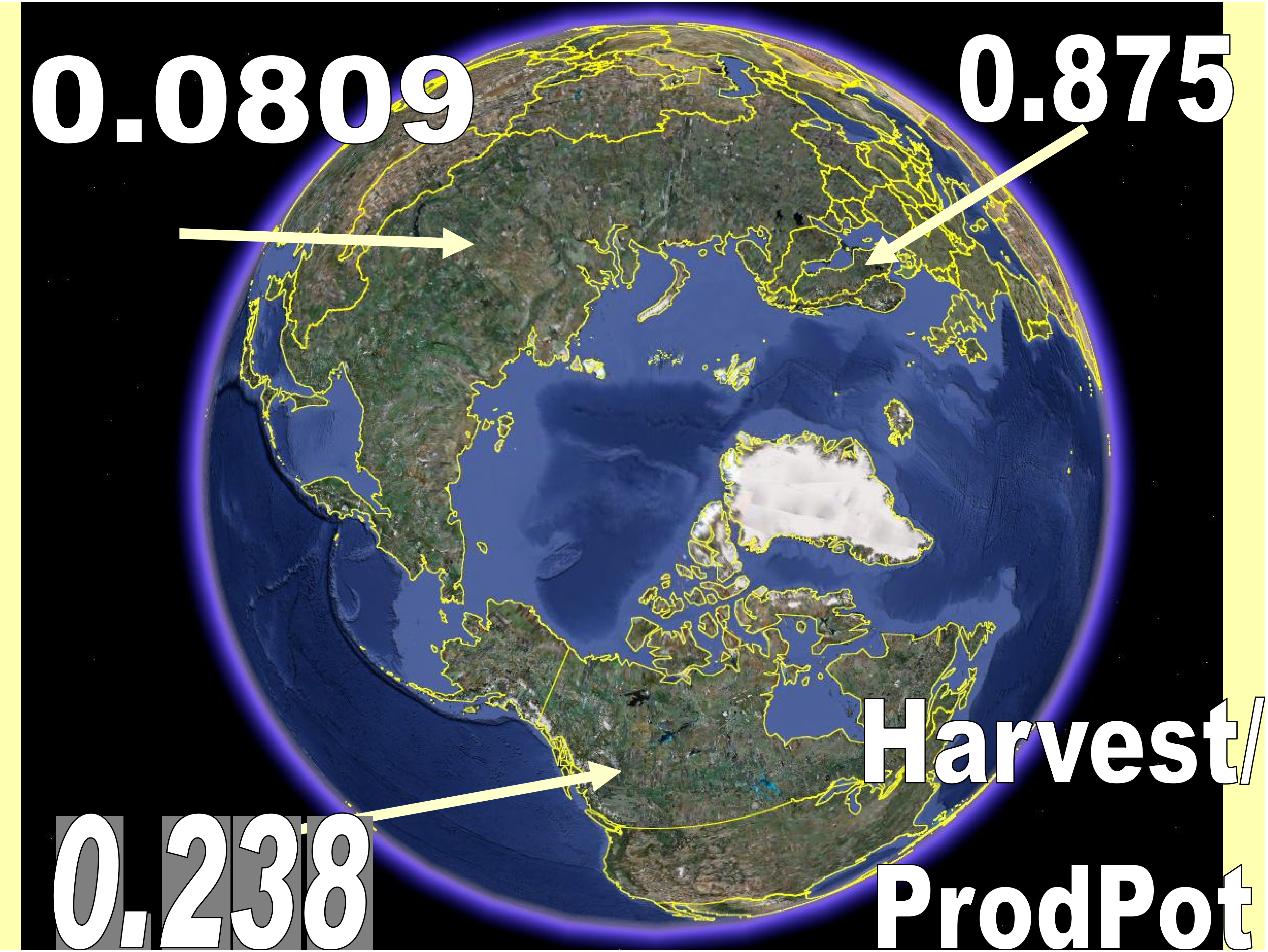
- *http://www.lohmander.com/RuMa09/Lohmander_Presentation.ppt*
- http://www.iiasa.ac.at/Research/FOR/forest_cdrom/english/for_fund_en.html


2918
83
940
Prod Potential
via Russian data

Forest production potential (using Russian figures per hectare) (million cubic metres per year):

- Sweden: 23.000*3.608 = **<u>83</u>** (Observed growth = 106 000, SVO, 2008)
- Russian Federation: 808.790 000*3.608 = **<u>2 918</u>**
- Canada: (non reserved land): 260.642*3.608 = **<u>940</u>**


106
Observed
Production


0.0809
0.875
Harvest/
ProdPot
0.238

Harvest in relation to observed growth and in relation to potential growth:

- Sweden (estimated): 92.8/83 = **1.12**
- Sweden (observed): 92.8/106 = **0.875**
- Russian Federation: 236/2918 = **0.0809**
- Canada: 223.5/940 = **0.238**

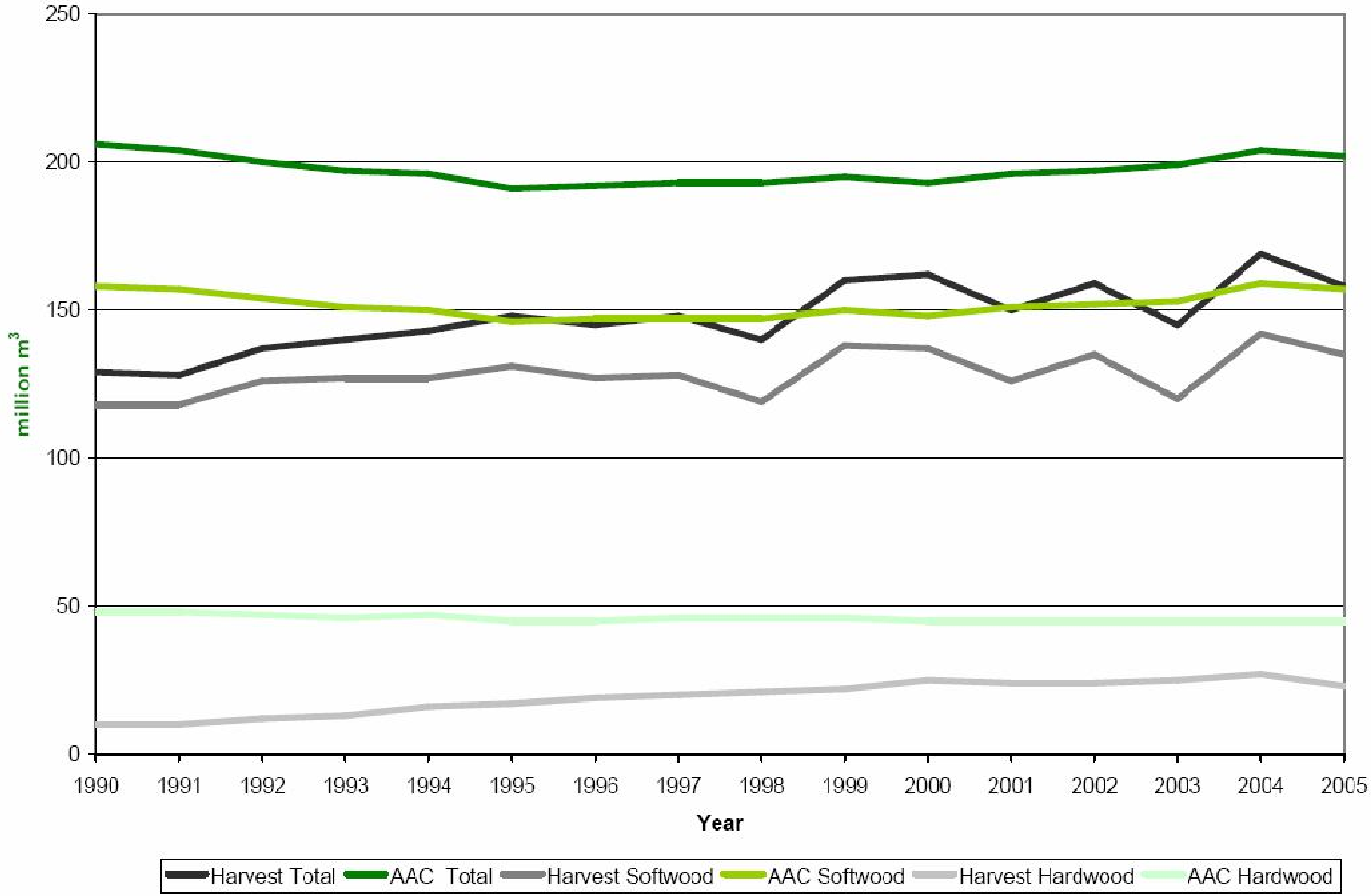
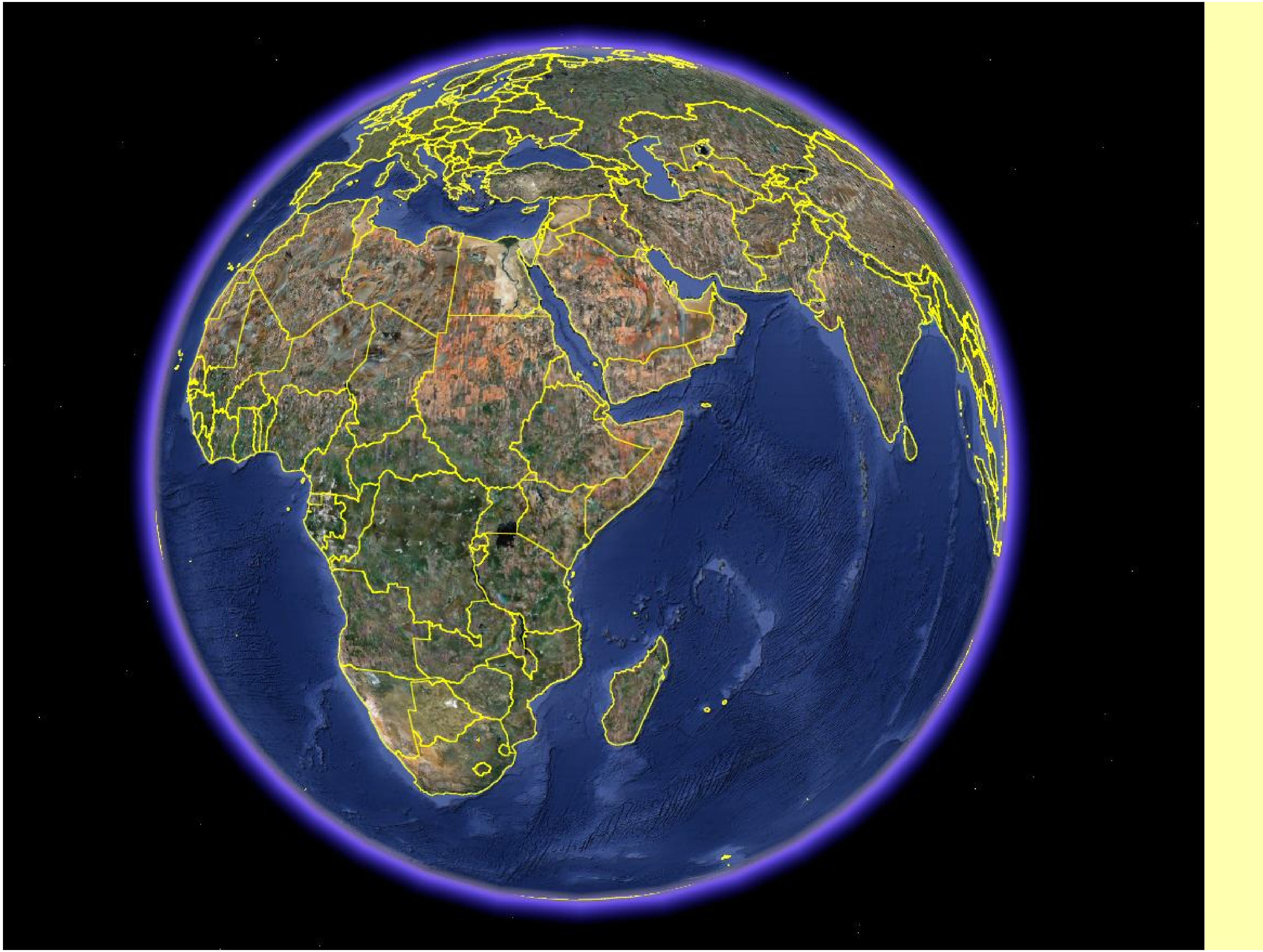
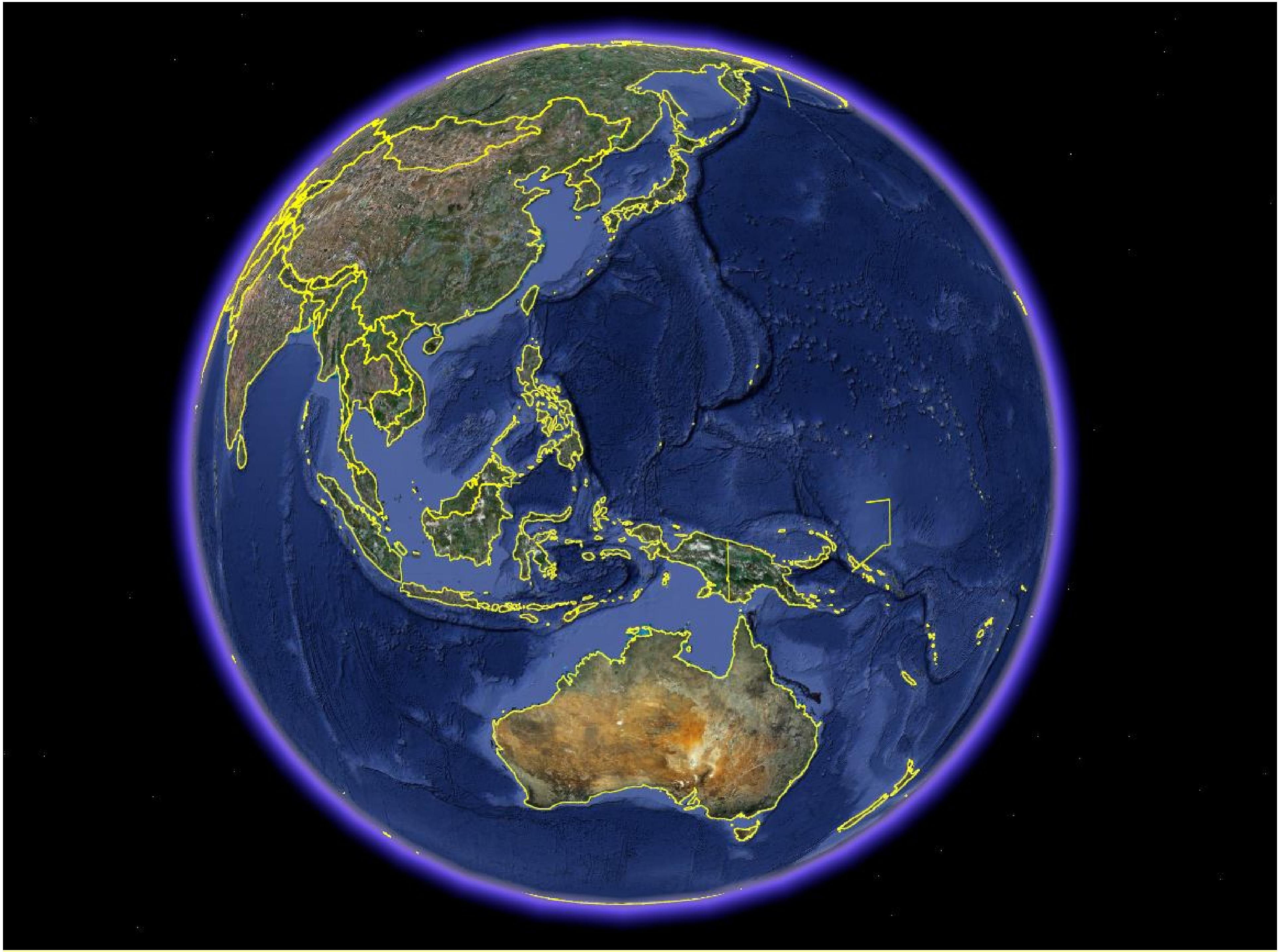


Figure 5.3a Allowable annual cut versus actual harvest (provincial crown land), 1990–2005 (million m3) (CCFM, 2008).

Criteria and Indicators of Sustainable Forest Management in Canada: National Status 2005
Data updated: January 2008
© Canadian Council of Forest Ministers

http://www.ccfm.org/ci/rprt2005/English/pdf/5.3a.pdf





Briefing on recent ideas

Skogen är viktig i Köpenhamn

”The forest is important in Copenhagen”

- [Debattartikel i Dagens Industri 091126]
- *Citat ur artikeln (Free translations of Citations):*
- ***Forests should be saved because of biodiversity considerations. However, fires, insects and storms can rapidly decrease the stock level in the forests. For this reason, we should not increase the stock level in the forest in order to increase the amount of stored carbon.***
- ”**Skogar ska sparas för mångfaldens skull, men bränder, insekter eller stormar kan på kort tid omintetgöra speciella satsningar på lagerökning i skog för kollagrets skull.**
- **It is a lot safer, and in the long run cheaper, to replace the use of coal and oil by forest fuels, than to increase the amount of stored carbon in the forests and forest land, if we want to reduce our influence on the climate.**
- **Att minska utsläppen från kol- och oljeeldning genom ersättning med skogsbränslen är betydligt säkrare och i längden billigare än att bygga extralager av kol i skog och mark om vi vill minska vår klimatpåverkan.”**

Monika Stridsman
generaldirektör, Skogsstyrelsen
Director General, Swedish Board of Forestry

Comment from Peter Lohmander

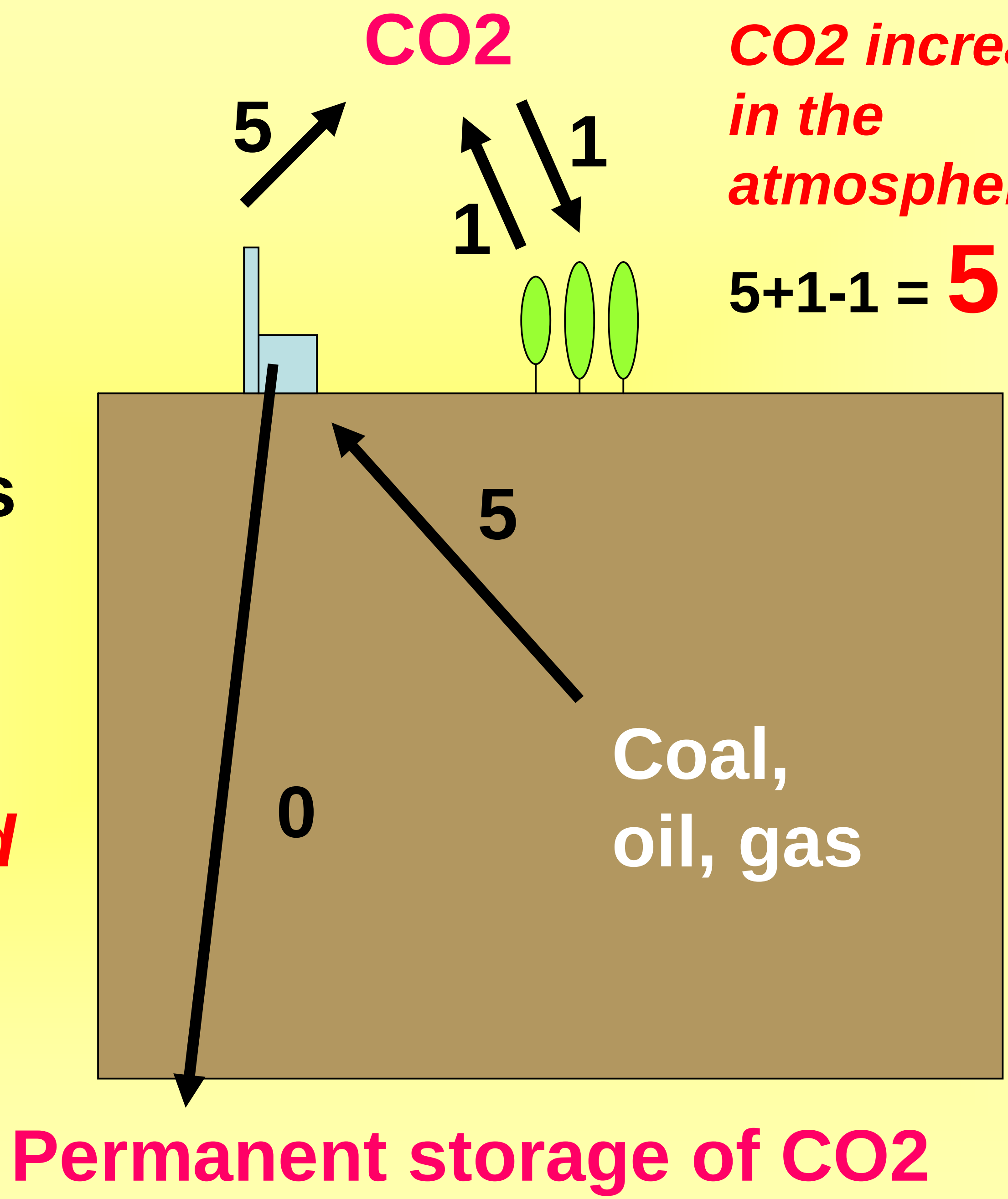
- **The general conclusions expressed by Director General Monika Stridsman, match the conclusions written here:**

- **Lohmander, P., Optimal dynamic control of the forest resource with changing energy demand functions and valuation of CO_2 storage**, The European Forest-based Sector: Bio-Responses to Address New Climate and Energy Challenges, Nancy, France, November 6-8, 2008, Proceedings: (forthcoming) in French Forest Review (2009) Abstract: Page 65 of: http://www.gip-ecofor.org/docs/34/rsums_confnancy2008__20081105.pdf
  Presentation as pdf: http://www.gip-ecofor.org/docs/nancy2008/ppt_des_presentations_orales/lohmander_session_3.1.pdf
  Conference: http://www.gip-ecofor.org/docs/34/nancy2008englishprogramme20081106.pdf

- ECOFOR, (in French) Summary of results by Peter Lohmander (on page 8) in "**Evaluation du developpement de la bioenergie**", in Bulletin d'information sur les forets europeennes, l'energie et climat, Volume 157, Numero 1, Lundi 10 novembre 2008 http://www.gip-ecofor.org/docs/34/nancy2008synthseiisd.pdf

  IISD, Summary of results by Peter Lohmander (on page 6) in "**Evaluation of Bioenergy Development**", in European Forests, Energy and Climate Bulletin, Published by the International Institute for Sustainable Development (IISD) http://www.iisd.org/ , Vol. 157, No. 1, Monday, 10 November, 2008 http://www.iisd.ca/download/pdf/sd/ymbvol157num1e.pdf

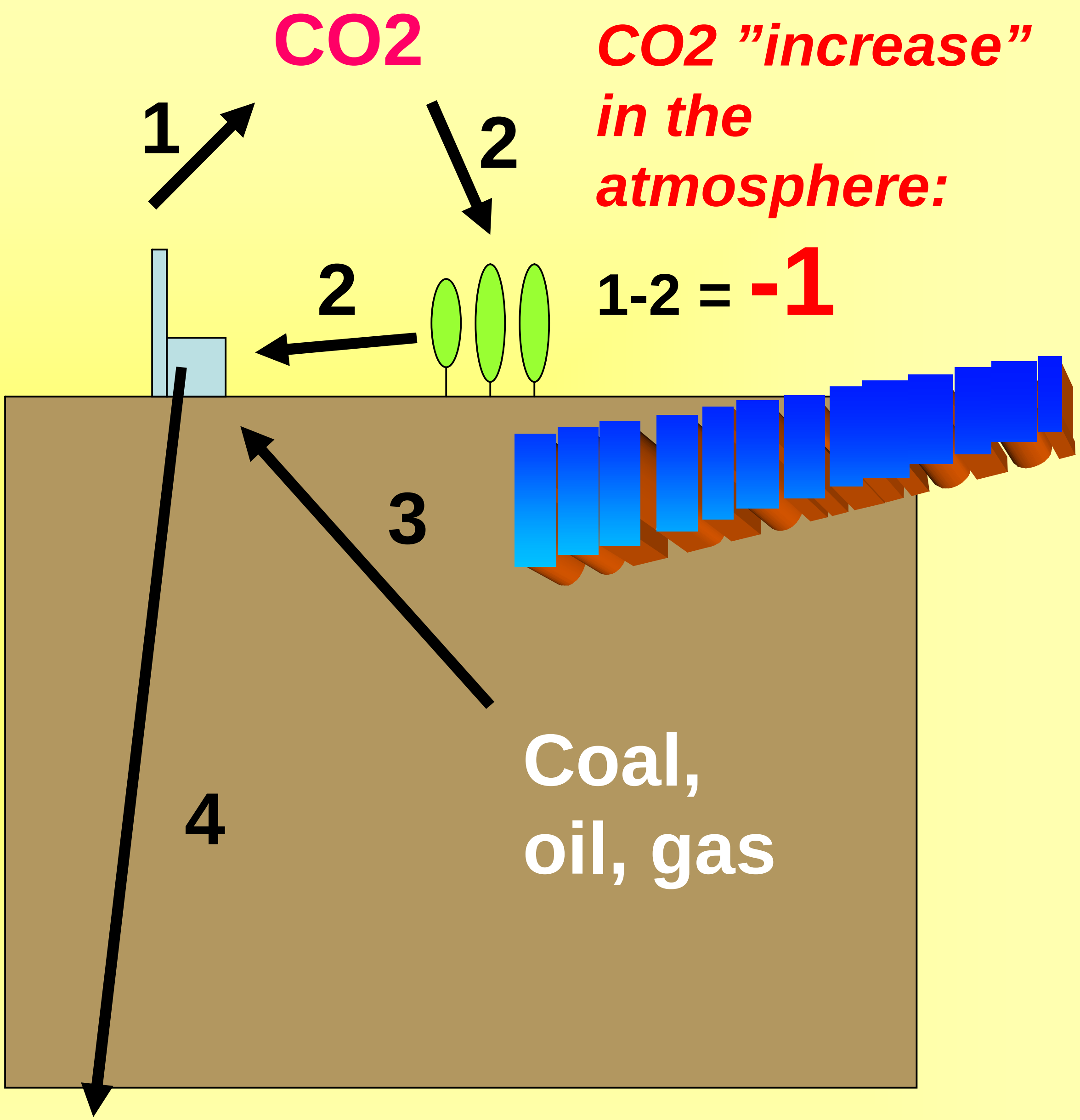
If we do not use the forest for energy production but use it as a carbon sink. *When the forest has reached equilibrium*, this happens:



CO2 increase in the atmosphere:

5+1-1 = 5

If we use CCS with 80% efficiency and use the forest with increased harvesting and high intensity silviculture.



Permanent storage of CO2

Säkra skogen med riskspridning

Make the forest safer via diversification

- mats.p.ostelius@lrfmedia.lrf.se
- **Skogsland** 4 december 2009
- http://www.skogsland.com/sakra-skogen-med-riskspridning/2009-12-04

- **Diversification is the key to the management of climatic changes in forestry, according to the Swedish Board of Forestry. SBF recently finished the climate policy document.** ”**Riskspridning är nyckeln till att klara klimatförändringarna i skogsbruket, enligt Skogsstyrelsen. Myndigheten blev nyligen klar med sin klimatpolicy.**”
- – Inget gäller knivskarpt alla skogsägare i alla lägen. Men alla bör få kunskap om hur man kan säkra sitt skogsbruk i ett varmare klimat. Produktionen kommer visserligen att öka men när klimatet förändras ökar också risken för skador, säger **Hillevi Eriksson, klimatexpert på Skogsstyrelsen**. **Climate Expert at the Swedish Board of Forestry**
- **One way to decrease the risk and diversify, is to use several tree species in plantations and to create mixed forests. Ett sätt att sprida riskerna är att föryngra med flera olika trädslag och att anlägga blandskogar.** Det ger till exempel minskad sårbarhet för vind samt för svamp- och insektsangrepp.

Comment from Peter Lohmander

- **The general conclusions expressed by Climate Expert Hillevi Eriksson, match the conclusions written here:**

- Lohmander, P., **Flexibilitet - en ledstjärna for all ekonomisk skoglig planering**,SKOGSFAKTA, Inventering och Ekonomi, No. 23, 4p, 1990
- Lohmander, P., **Economic two stage multi period species management in a stochastic environment: The value of selective thinning options and stochastic growth parameters**, SYSTEMS ANALYSIS - MODELLING -SIMULATION, Vol. 11, 287-302, 1993
- Lohmander, P., **Optimal sequential forestry decisions under risk**, ANNALS OF OPERATIONS RESEARCH, Vol. 95, pp. 217-228, 2000
- Lohmander, P., **Optimala beslut inför osäker framtid**, FAKTA SKOG, SUAS, Nr 10, 2001
- Lohmander, P., **Adaptive Optimization of Forest Management in a Stochastic World**, in Weintraub A. et al (Editors), Handbook of Operations Research in Natural Resources, Springer, Springer Science, International Series in Operations Research and Management Science, New York, USA, pp 525-544, 2007
  http://www.amazon.ca/gp/reader/0387718141/ref=sib_dp_pt/701-0734992-1741115#reader-link

Principles of optimal forest utilization and the global warming problem

- from different perspectives

Optimal dynamic control of the forest resource with changing energy demand functions and valuation of CO2 storage

Presentation at the Conference:

The European Forest-based Sector:
Bio-Responses to Address New Climate and Energy Challenges?
Nancy, France, November 6-8, 2008

Peter Lohmander

Professor of Forest Management and Economic Optimization
SLU, Swedish University of Agricultural Sciences
Umea, Sweden

http://www.Lohmander.com

Structure of the presentation:

#1. Introduction to rational use of the forest when we consider CO2 and energy production

#2. Optimal dynamic control of the forest resource with changing energy demand functions and valuation of CO2 storage (expanded)

#3. Optimal CCS, Carbon Capture and Storage, Under Risk

#4. Conclusions

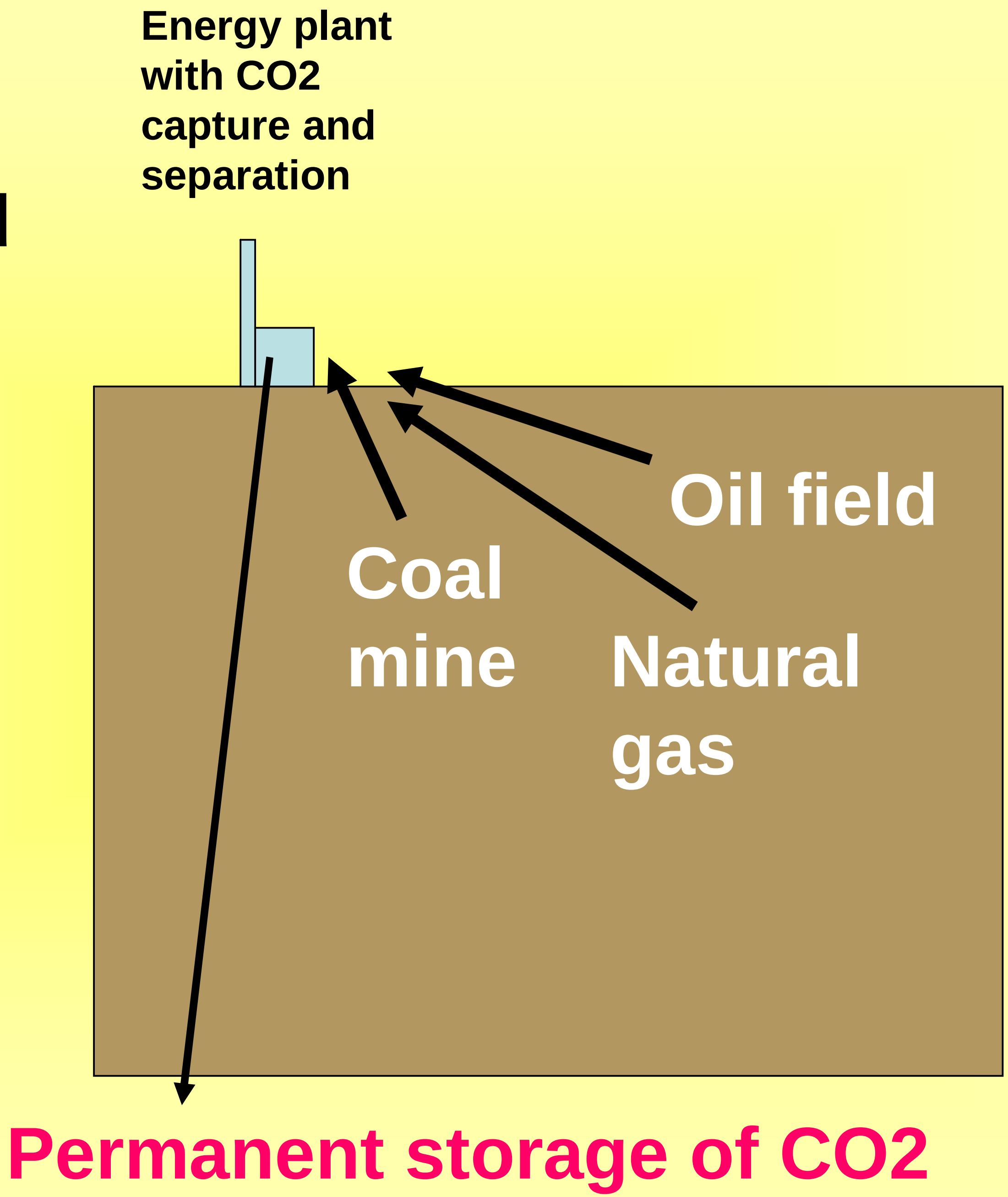
#1. Introduction to rational use of the forest when we consider CO2 and energy production

The role of the forest?

- The best way to reduce the CO_2 in the atmosphere may be to ***increase harvesting of the presently existing forests (!)***, to produce energy with CCS and to increase forest production in the new forest generations.

- ***We capture and store more CO_2!***

CCS, Carbon Capture and Storage, has already become the main future emission reduction method of the fossile fuel energy industry



BBC World News 2008-10-17:

- ***The British government declares that the CO2 emissions will be reduced by 80% by 2050!***
- ***CCS is the method to be used in combination with fossile fuels such as coal.***

Reference to CCS in the energy industry and EU policy

2nd Annual EMISSIONS REDUCTION FORUM: - Establishing Effective CO2, NOx, SOx Mitigation Strategies for the Power Industry, CD, Marcus Evans Ltd, Madrid, Spain, 29th & 30th September 2008

The CD (above) includes presentations where several dominating European energy companies show how they develop and use CCS and where the European Commission gives the general European emission and energy policy perspective.

Conference programme:

http://www.lohmander.com/Madrid08/MadridProg08.pdf

Lohmander, P., **Guidelines for Economically Rational and Coordinated Dynamic Development of the Forest and Bio Energy Sectors with CO2 constraints**, Proceedings from the 16th European Biomass Conference and Exhibition, Valencia, Spain, 02-06 June, 2008 (In the version in the link, below, an earlier misprint has been corrected.) http://www.Lohmander.com/Valencia2008.pdf

Lohmander, P., **Economically Optimal Joint Strategy for Sustainable Bioenergy and Forest Sectors with CO2 Constraints**, European Biomass Forum, Exploring Future Markets, Financing and Technology for Power Generation, CD, Marcus Evans Ltd, Amsterdam, 16th-17th June, 2008 http://www.Lohmander.com/Amsterdam2008.ppt

Lohmander, P., **Tools for optimal coordination of CCS, power industry capacity expansion and bio energy raw material production and harvesting**, 2nd Annual EMISSIONS REDUCTION FORUM: - Establishing Effective CO2, NOx, SOx Mitigation Strategies for the Power Industry, CD, Marcus Evans Ltd, Madrid, Spain, 29th & 30th September 2008

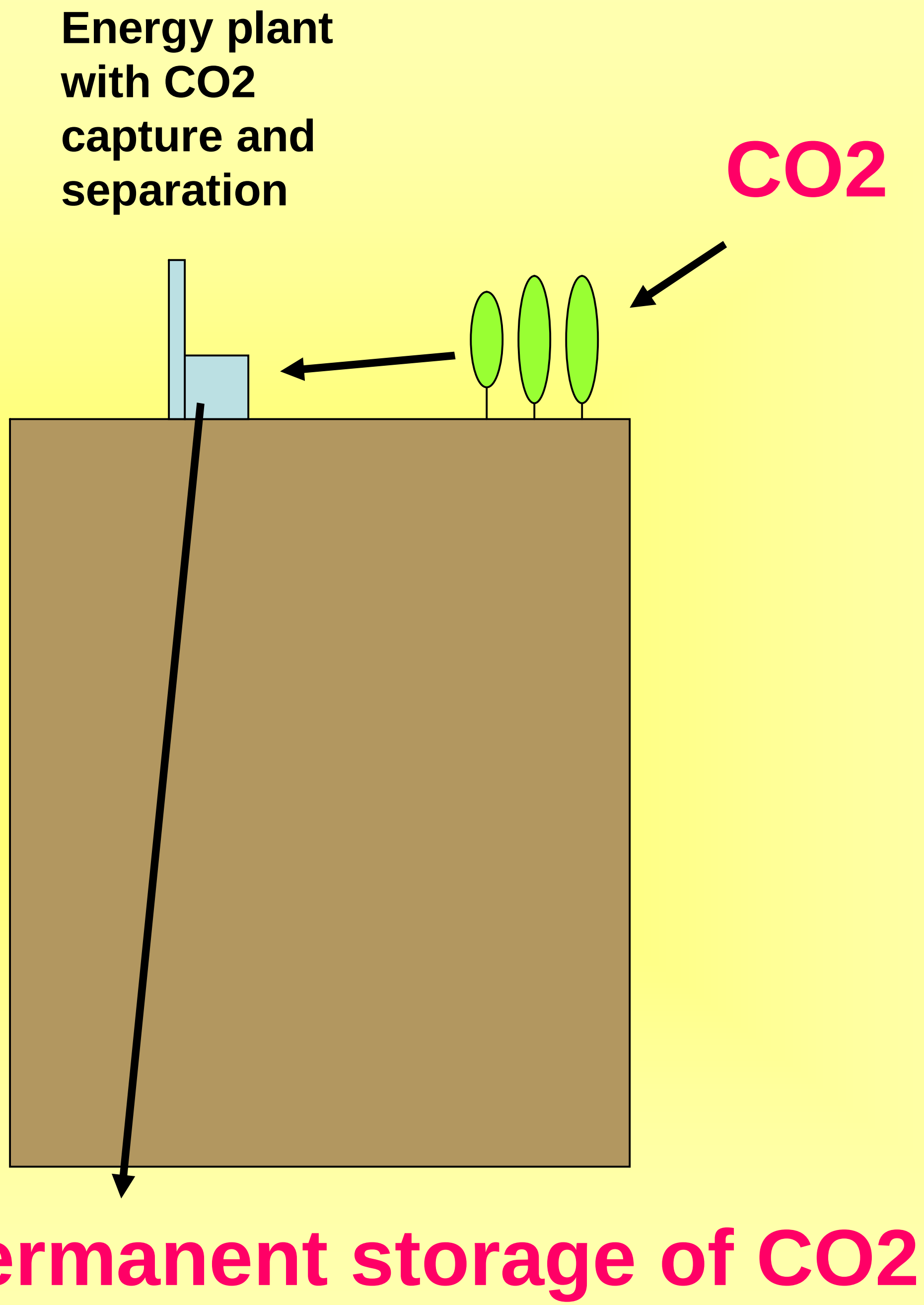
http://www.lohmander.com/Madrid08/Madrid_2008_Lohmander.ppt

Lohmander, P., **Optimal CCS, Carbon Capture and Storage, Under Risk**, International Seminars in Life Sciences, UPV, Universidad Politécnica de Valencia, Thursday 2008-10-16

http://www.Lohmander.com/OptCCS/OptCCS.ppt

How to ***reduce the CO2 level*** in the atmosphere,

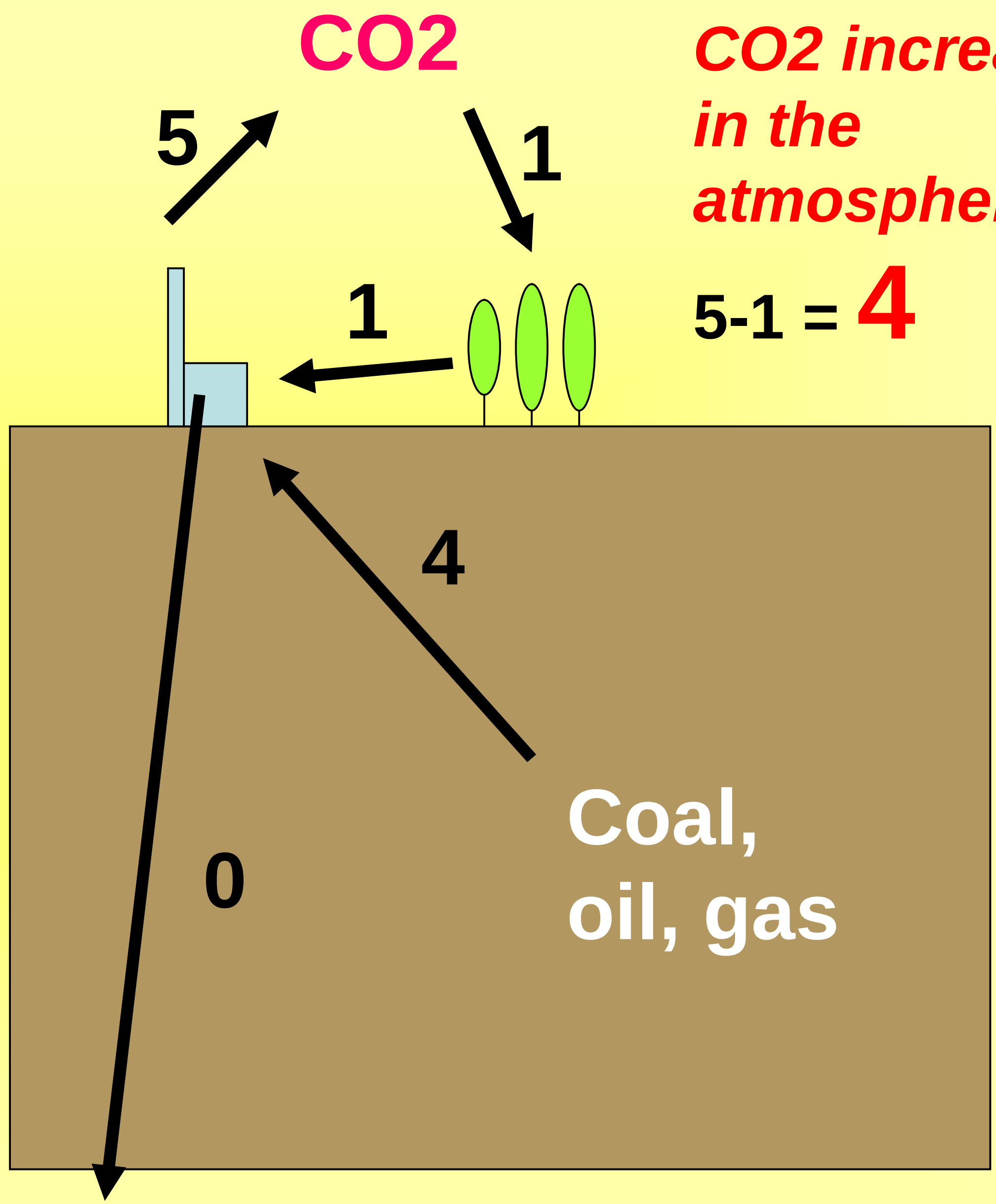
not only to decrease the emission of CO2



The role of the forest in the CO2 and energy system

- ***The following six pictures show that it is necessary to intensify the use of the forest for energy production in combination with CCS in order to reduce the CO2 in atmosphere!***
- **All figures and graphs have been simplified as much as possible, keeping the big picture correct, in order to make the main point obvious.**
- **In all cases, we keep the total energy production constant.**

The present situation.

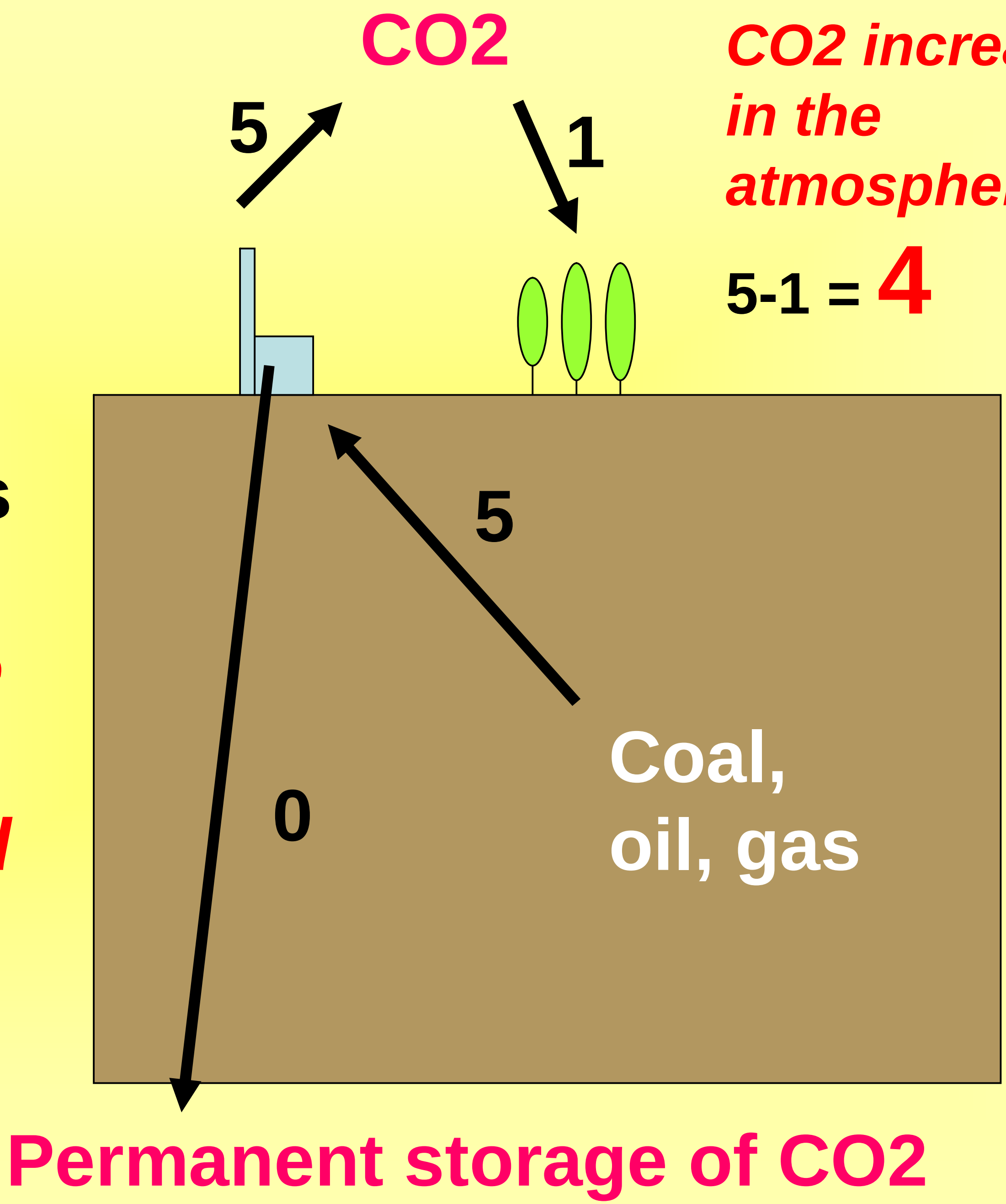


CO2 increase in the atmosphere:

5-1 = 4

Permanent storage of CO2

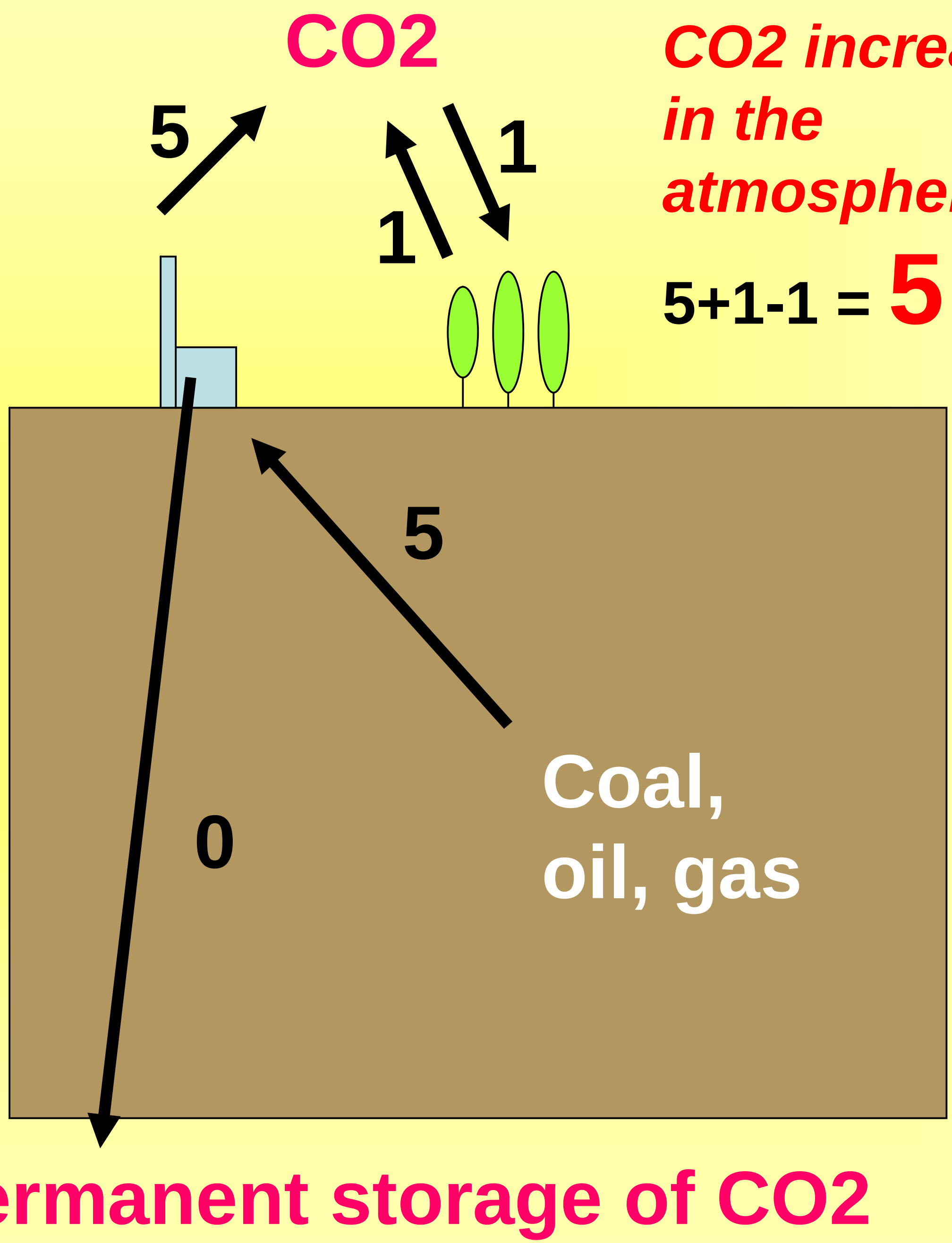
If we do not use the forest for energy production but use it as a carbon sink. *Before the forest has reached equilibrium*, this happens:



CO2 increase in the atmosphere:

5-1 = 4

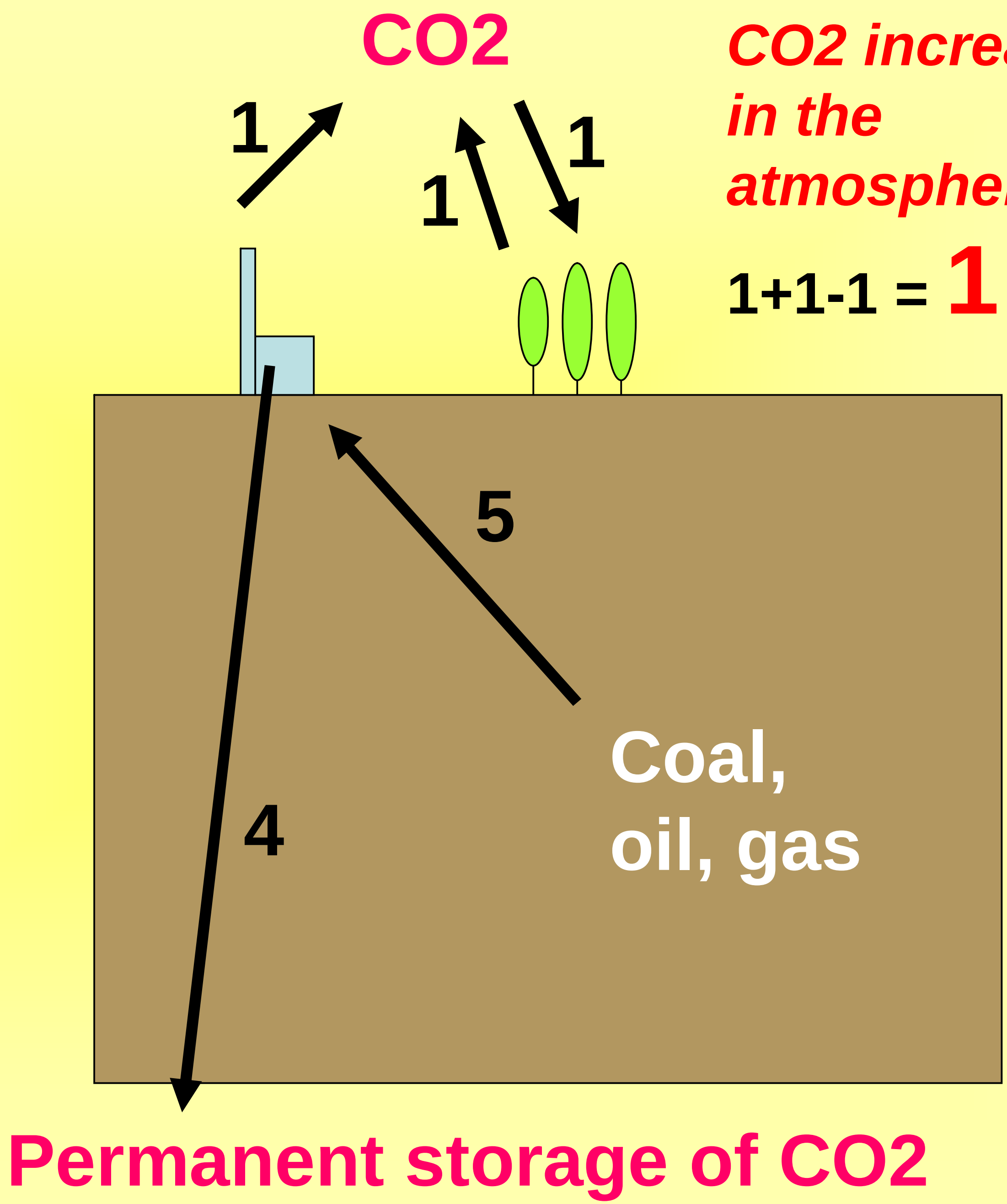
If we do not use the forest for energy production but use it as a carbon sink. ***When the forest has reached equilibrium***, this happens:



CO2 increase in the atmosphere:

5+1-1 = **5**

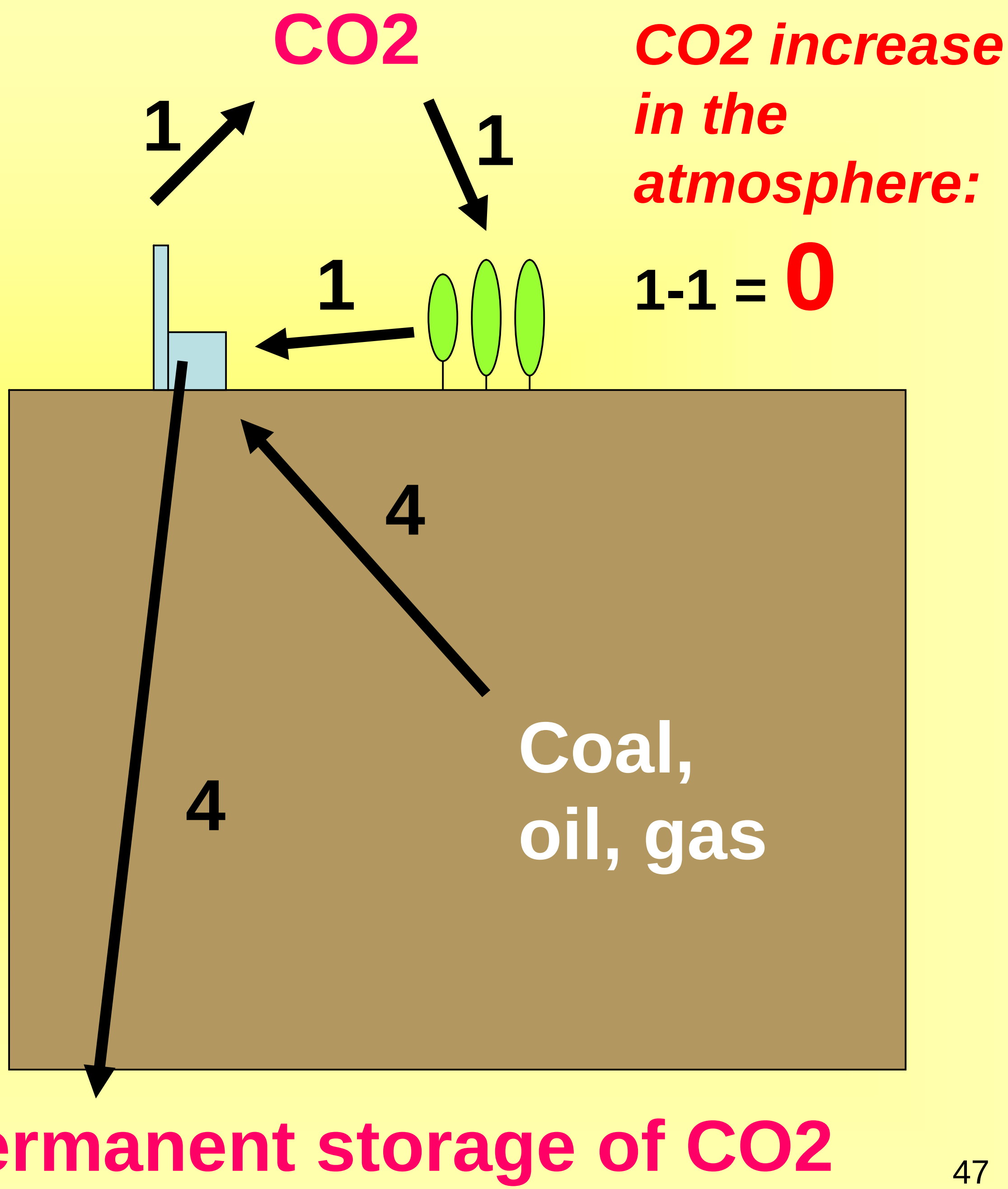
If we use CCS with 80% efficiency and let the forest grow until it reaches equilibrium.



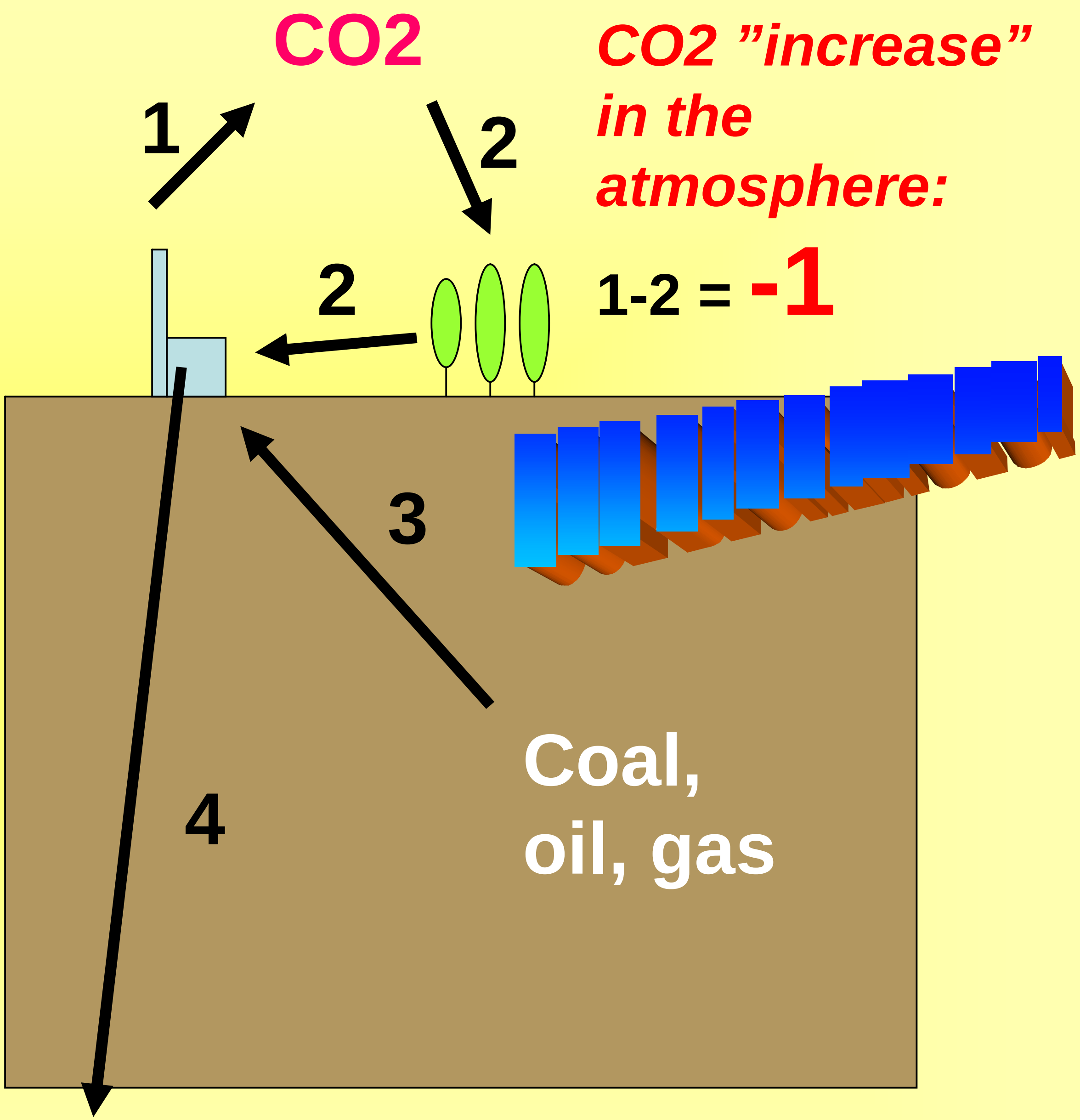
CO2 increase in the atmosphere:

1+1-1 = 1

If we use CCS with 80% efficiency and use the forest with ”traditional” low intensity harvesting and silviculture.



If we use CCS with 80% efficiency and use the forest with increased harvesting and high intensity silviculture.



Permanent storage of CO2

General conclusions:

- The best way to reduce the CO_2 in the atmosphere may be to ***increase harvesting of the presently existing forests (!)***, to produce energy with CCS and to increase forest production in the new forest generations.

- ***We capture and store more CO_2!***

#2. Optimal dynamic control of the forest resource with changing energy demand functions and valuation of CO_2 storage

The optimal control derivations and the software are found here:

Lohmander, P., Optimal resource control model & General continuous time optimal control model of a forest resource, comparative dynamics and CO2 consideration effects, Seminar at SLU, Umea, Sweden, 2008-09-18

http://www.lohmander.com/CM/CMLohmander.ppt

Software:

http://www.lohmander.com/CM/CM.htm

Economic valuation of CO2 storage in the natural resource

Economic Valuation of the Production of Energy and Other Industrial Products

$$\max\left\{ J = \int_{t_1}^{t_2} e^{-rt}\left(\left(f_1 + f_2 t\right)x + \left(k_1 + k_2 t\right)u + k_3 u^2\right)dt \right\}$$

The Total Economic Result (Present Value)

The Stock Level

The ”Control” Level

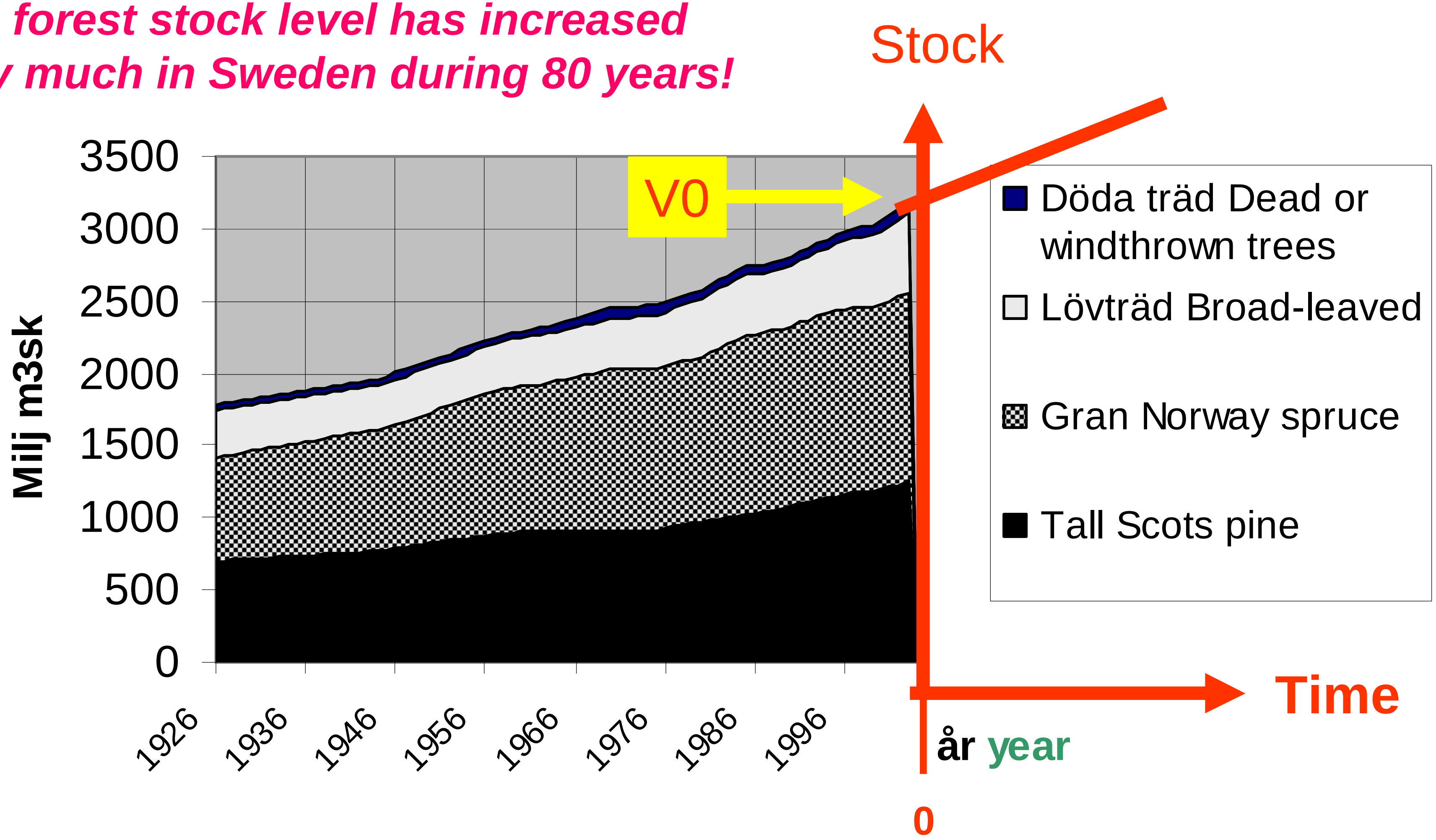
$$\dot{x} = f(x,u,t) \quad ; \quad x(t_1) = x_1, \quad x(t_2) = x_2$$

The change of
the stock level
during a marginal
time interval

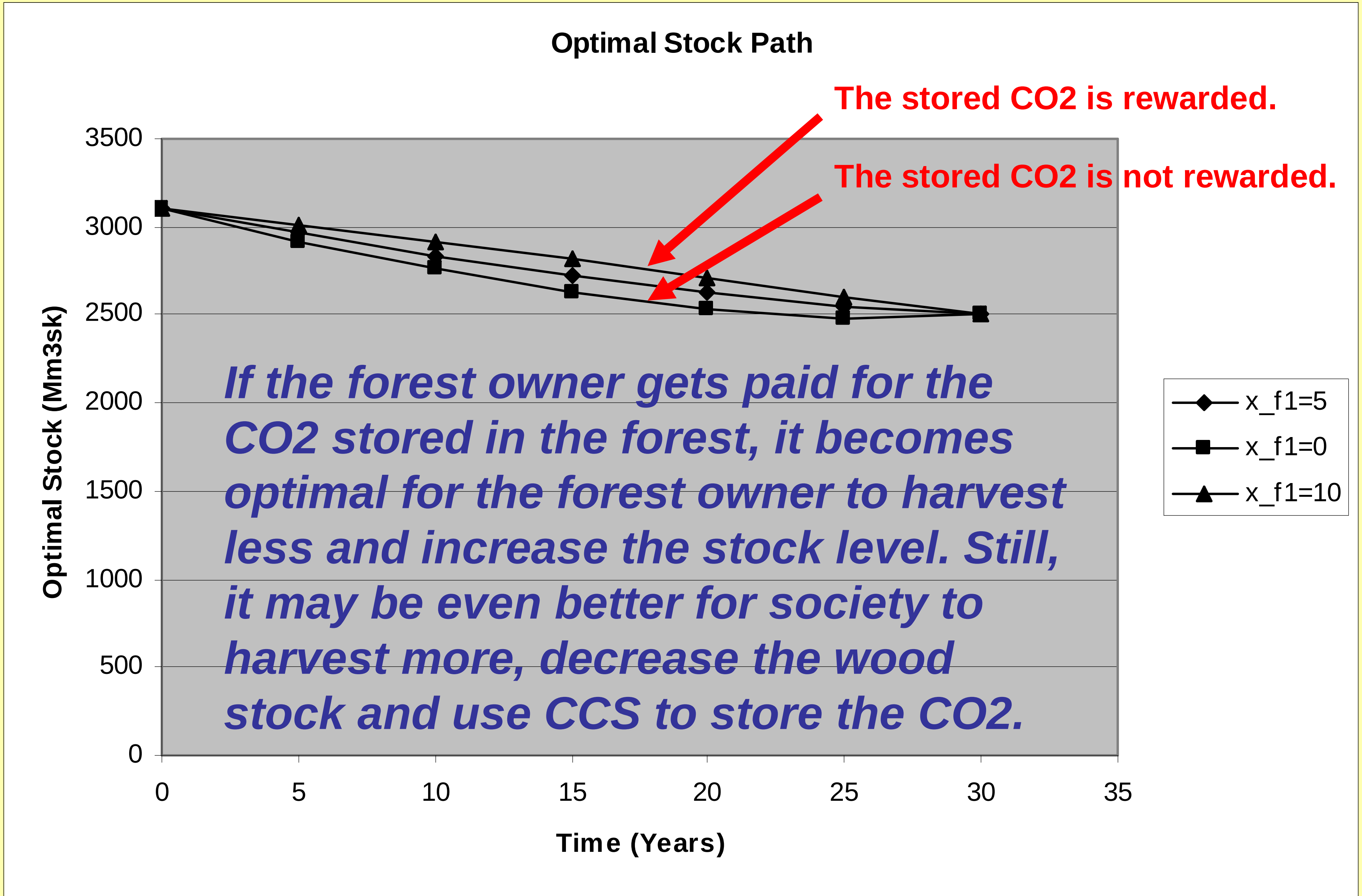
Initial stock level

Terminal stock level

The forest stock level has increased very much in Sweden during 80 years!



1 Exkl. fjäll, fridlyst mark, militära impediment, bebyggd mark samt söt- och saltvatten.
Excl. high mountains, restricted military areas, urban land and water surfaces.
Milj. M3sk Millions cubic metre standing volume (stem volume over bark from stump to tip)


Optimal Stock Path
The stored CO2 is rewarded.
The stored CO2 is not rewarded.
If the forest owner gets paid for the CO2 stored in the forest, it becomes optimal for the forest owner to harvest less and increase the stock level. Still, it may be even better for society to harvest more, decrease the wood stock and use CCS to store the CO2.
Optimal Stock (Mm3sk)
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
Time (Years)
x_f1=5
x_f1=0
x_f1=10

Derivation of the Economically Optimal Joint Strategy for Development of the Bioenergy and Forest Products Industries

European Biomass and Bioenergy Forum, MarcusEvans, London, 8-9 June, 2009

Peter Lohmander

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Integrated regional study with risk management

Stage 1.

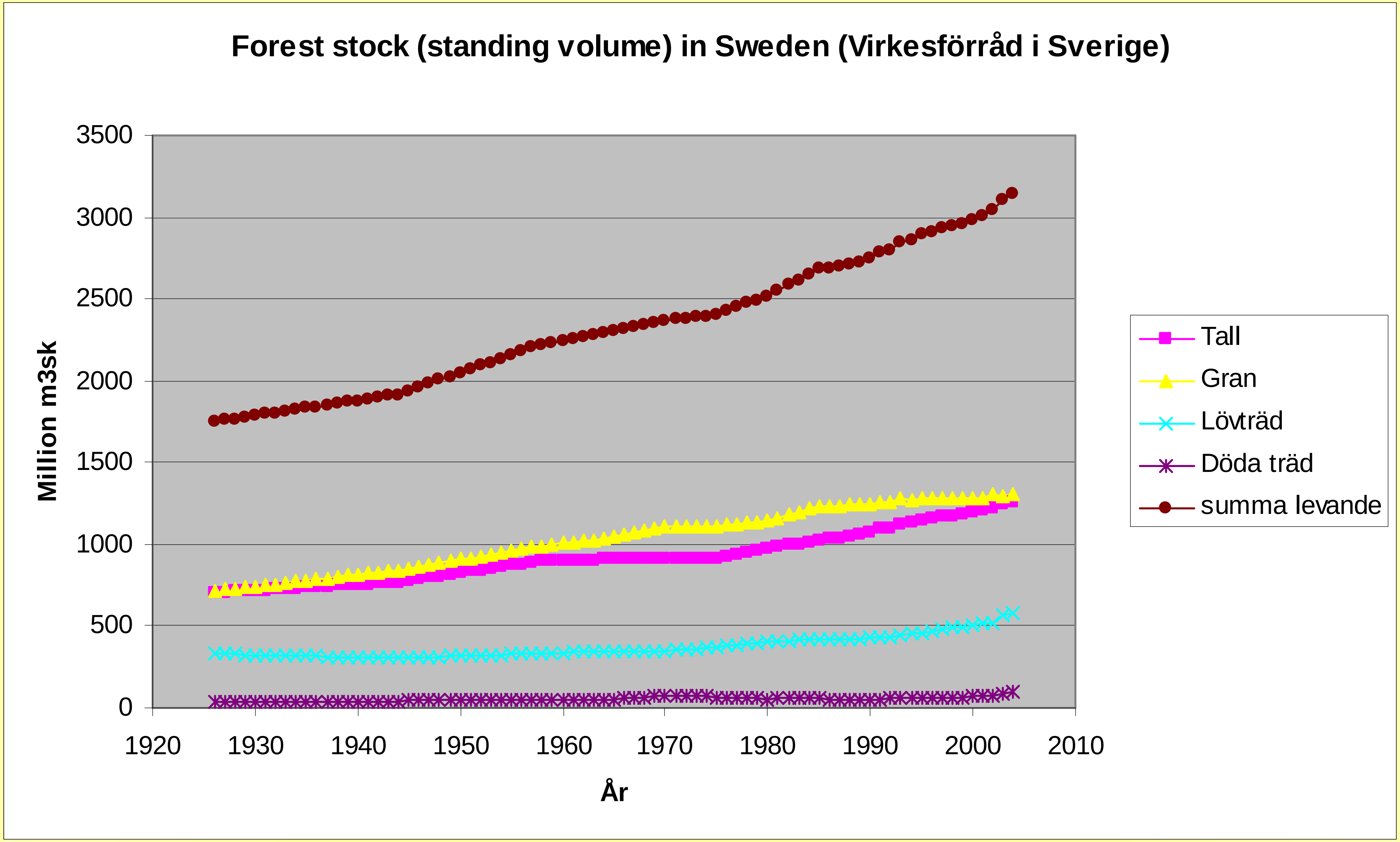
Properties:

A full system multi period optimization model with forest production, the forest- and energy industries and demand functions.

The method is multi period quadratic programming, which makes sure that the globally optimal solution is obtained in a finite number of iterations.

The multi dimensional state space is continuous. Complete and consistent solutions are obtained in seconds. These properties of the model make it useful as a tool during continuous discussions with decision makers.

This version of the model does not explicitly include interregional flows of raw materials and products, or stochastic processes and adaptive decisions. Such properties will be developed in future versions of the model.



(Exkluding high mountains, nature reserves, restricted military areas and water surfaces.)

Source: Swedish National Forest Inventory

Sveriges officiella statistik

Comparisions:

Case 0
Stock >= 2500

*DELTA1 = **42686.9***
*DELTA2 = 42686.9/300 = **142.3***

Case 1
Stock >= 2800

*DELTA1 = **79426***
*DELTA2 = 79426/434 = **183.0***

Case 2
Stock >= 3234

Results: EPV = Optimal total present value.
(Relevant currency)

EPV
1716664,9

Results: EPV = Optimal total present value.
(Relevant currency)

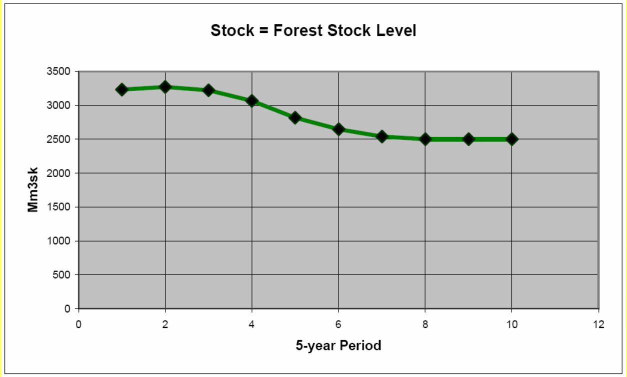
EPV
1673978

Results: EPV = Optimal total present value.
(Relevant currency)

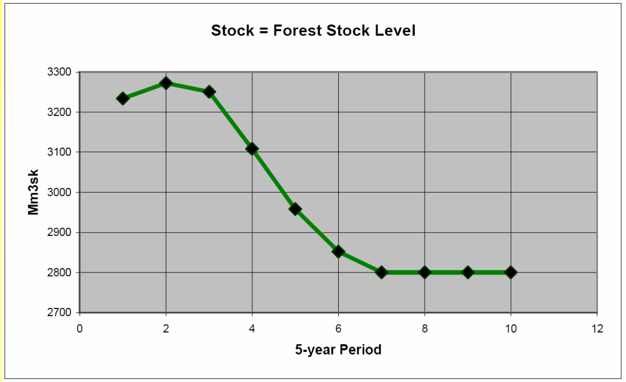
EPV
1594552

Comparisions:

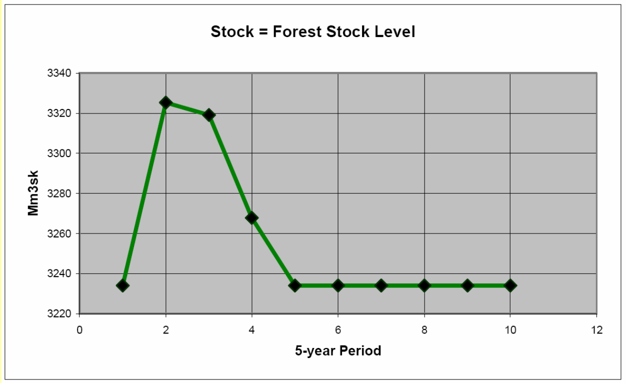
Case 0
Stock >= 2500



Case 1
Stock >= 2800

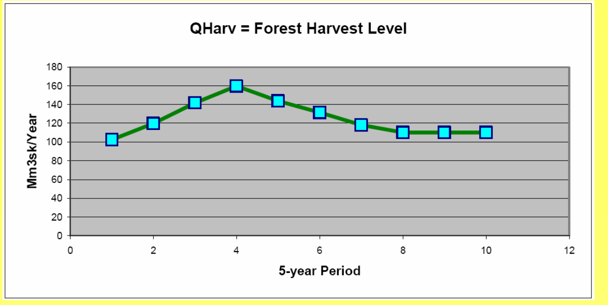


Case 2
Stock >= 3234

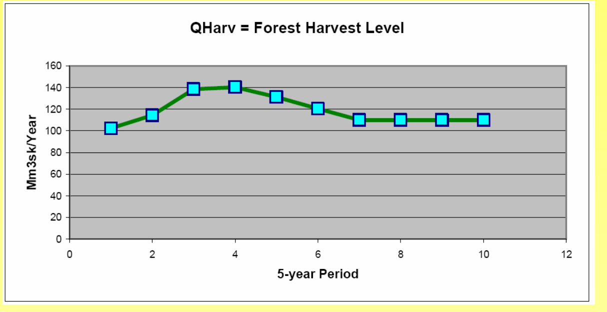


Comparisions:

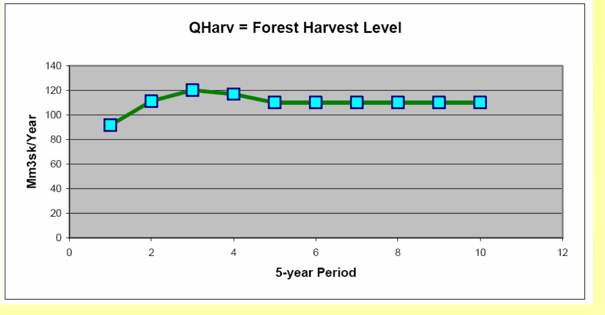
Case 0
Stock >= 2500



Case 1
Stock >= 2800

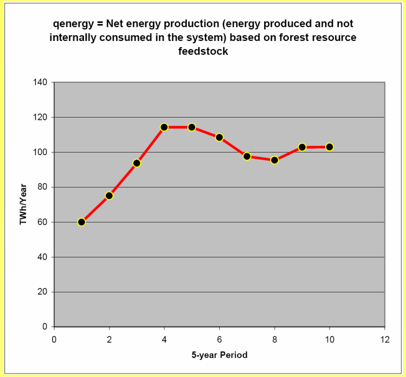


Case 2
Stock >= 3234

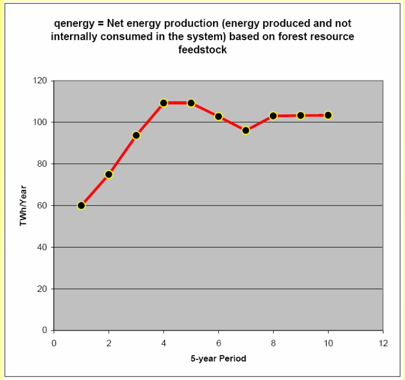


Comparisions:

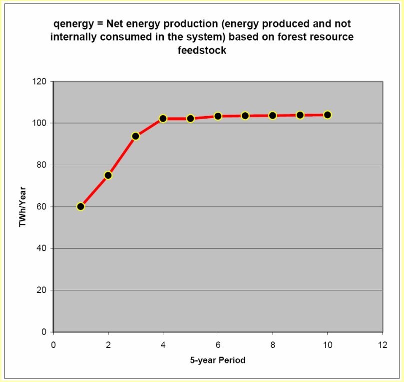
Case 0
Stock >= 2500



Case 1
Stock >= 2800

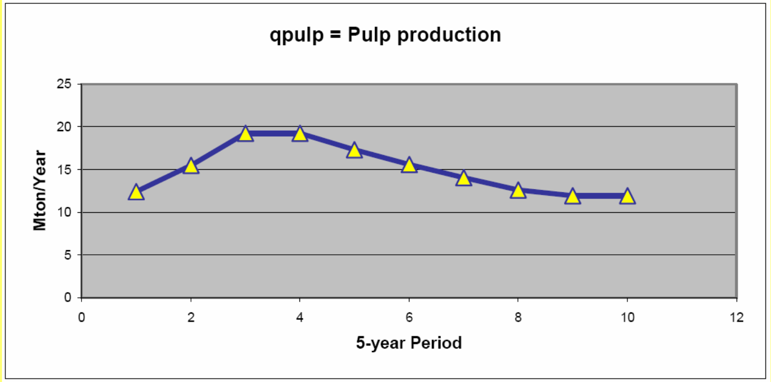


Case 2
Stock >= 3234

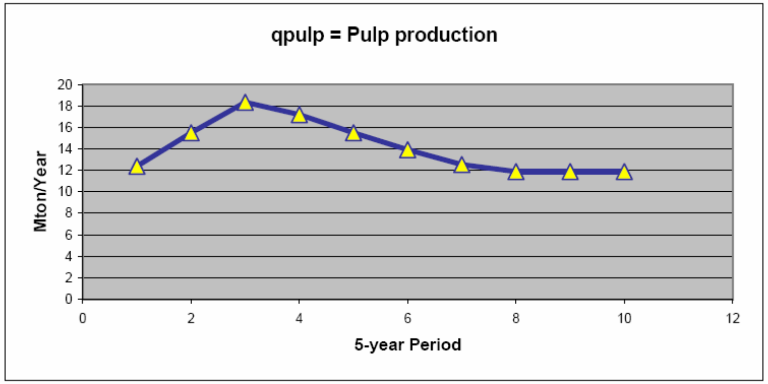


Comparisions:

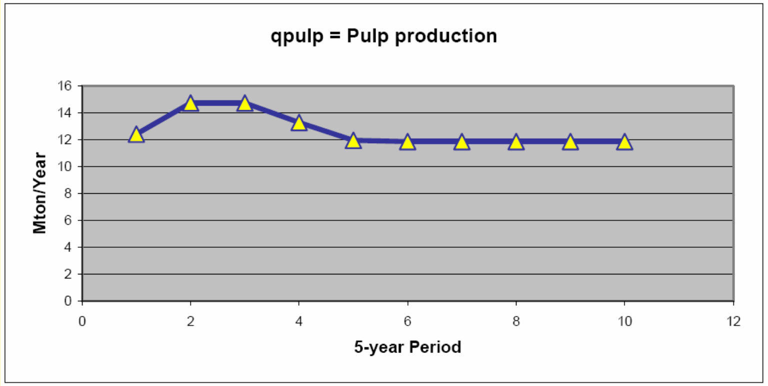
Case 0
Stock >= 2500



Case 1
Stock >= 2800



Case 2
Stock >= 3234



Strategic options for the forest sector in Russia with focus on economic optimization, energy and sustainability

International Seminar: Economics of Forestry and the Forest Sector: Actual Problems and Trends, Saint Petersburg, Russia, March 26-27, 2009

Saint-Petersburg State Forest Technical Academy, PROCES – EFI Project Centre in Saint Petersburg, International Centre of Forestry and Forest Industry (ICFFI)

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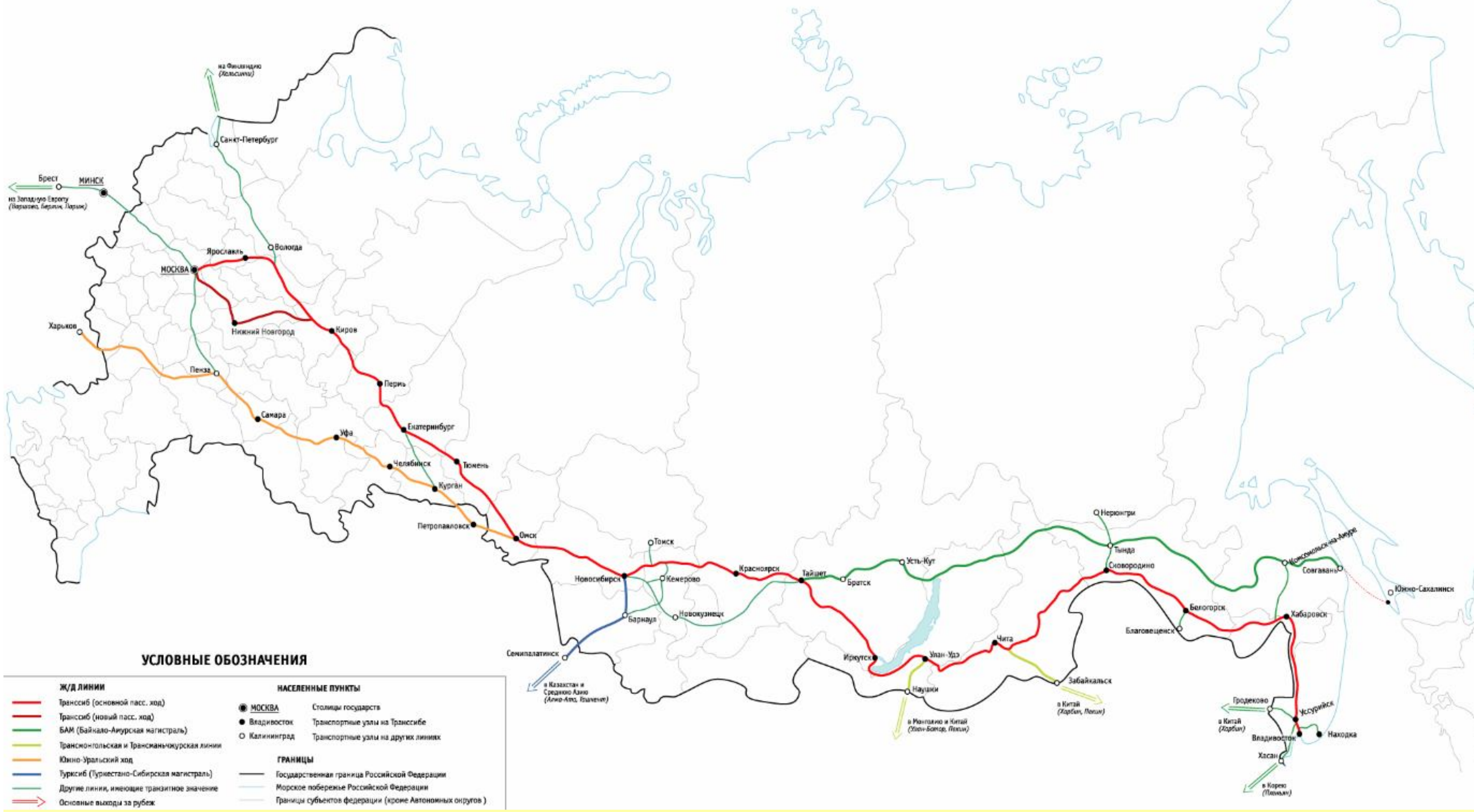
Umea, Sweden

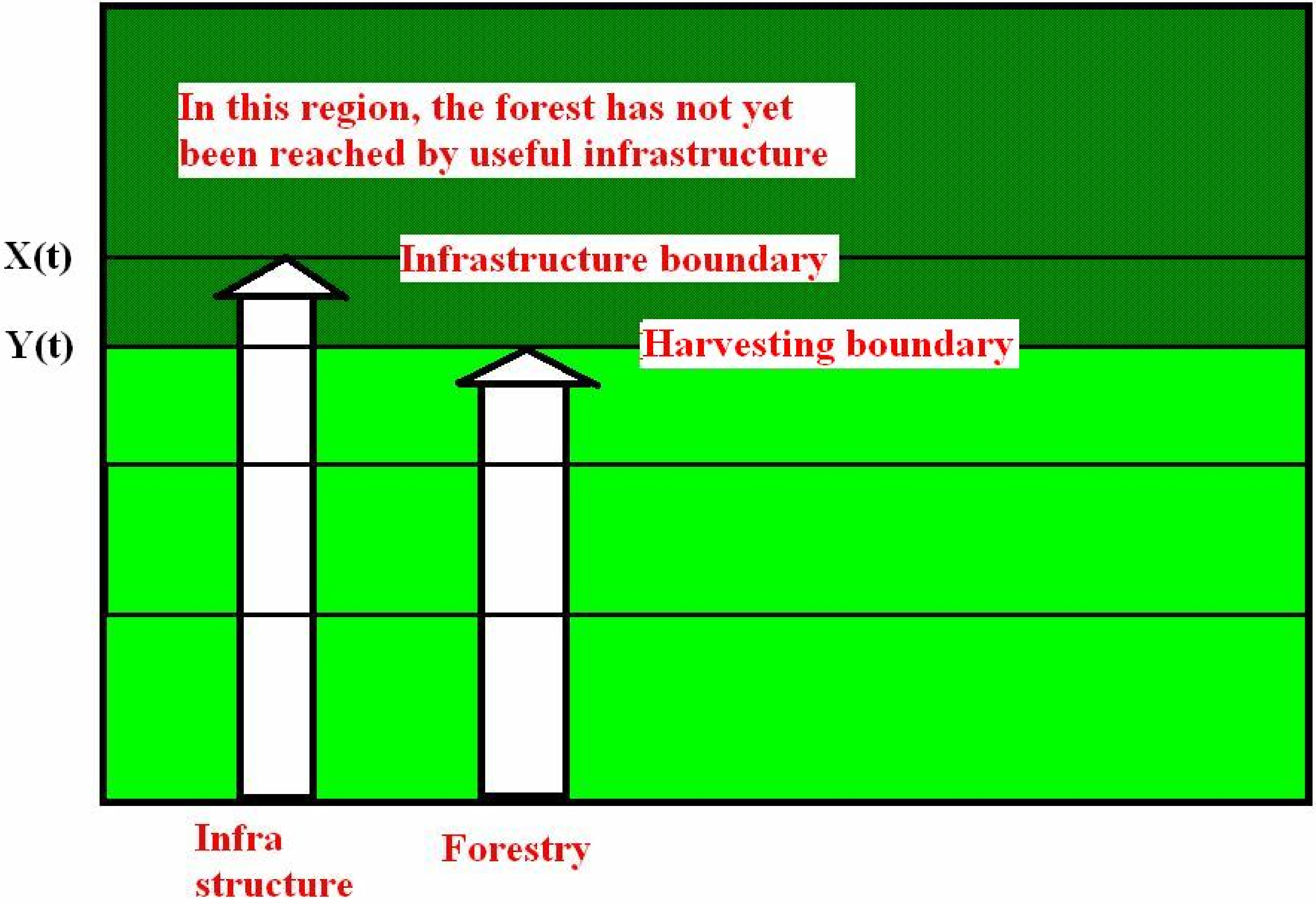
http://www.Lohmander.com

ТРАНССИБИРСКАЯ МАГИСТРАЛЬ
и другие основные транзитные линии России



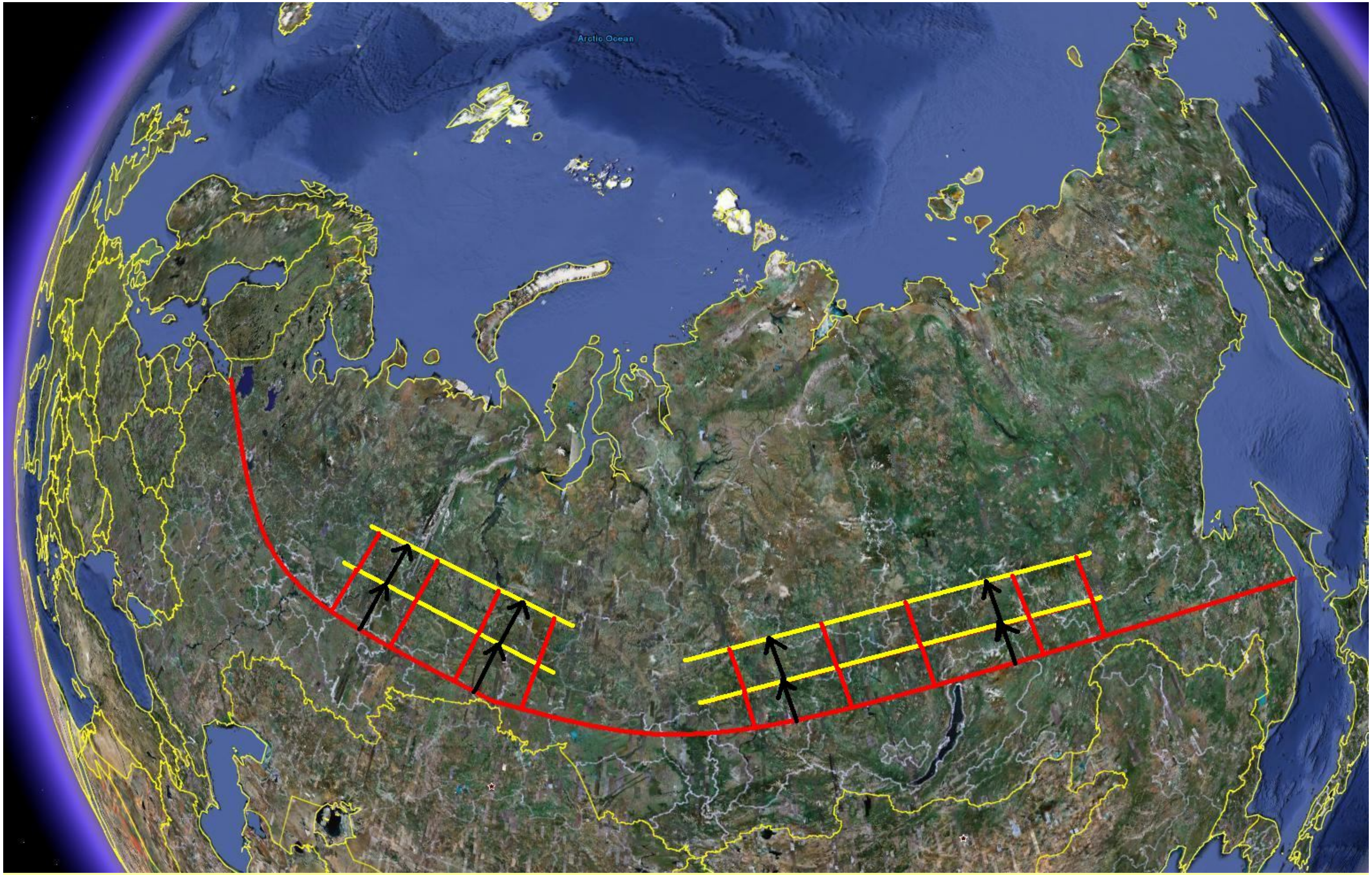

Arctic Ocean

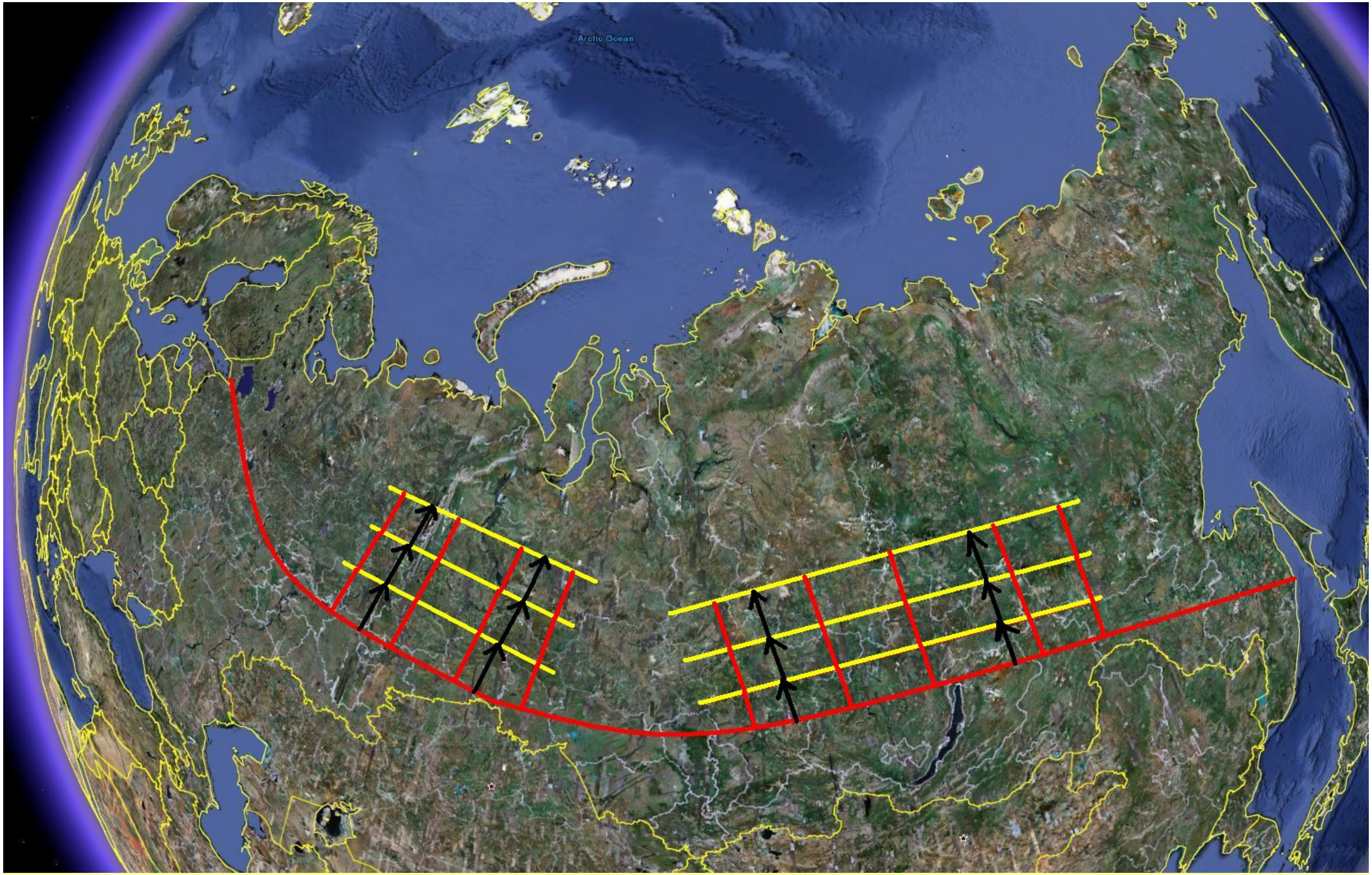

Arctic Ocean


In this region, the forest has not yet been reached by useful infrastructure
X(t)
Infrastructure boundary
Y(t)
Harvesting boundary
Infra structure
Forestry


Arctic Ocean


Arctic Ocean


Arctic Ocean


Arctic Ocean

Central components of the structure of the dynamic strategy optimization problem are given.

Because of page limitations, the problem description is not rigorous.

Method:

Multi period quadratic programming

Objective function = Total present value

$$\max_{d_1,\ldots,d_T} \Pi = \sum_t e^{-rt}\pi(t)$$

The profit in a particular period is a function of the decision in that period and the decision in earlier periods

$$\pi(t) = \pi(t, d_t, d_{t-1}, .., d_0; \bullet) \quad , \quad \forall t$$

The decisions include investments and other decisions in infrastructure, forest industry and energy industry (=x) and forestry (=y).

$$d_t = \{x_t, y_t\} \quad , \quad \forall t$$

In each period, the forestry activities are constrained by the infrastructure boundary

$$y_t <= x_t \quad , \quad \forall t$$

The volume of ”first harvest” during a particular period can be described as a function of the change of the ”harvesting boundary”.

$$h_{0,t} = h_{0,t}(y_t, y_{t-1}; \bullet) \quad , \quad \forall t$$

The volume of ”later harvests” during a particular period can be described as a function of the earlier changes of the ”harvesting boundaries”.

$$h_{n,t} = h_{n,t}(y_{t-s}, y_{t-s-1}, y_{t-2s}, y_{t-2s-1}, .., y_{t-ns}, y_{t-ns-1}; \bullet) \quad , \quad \forall t, n$$

Investments (of different kinds) during a particular period are functions of the change of the infrastructure boundary.

$$inv_t = inv_t(x_t, x_{t-1}; \bullet) \quad , \quad \forall t$$

In a particular period, the capacities of railroads, roads and different kinds of industries are functions of the infrastructure boundary

$$rail_t = rail_t(x_t;\bullet) \quad , \quad \forall t$$

$$road_t = road_t(x_t;\bullet) \quad , \quad \forall t$$

$$indc_t = indc_t(x_t;\bullet) \quad , \quad \forall t$$

#3. Optimal CCS, Carbon Capture and Storage, Under Risk

The stochastic optimal control derivations of CCS are found here:

- **Lohmander, P., Optimal CCS, Carbon Capture and Storage, Under Risk,** ***International Seminars in Life Sciences, Universidad Politécnica de Valencia, Thursday 2008-10-16***
- **http://www.Lohmander.com/OptCCS/OptCCS.ppt**

Optimal CCS, Carbon Capture and Storage, Under Risk

The objective function is the total present value of CO2 storage minus CCS costs.

$$\int_0^\infty e^{-rt}\left(k_1 u + k_2 u^2 + f_1 x + f_2 x^2\right)dt$$

Discounting factor

u = control = CCS level

x = The total storage level of CO2

The controlled storage

A stochastic differential equation:

$$dx = \left(u - Lx - S\right)dt + \sigma x\,dz$$

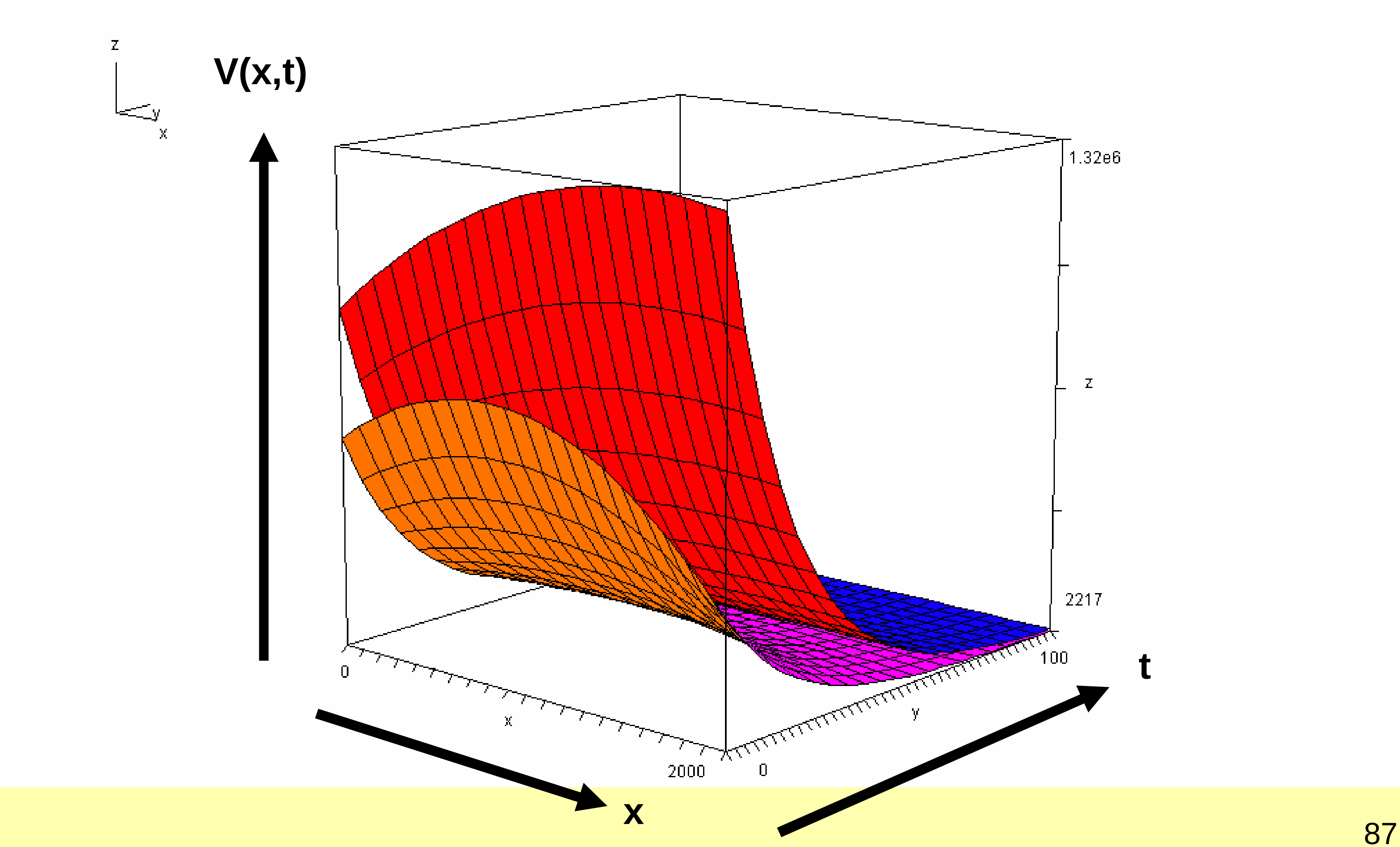
Expected CO2 leakage.

Change of the CO2 storage level.

Control = CCS level.

The CO2 storage level is to some extent affected by stochastic leakage and other stochastic events.
Z = standard Wiener process.

The optimal CCS objective function for different risk levels. The details are found in the reference.



#4. Conclusions

Optimal Forest management conclusions:

- **If the forest owner gets paid for the CO_2 stored in the forest, it becomes optimal for the forest owner to harvest less and increase the stock level. Still, it may be even better for society to harvest more, decrease the present wood stock and use CCS to store the CO_2.**
- **The best way to reduce the CO_2 in the atmosphere may be to *increase harvesting of the presently existing forests (!)*, to produce energy with CCS and to increase forest production in the new forest generations.**

Final conclusions

- The forest management and CO2 problems should not be studied in isolation.
- They should be integrated in the general problems of the world, where also industrial production, energy production, infrastructure, regional development and trade are considered.
- **It is really possible to find optimal solutions also to the relevant problems!**

Thank you for listening!
Here you may reach me in the future:

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