Climate change under CO2 emission control and optimal forestry (Edition 210214)

Webinar on Forest Management and Climate Changes

University of Guilan- Faculty of Natural Resources

February 15th, 2021, 13:00-14:30 (Iran time), 10:30-12:00 (CET)

Prof. Dr. Peter Lohmander

http://www.lohmander.com/Information/Ref.htm

Peter@Lohmander.com

1974 UNIVERSITY of GUILAN دانشگاه گیلان ۱۳۵۳

ipt Instituto Politécnico de Tomar

Optimal Solutions
Peter Lohmander

International Webinar on

وبینار بین المللی

Forest Management and Climate Changes

مدیریت جنگل و تغییرات اقلیم

Professor Dr. Peter Lohmander
Optimal Solutions in cooperation with Linnaeus University, Sweden
Title: Climate change under CO_2 emission control and optimal forestry
Time: 13:00-13:30

Professor Dr. Luis Santos
Polytechnic Institute of Tomar, Portugal
Title: Forest fire risk assessment methodology, a climate change mitigation strategy
Time: 13:30-14:00

Professor Dr. Soleiman Mohammadi Limaei
University of Guilan, Iran
Title: Climate smart forest management considering economics and carbon dynamic
Time: 14:00-14:30

February 15th, 2021
13:00-14:30 IRST
۲۷ بهمن ۱۳۹۹
ساعت ۱۳:۰۰ تا ۱۴:۳۰

Webinar Link: لینک وبینار:

https://join.skype.com/ejzJLz6HTPWK

University of Guilan- Faculty of Natural Resources
دانشگاه گیلان، دانشکده منابع طبیعی

Contact details:

Prof. Dr. Peter Lohmander
Optimal Solutions
Hoppets Grand 6
SE-903 34 Umea
Sweden

Peter@Lohmander.com
Peter.Lohmander@icloud.com

http://www.lohmander.com/Information/Ref.htm

This presentation is based on the following articles:

Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7-15. https://medcraveonline.com/IRATJ/IRATJ-06-00197.pdf

Lohmander, P., Optimization of continuous cover forestry expansion under the influence of global warming, International Robotics & Automation Journal, Volume 6, Issue 3, 2020, 127-132.
https://medcraveonline.com/IRATJ/IRATJ-06-00211.pdf
https://medcraveonline.com/IRATJ/IRATJ-06-00211A.pdf

Connected articles:

Lohmander, P., Fundamental principles of optimal utilization of forests with consideration of global warming, Central Asian Journal of Environmental Science and Technology Innovation, Volume 1, Issue 3, May and June 2020, 134-142. doi: 10.22034/CAJESTI.2020.03.02
http://www.cas-press.com/article_111213.html
http://www.cas-press.com/article_111213_5ab21574a30f6f2c7bdc0a0733234181.pdf

Lohmander, P., Adaptive mobile firefighting resources, stochastic dynamic optimization of international cooperation, International Robotics & Automation Journal, Volume 6, Issue 4, 2020, pages 150-155.
https://medcraveonline.com/IRATJ/IRATJ-06-00213.pdf

Lohmander, P., Forest fire expansion under global warming conditions: multivariate estimation, function properties and predictions for 29 countries, Central Asian Journal of Environmental Science and Technology Innovation, Volume 1, Issue 5, 2020, 134-142. doi:10.22034/CAJESTI.2020.05.03.
http://www.cas-press.com/article_122566.html

Lohmander, P., Optimization of forestry, infrastructure and fire management,
Caspian Journal of Environmental Sciences (Forthcoming. Accepted for publication).

Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7-15.

Abstract PART 1(6):

The analysis in this paper shows that the fundamental theory of the CO2 level in the atmosphere, under the influence of changing CO2 emissions, can be modeled as a first order linear differential equation with a forcing function, describing industrial emissions.

The natural CO2 dynamics

$$\dot{x} = \frac{dx}{dt} = a_0 + a_x x$$

Change of the CO2 level in the atmosphere

Natural emissions from vulcanos etc.

Net absorbtion of CO2 by the sea and natural environment

$$\dot{x} = \frac{dx}{dt} = \underset{> 0}{a_0} + \underset{< 0}{a_x}\, x$$

$$\left(\dot{x} = 0\right) \Rightarrow \left(a_0 + a_x x_{eq} = 0\right)$$

$$\boxed{x_{eq} = \frac{-a_0}{a_x} \approx 280\ (?)}$$

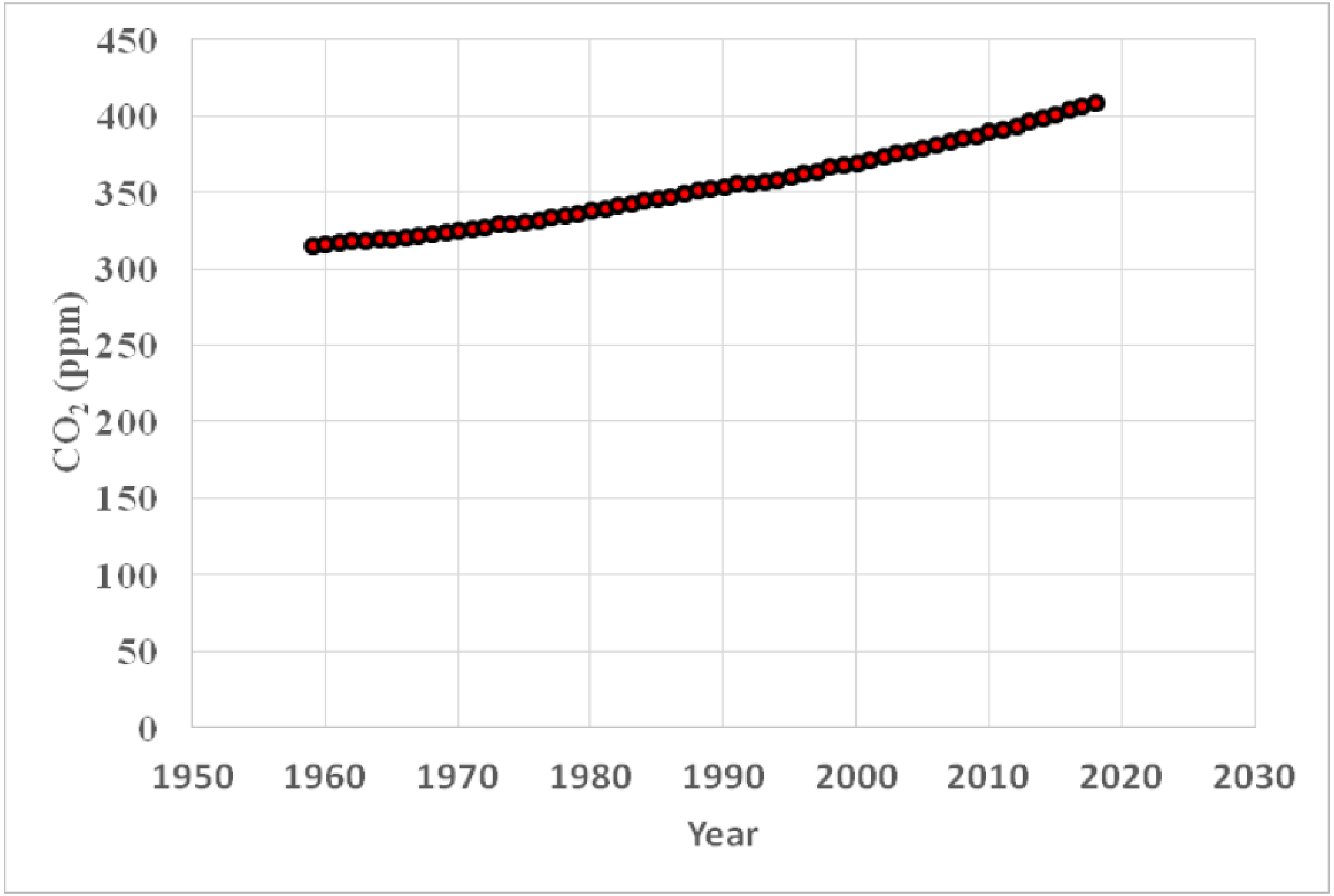
Natural "pre- industrial" equilibrium

Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7-15.

Abstract PART 2(6):

Observations of the CO2 level at the Mauna Loa CO2 observatory and official statistics of global CO2 emissions, from Edgar, the Joint Research Centre at the European Commission, are used to estimate all parameters of the forced CO2 differential equation.

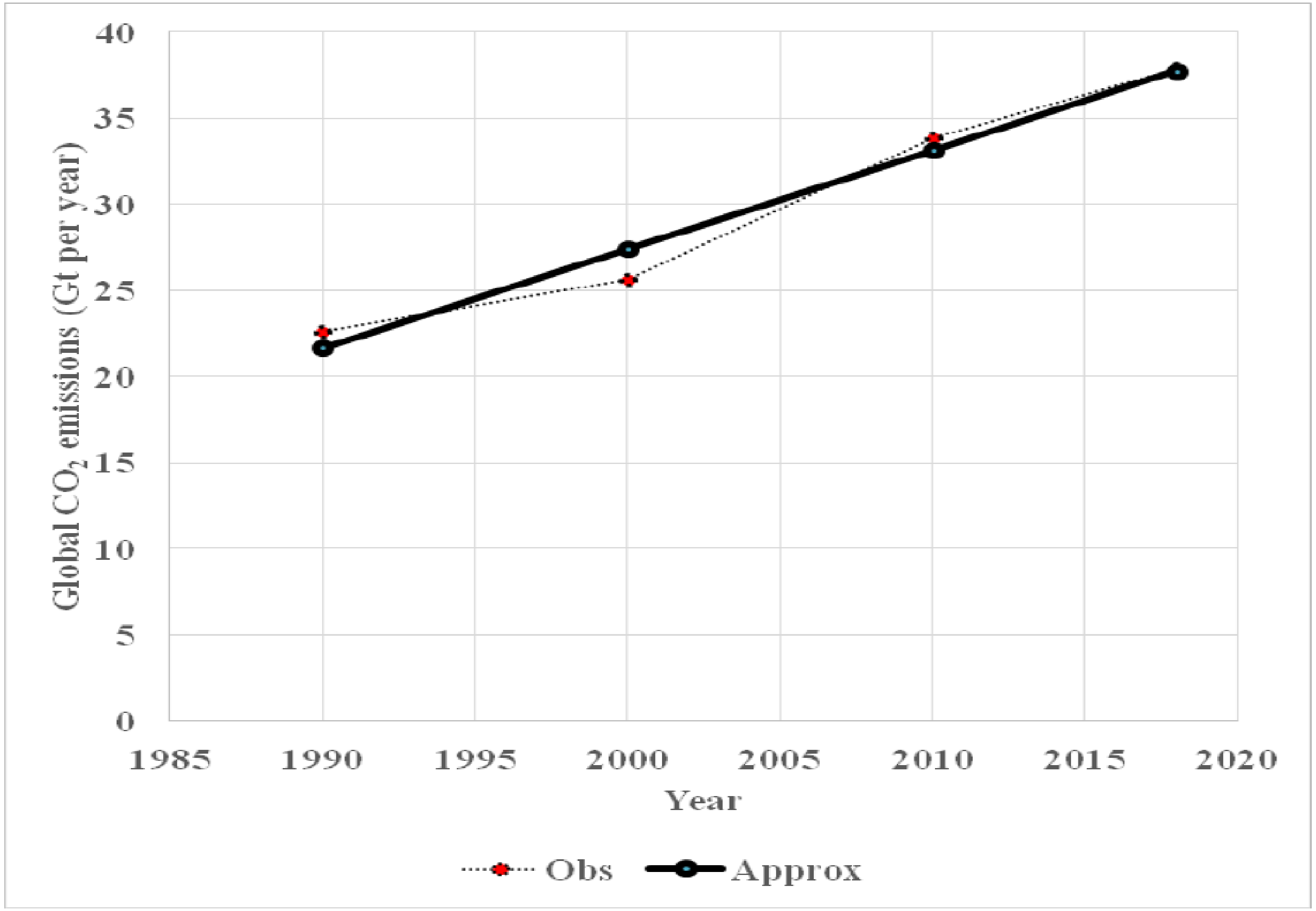
X = CO2 in atmosphere, ppm



Year

Figure 1 CO_2 in the atmosphere, annual mean values, Mauna Loa, (ppm). Source: Tans and Keeling.[2]

φ = Emissions, Gt per year



Year

Figure 2 Obs=Observations of global CO$_2$ emissions from fossil fuels combustion and processes. Source: European Commission.[4] Approx=Linear approximation via the least squares method, by the author of this paper. Compare equation (47). Approx $=21.672+0.57366(Year-1990)$. $R \approx 0.984$.

Table 1 Atmospheric CO_2 data

					x			$\dot{x}$
i (period)	t (year)	ψ_t (ppm)	Δx_i (ppm)	Δt (years)	x_i (ppm)	x_i (Gt CO_2)	$\dot{x}_i \approx \frac{\Delta x}{\Delta t}$ (ppm per year)	$\dot{x}_i \approx \frac{\Delta x}{\Delta t}$ (Gt Co_2 per year)
	1990	354.39						
1			15.16	10	361.97	2824.9	1.516	11.831
	2000	369.55						
2			20.35	10	379.725	2963.5	2.035	15.882
	2010	389.90						
3			18.62	8	399.21	3115.6	2.3275	18.165
	2018	408.52						

Definitions in table 1: $\psi_t = CO_2$ in atmosphere, annual mean value of observations, Mauna Loa

$x_i = CO_2$ in atmosphere, calculated mean value

Gt denotes Giga tonnes and ppm denotes parts per million

The CO2 dynamics affected by industrial emissions

Industrial emissions of CO2

$$\dot{x} = a_0 + a_x x + \varphi(t)$$

$$y(t) = \dot{x} - \varphi(t) = a_0 + a_x x$$

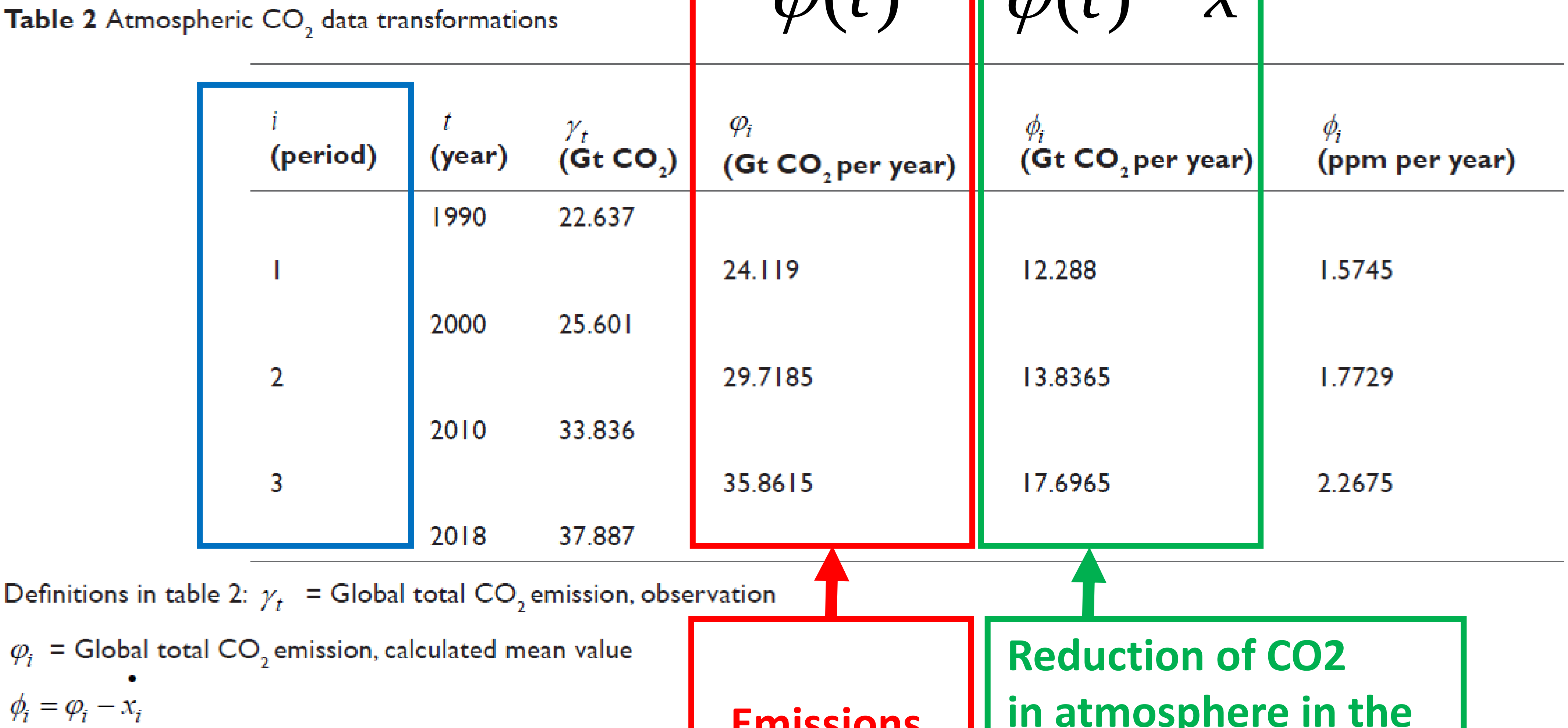


Table 2 Atmospheric CO_2 data transformations

$\varphi(t)$

$\varphi(t) - \dot{x}$

i (period)	t (year)	γ_t (Gt CO_2)	φ_i (Gt CO_2 per year)	ϕ_i (Gt CO_2 per year)	ϕ_i (ppm per year)
	1990	22.637			
1			24.119	12.288	1.5745
	2000	25.601			
2			29.7185	13.8365	1.7729
	2010	33.836			
3			35.8615	17.6965	2.2675
	2018	37.887			

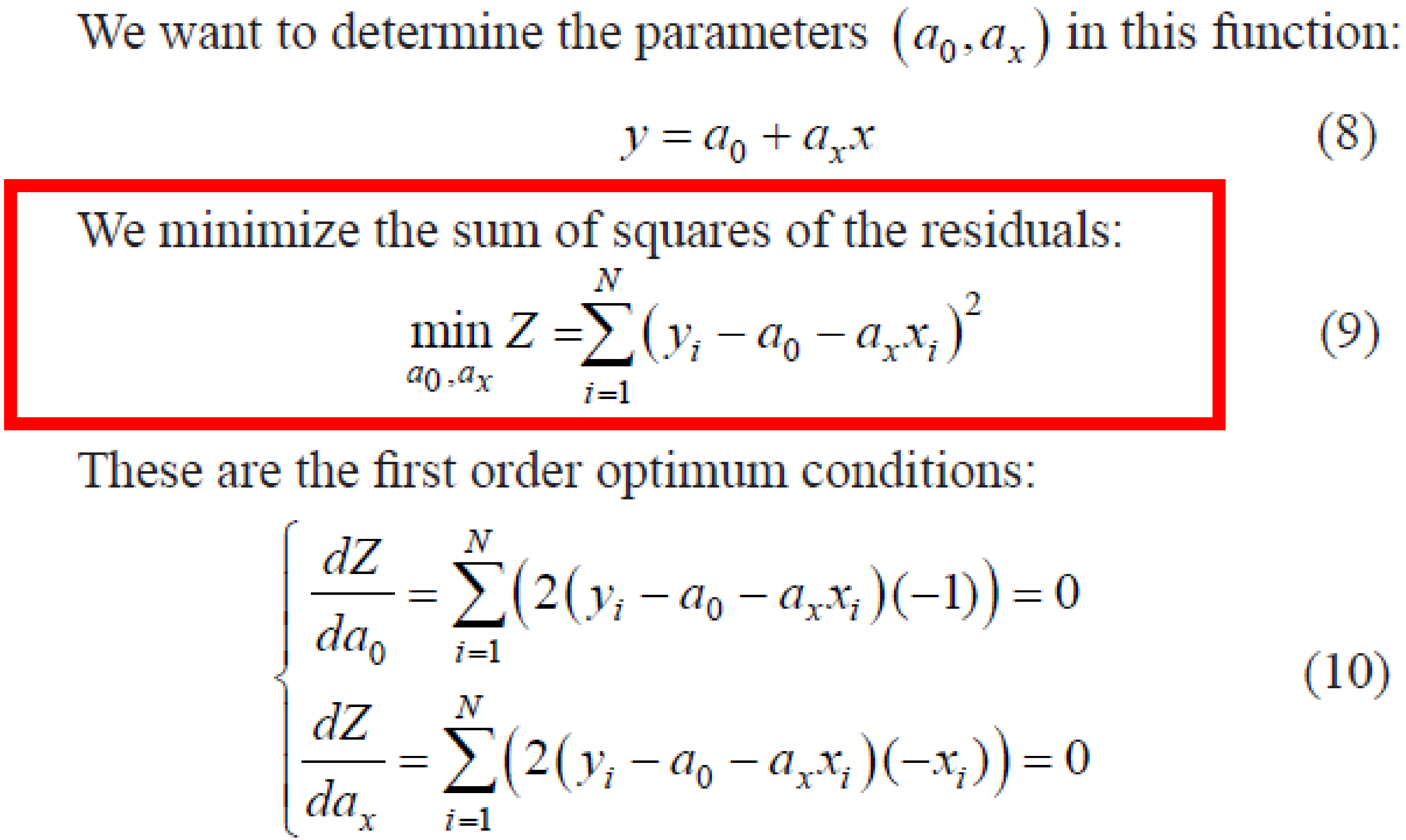
Definitions in table 2: γ_t = Global total CO_2 emission, observation

φ_i = Global total CO_2 emission, calculated mean value

$\phi_i = \varphi_i - \dot{x}_i$

Emissions

Reduction of CO2 in atmosphere in the absence of emissions.



We want to determine the parameters (a_0, a_x) in this function:

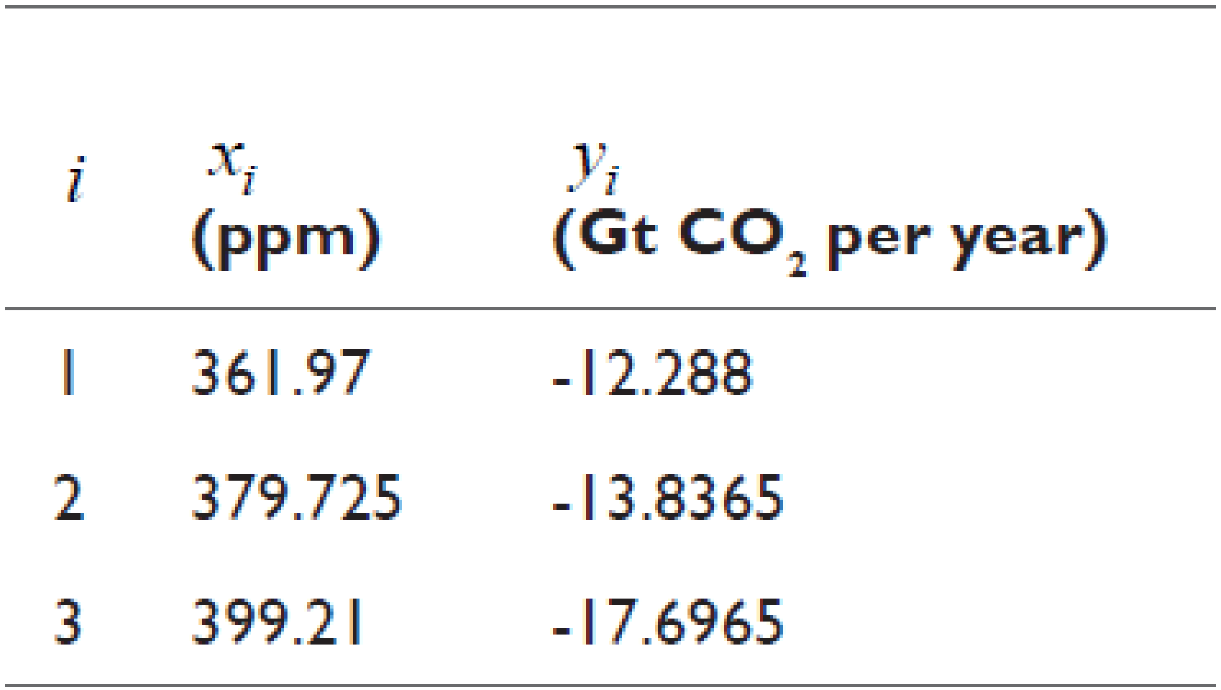
$$y = a_0 + a_x x \tag{8}$$

We minimize the sum of squares of the residuals:

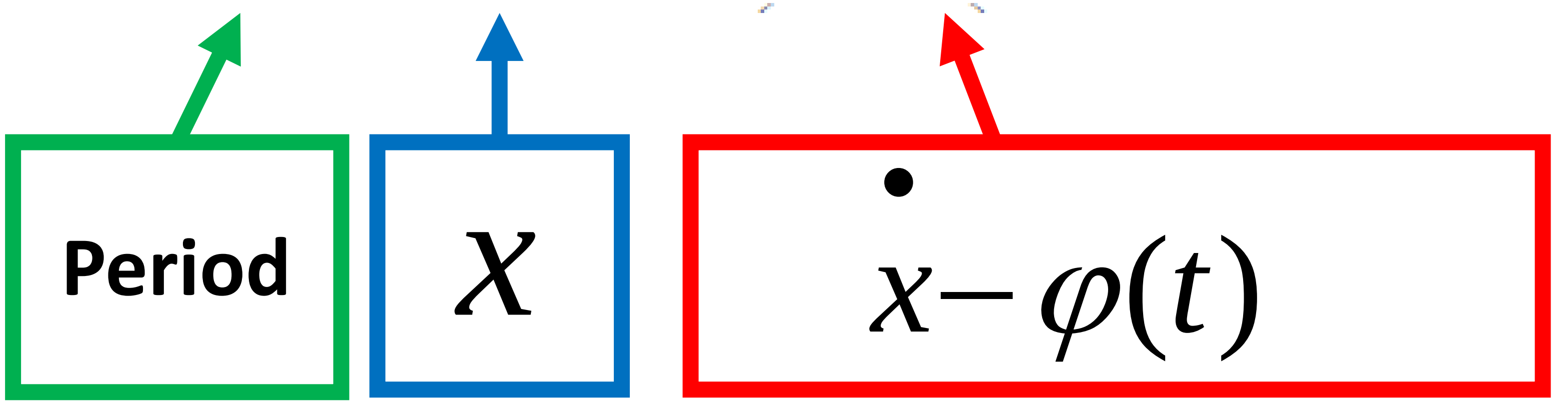
$$\min_{a_0, a_x} Z = \sum_{i=1}^{N} \left(y_i - a_0 - a_x x_i\right)^2 \tag{9}$$

These are the first order optimum conditions:

$$\begin{cases} \dfrac{dZ}{da_0} = \displaystyle\sum_{i=1}^{N} \Big(2\left(y_i - a_0 - a_x x_i\right)(-1)\Big) = 0 \\ \dfrac{dZ}{da_x} = \displaystyle\sum_{i=1}^{N} \Big(2\left(y_i - a_0 - a_x x_i\right)(-x_i)\Big) = 0 \end{cases} \tag{10}$$



i	x_i (ppm)	y_i (Gt CO_2 per year)
1	361.97	-12.288
2	379.725	-13.8365
3	399.21	-17.6965



Period

X

$\dot{x} - \varphi(t)$

Change of CO2 in atmosphere (in the absence of emissions)

If we express $\dot{x}$ in the unit Gt CO_2/year, and x in the unit ppm, we have this equation:

$$\dot{x} = 40.951 - 0.14609x \tag{23}$$

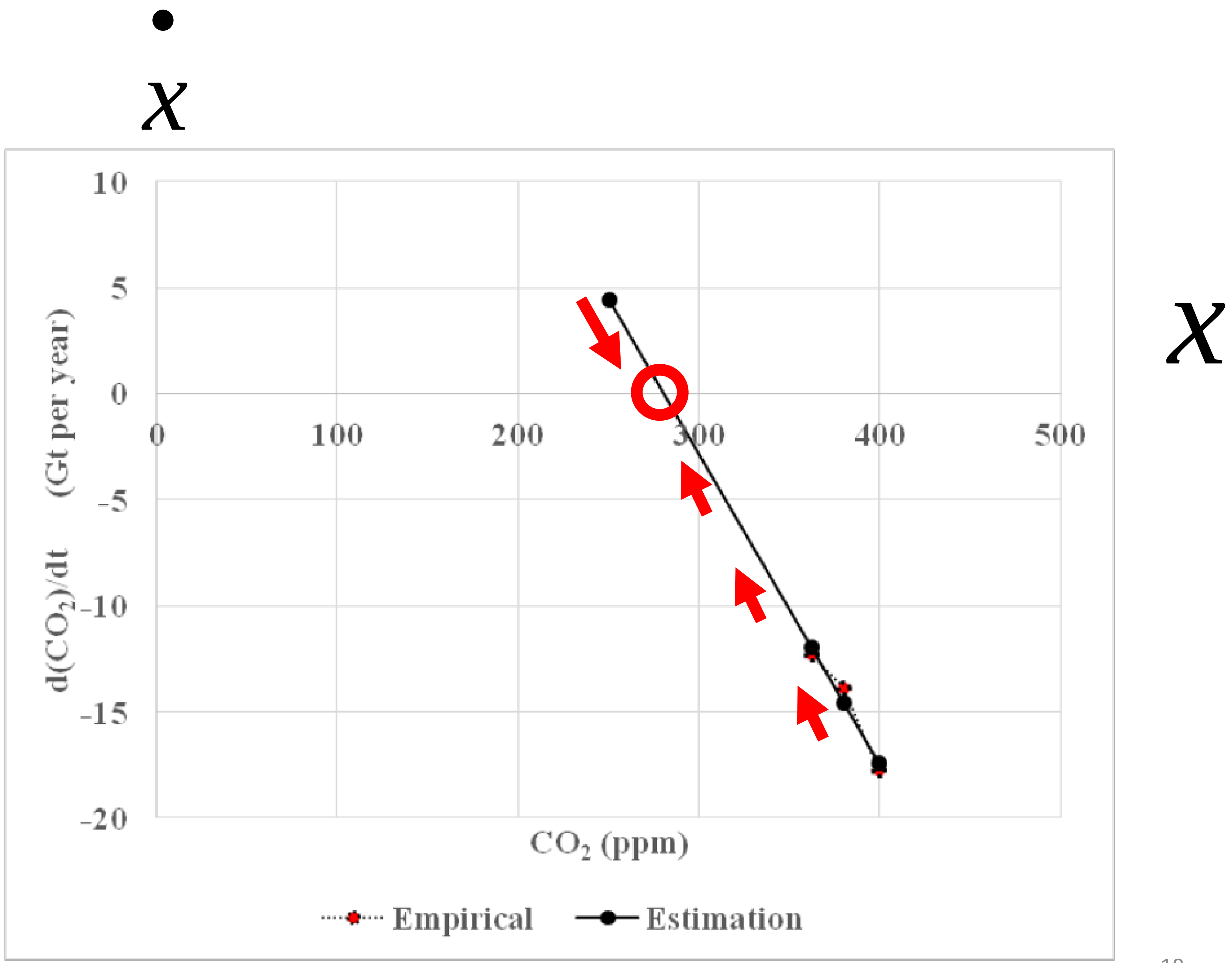
The estimated “natural” differential function

$$\dot{x} = \frac{dx}{dt} = a_0 + a_x x_{eq} = 0$$

$$x_{eq} = \frac{-a_0}{a_x} \boxed{\approx 280.31 \quad (ppm)}$$

The estimated equilibrium of the natural system without industrial emissions

Change of CO2 in atmosphere
(in the absence of emissions)



In the absence of emissions, the CO2 level converges to a stable equilibrium of 280 ppm.

Determination of a solution of the form

$$x(t) = Ae^{bt} + k_0 + k_1 t$$

to the differential equation

$$\overset{\bullet}{x} = a_0 + a_x x + \varphi(t)$$

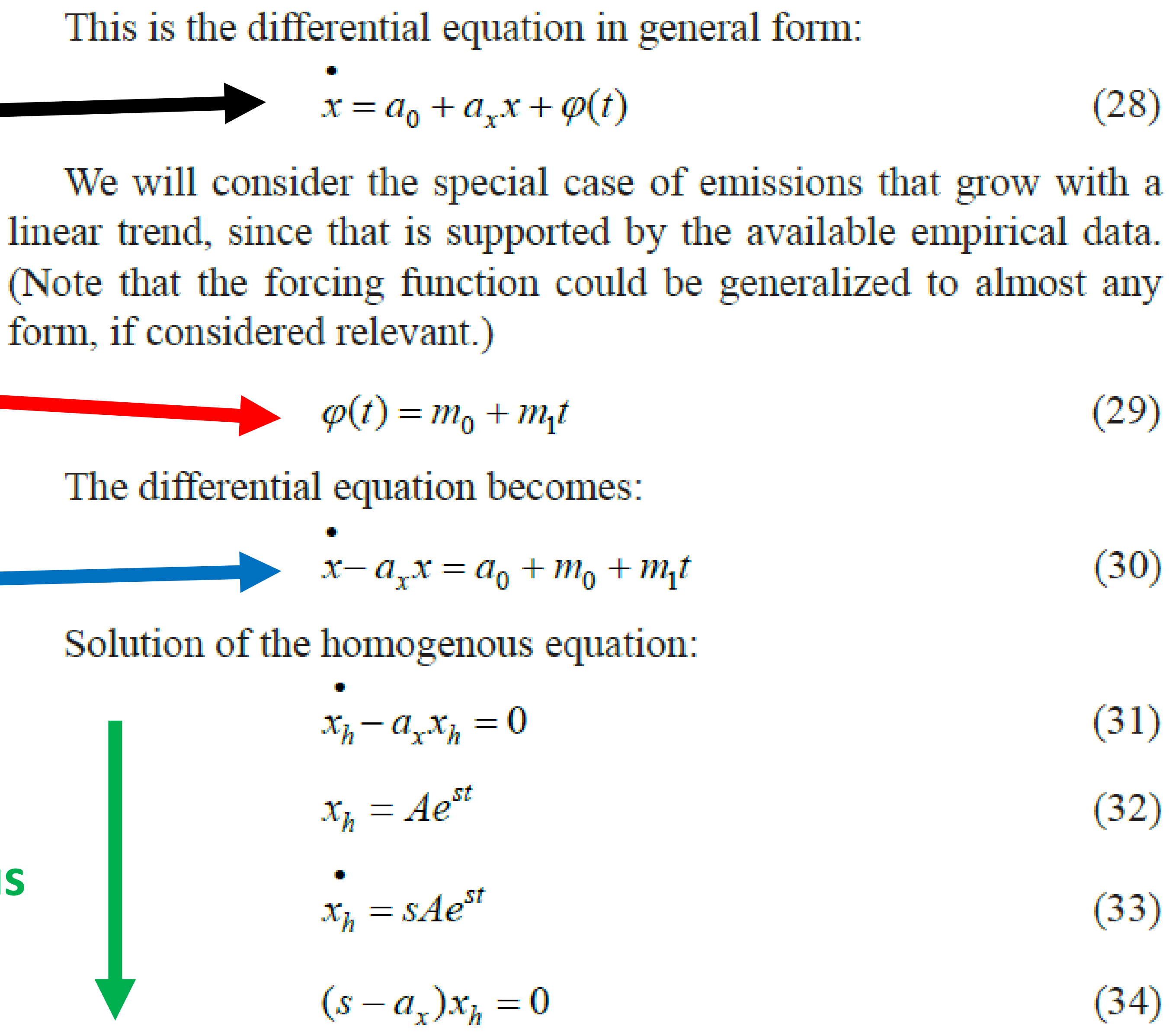
based on the historical emissions.

General form of emission function

Specific form of emission function

The differential equation with specific emission function

Solution of the homogenous differential equation.



This is the differential equation in general form:

$$\dot{x} = a_0 + a_x x + \varphi(t) \tag{28}$$

We will consider the special case of emissions that grow with a linear trend, since that is supported by the available empirical data. (Note that the forcing function could be generalized to almost any form, if considered relevant.)

$$\varphi(t) = m_0 + m_1 t \tag{29}$$

The differential equation becomes:

$$\dot{x} - a_x x = a_0 + m_0 + m_1 t \tag{30}$$

Solution of the homogenous equation:

$$\dot{x}_h - a_x x_h = 0 \tag{31}$$

$$x_h = Ae^{st} \tag{32}$$

$$\dot{x}_h = sAe^{st} \tag{33}$$

$$(s - a_x)x_h = 0 \tag{34}$$

Determination of the particular solution.

$$\left(x_h \neq 0\right) \Rightarrow s = a_x \tag{35}$$

$$x_h(t) = Ae^{a_x t} \tag{36}$$

Determination of the particular solution:

$$x_p = k_0 + k_1 t \tag{37}$$

$$\dot{x}_p - a_x x_p = a_0 + m_0 + m_1 t \tag{38}$$

$$k_1 - a_x\left(k_0 + k_1 t\right) = a_0 + m_0 + m_1 t \tag{39}$$

$$\begin{cases} k_1 - a_x k_0 = a_0 + m_0 \\ -a_x k_1 = m_1 \end{cases} \tag{40}$$

$$\left(-a_x k_1 = m_1\right) \Rightarrow k_1 = \frac{-m_1}{a_x} \tag{41}$$

$$\left(k_1 - a_x k_0 = a_0 + m_0\right) \wedge \left(k_1 = \frac{-m_1}{a_x}\right) \Rightarrow \left(\frac{-m_1}{a_x} - a_x k_0 = a_0 + m_0\right) \tag{42}$$

$$k_0 = \frac{-\left(a_0 + m_0 + \dfrac{m_1}{a_x}\right)}{a_x} \tag{43}$$

Determination of the numerical parameter values based on the historical data.

$$\varphi(t) = 21.672 + 0.57366\, t \qquad (47)$$

$$k_1 = \frac{-m_1}{a_x} = \frac{-0.57366}{-0.0187191} \approx 30.646 \qquad (48)$$

$$k_0 = \frac{-\left(a_0 + m_0 + \frac{m_1}{a_x}\right)}{a_x} = \frac{-(40.951 + 21.672 - 30.646)}{-0.0187191} \approx 1708.27$$

$$(49)$$

$$x(t) = Ae^{-0.0187191\, t} + 1708.27 + 30.646\, t \qquad (50)$$

$$x(0) = A + 1708.27 \qquad (51)$$

$$A = x(0) - 1708.27 \qquad (52)$$

$$A = 354.39 \cdot 2.13 \cdot 3.664 - 1708.27 \qquad (53)$$

$$A \approx 1057.52 \qquad (54)$$

The solution based on the historical emissions:

$$x(t) = 1057.52 e^{-0.0187191\, t} + 1708.27 + 30.646\ t \qquad (Gt) \qquad (55)$$

If the function is divided by (2.13*3.664), the unit becomes ppm.

$$x(t) = 135.50 e^{-0.0187191\, t} + 218.89 + 3.927\ t \qquad (ppm) \qquad (56)$$

The solution based on the historical emissions:

$$x(t) = Ae^{bt} + k_0 + k_1 t \qquad (ppm)$$

$A = 135.50$

$b = -0.0187191$

$k_0 = 218.89$

$k_1 = 3.927$

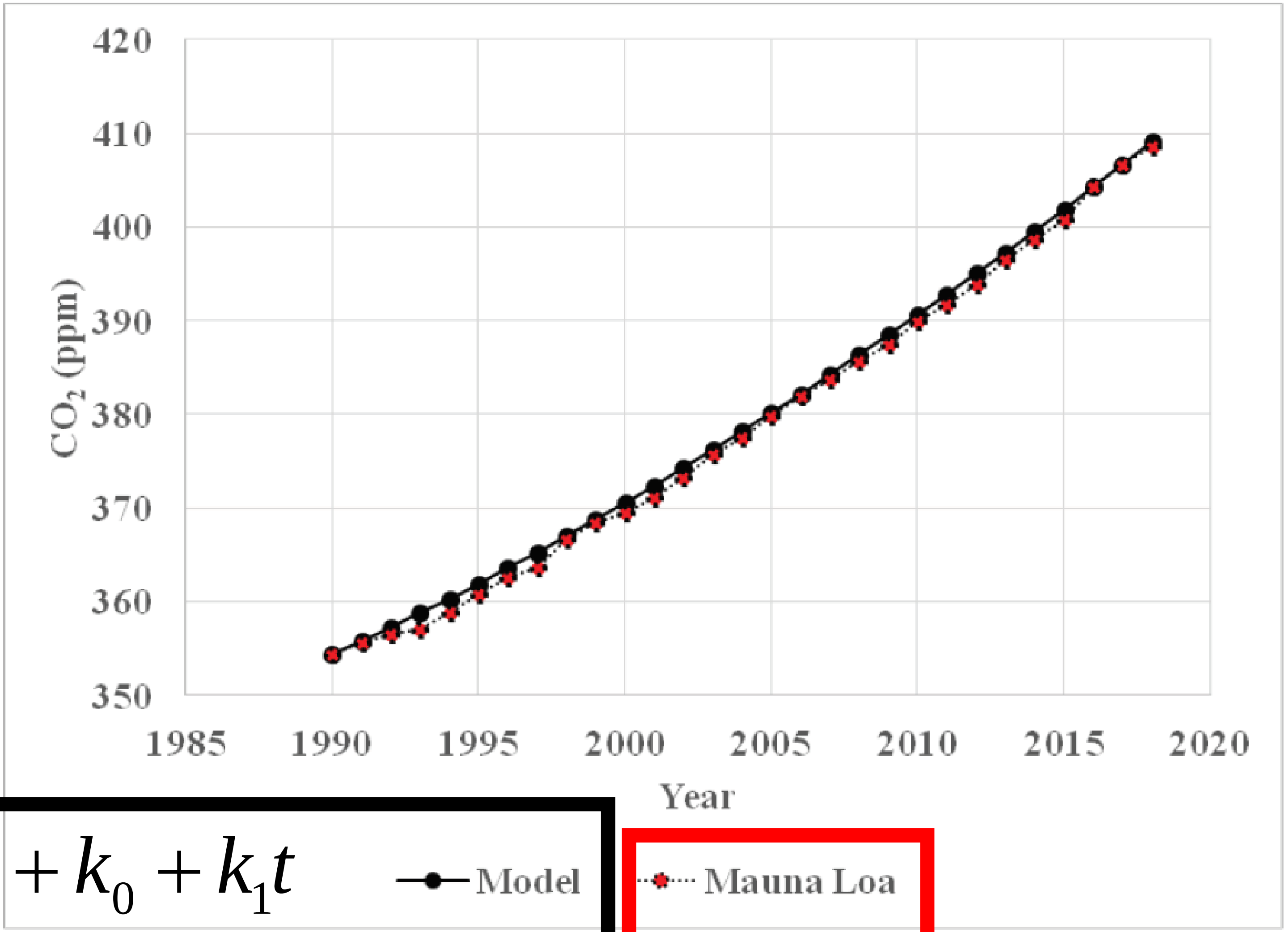
Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7-15.

Abstract PART 3(6):

The estimated differential equation has a logical theoretical foundation and convincing statistical properties. It is used to reproduce the time path of the CO2 data from Mauna Loa, from year 1990 to 2018, with very small errors.

X

(ppm)



Year

$$x(t) = Ae^{bt} + k_0 + k_1 t$$

Figure 4_Mauna Loa= CO_2 observations from 1990 to 2018. Model= CO_2 prediction model. The empirical CO_2 observations from Mauna Loa, compare Figure 1 and the prediction according to the derived differential equation model are almost identical. The graph was derived with the following equation: $x(t) = 135.50e^{-0.0187191\,t} + 218.89 + 3.927\,t(ppm)$.

Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7-15.

Abstract PART 4(6):

Furthermore, the differential equation shows that the global CO2 level, without emissions, has a stable equilibrium at 280 ppm. This value has earlier been reported by IPCC as the pre-industrial CO2 level.

If we express $\dot{x}$ in the unit Gt CO_2/year, and x in the unit ppm, we have this equation:

$$\dot{x} = 40.951 - 0.14609x \qquad (23)$$

The estimated function leads to stability.

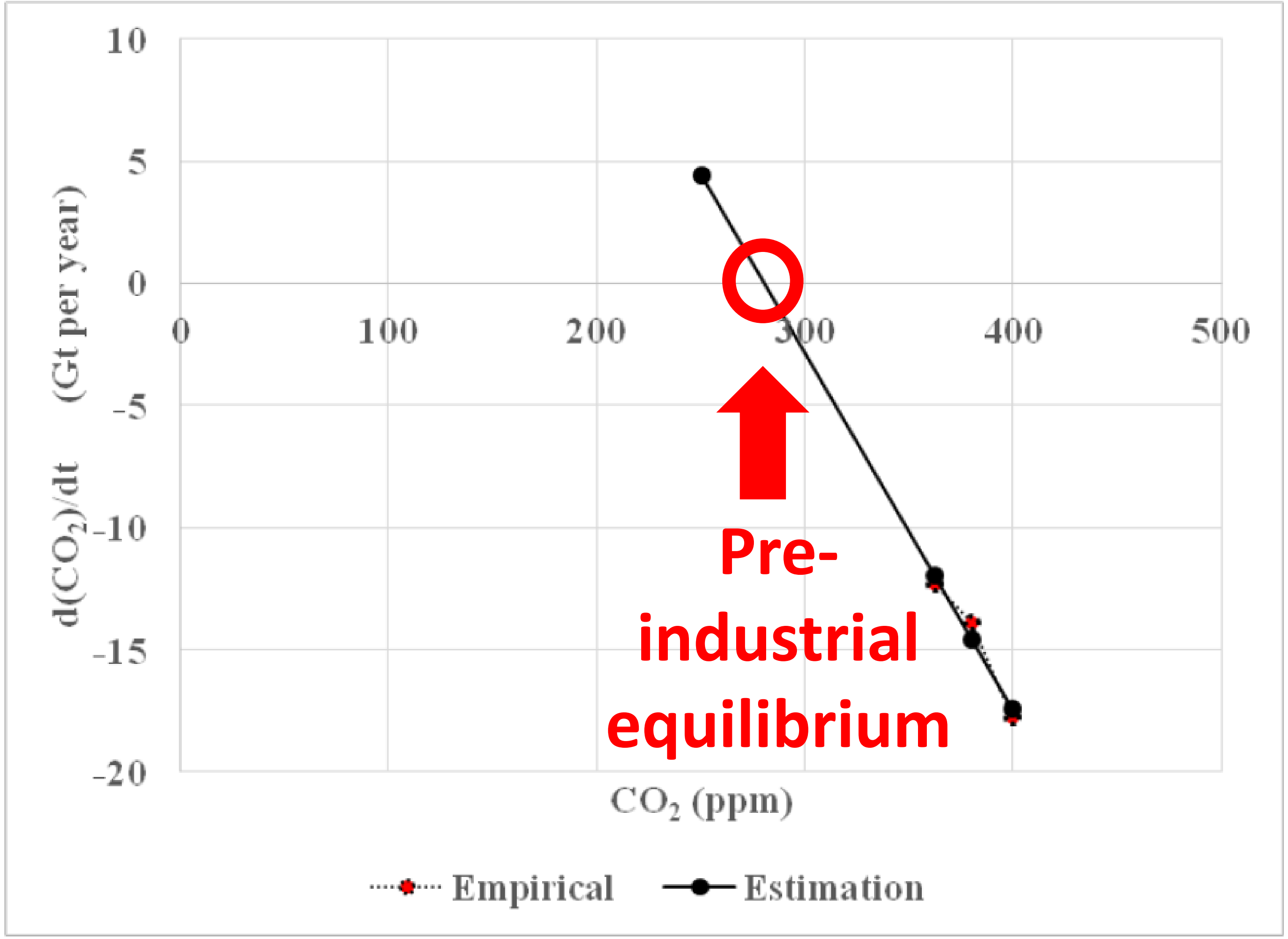
$$\dot{x} = \frac{dx}{dt} = a_0 + a_x x_{eq} = 0$$

$$x_{eq} = \frac{-a_0}{a_x} \boxed{\approx 280.31 \quad (ppm)}$$

The estimated equilibrium is equal to the pre-industrial level.

Change of CO2 in atmosphere
(in the absence of emissions)

The differential equation determines the pre-industrial equilibrium correctly.



Pre-industrial equilibrium

X

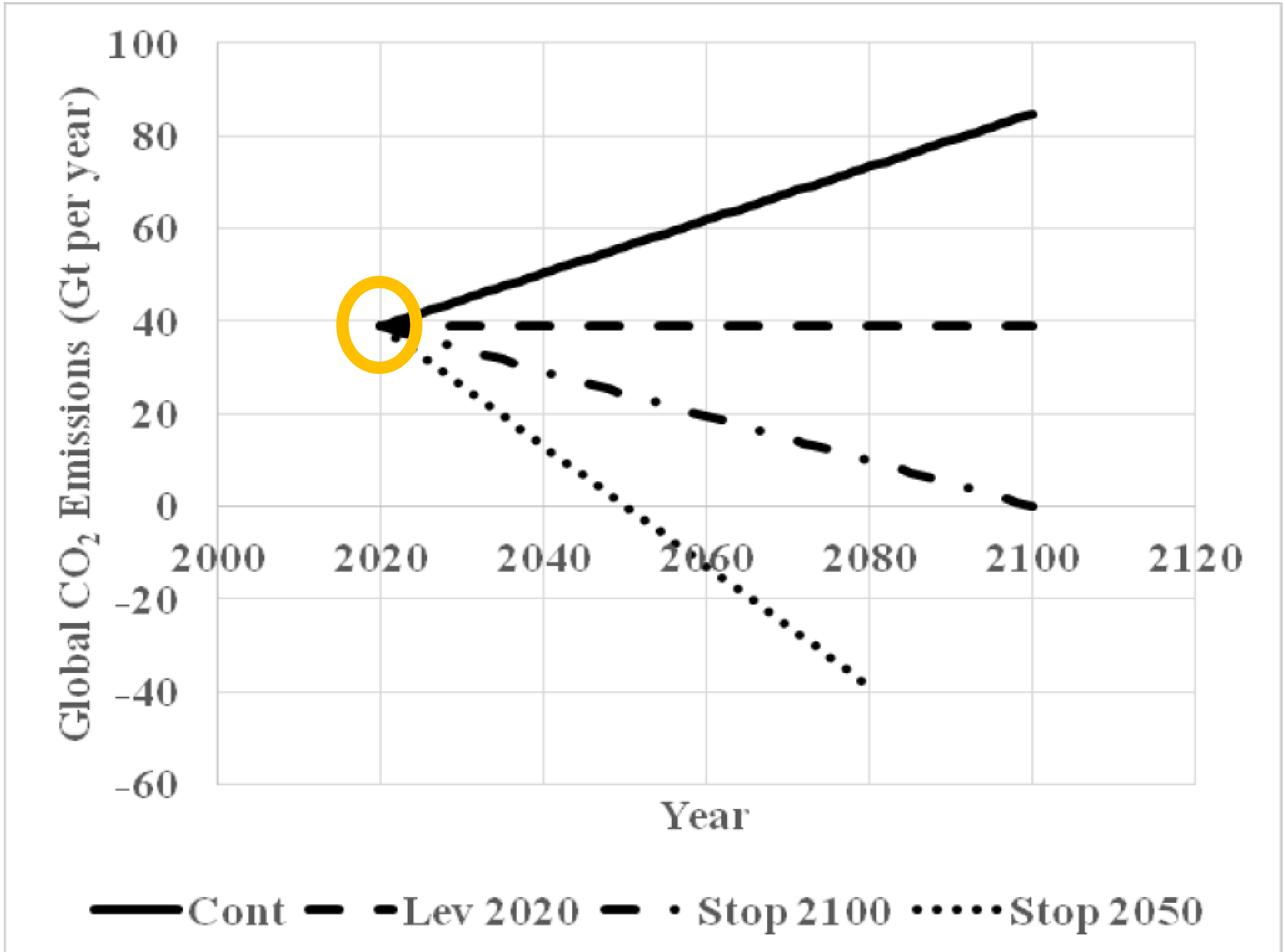
Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7-15.

Abstract PART 5(6):

The differential function is applied to derive four dynamic cases of the global CO2 level, from the year 2020 until 2100, conditional on four different strategies concerning the development of global CO2 emissions:

1. **Emissions continue to increase according to the trend during 1990–2018.**
2. **Emissions stay for ever at the 2020 level.**
3. **Emissions are reduced with a linear trend to become zero year 2100.**
4. **Emissions are reduced with a linear trend to become zero year 2050.**

Alternative Emission Strategies



Determination of a prediction model

$$x(t) = Ae^{bt} + k_0 + k_1 t$$

based on the differential equation

$$\dot{x} = a_0 + a_x x + \varphi(t)$$

and the different emission strategies.

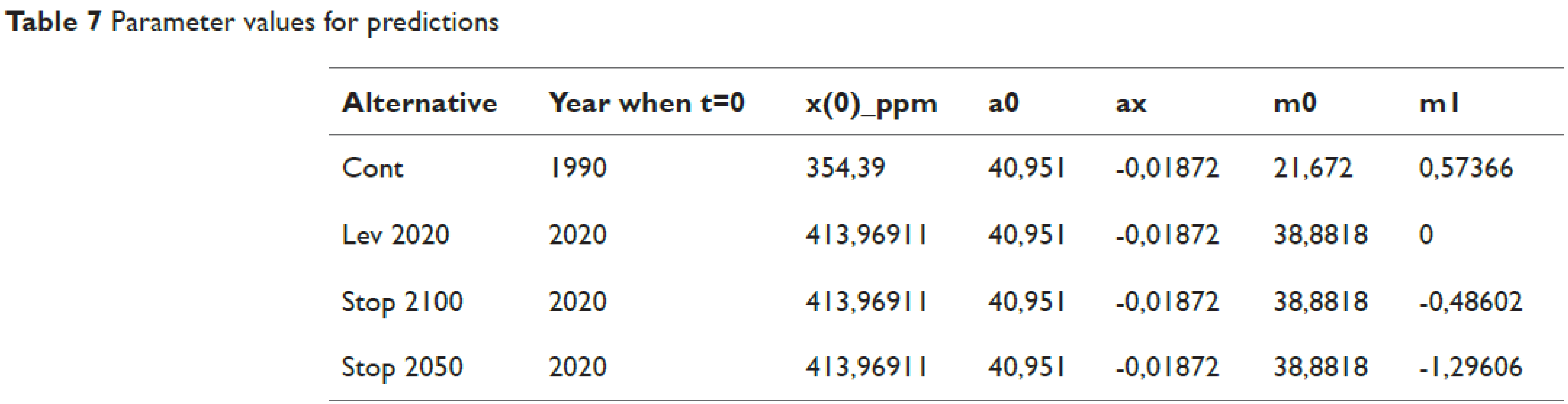
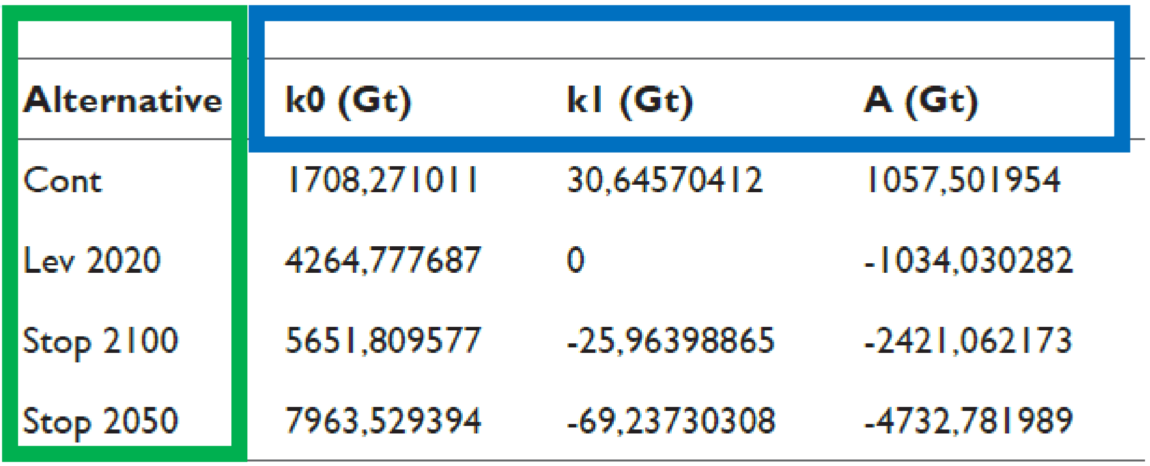


Table 7 Parameter values for predictions

Alternative	Year when t=0	x(0)_ppm	a0	ax	m0	m1
Cont	1990	354,39	40,951	-0,01872	21,672	0,57366
Lev 2020	2020	413,96911	40,951	-0,01872	38,8818	0
Stop 2100	2020	413,96911	40,951	-0,01872	38,8818	-0,48602
Stop 2050	2020	413,96911	40,951	-0,01872	38,8818	-1,29606

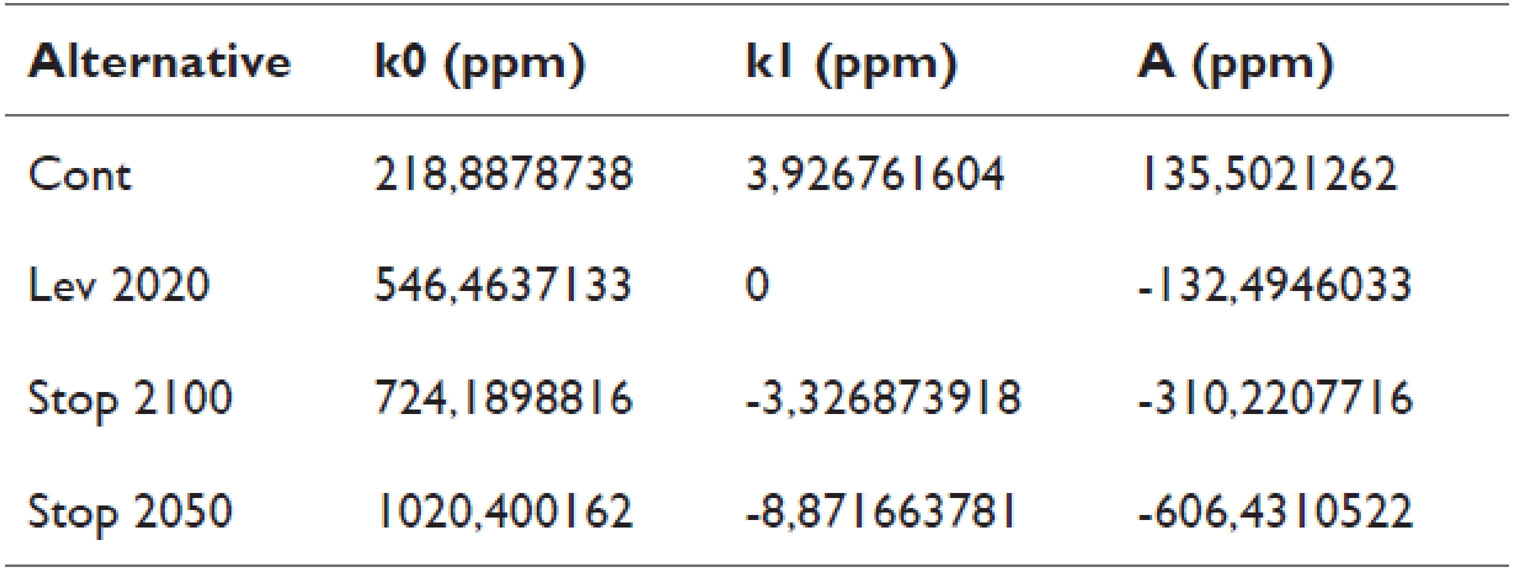
Table 8 Parameter values for predictions



Alternative	k0 (Gt)	k1 (Gt)	A (Gt)
Cont	1708,271011	30,64570412	1057,501954
Lev 2020	4264,777687	0	-1034,030282
Stop 2100	5651,809577	-25,96398865	-2421,062173
Stop 2050	7963,529394	-69,23730308	-4732,781989

Alternative emission strategies →

Alternative emission strategies ➡



Alternative	k0 (ppm)	k1 (ppm)	A (ppm)
Cont	218,8878738	3,926761604	135,5021262
Lev 2020	546,4637133	0	-132,4946033
Stop 2100	724,1898816	-3,326873918	-310,2207716
Stop 2050	1020,400162	-8,871663781	-606,4310522

$$\boxed{x(t) = Ae^{-0.0187191\,t} + k_0 + k_1\ t \qquad (ppm)}$$

Prediction model

Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7-15.

Abstract PART 6(6):

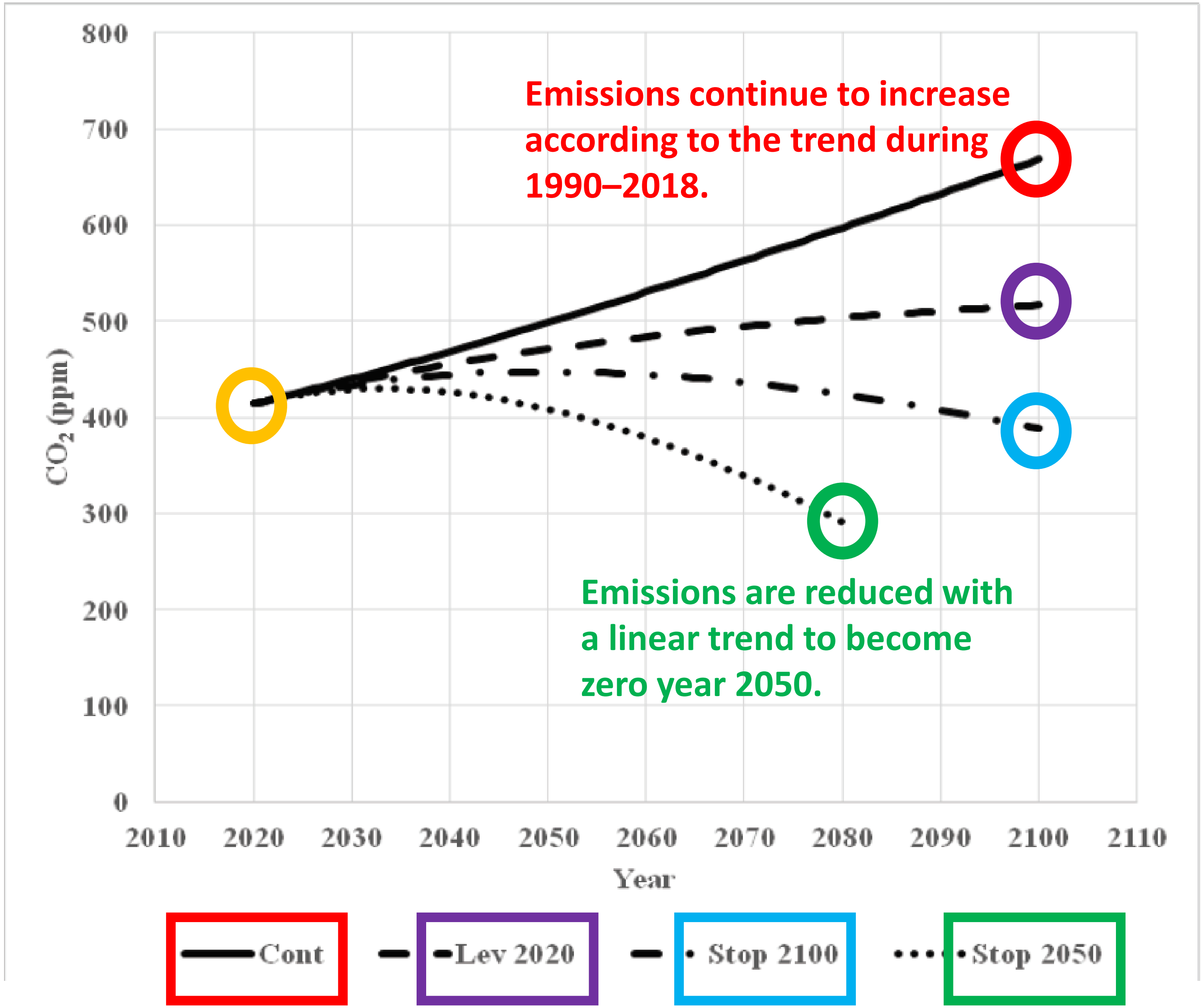
In case i., the CO2 level year 2100 will be 688 ppm.

In cases ii. and iii., the CO2 levels in 2100 will be 517 ppm and 389 respectively.

In case iv., the CO2 level in 2050 is 408 ppm and then rapidly falls.

X

The different emission strategies give different future developments of the CO2 level in the atmosphere.


Emissions continue to increase according to the trend during 1990–2018.

Emissions are reduced with a linear trend to become zero year 2050.

Optimization of continuous cover forestry expansion under the influence of global warming

Lohmander, P., Optimization of continuous cover forestry expansion under the influence of global warming, International Robotics & Automation Journal, Volume 6, Issue 3, 2020, 127-132.
https://medcraveonline.com/IRATJ/IRATJ-06-00211.pdf
https://medcraveonline.com/IRATJ/IRATJ-06-00211A.pdf

In this article:

Lohmander, P., Optimization of continuous cover forestry expansion under the influence of global warming, International Robotics & Automation Journal, Volume 6, Issue 3, 2020, 127-132.
https://medcraveonline.com/IRATJ/IRATJ-06-00211.pdf
https://medcraveonline.com/IRATJ/IRATJ-06-00211A.pdf

the CO2 differential function developed in this article:

Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7 - 15. https://medcraveonline.com/IRATJ/IRATJ-06-00197.pdf

is applied and adjusted for alternative levels of CCF forestry area expansion paths.

Abstract part 1(4)

Planet Earth faces the problem of global warming. Recent research on the dynamics of the CO2 concentration in the atmosphere has shown how reductions of global industrial emissions of CO2 can solve a large part of the global warming problem. However, there are more control options available.

Our world is covered by large areas of primary (natural) forests that are almost not managed at all. They do not contribute very much to the net absorption of CO2.

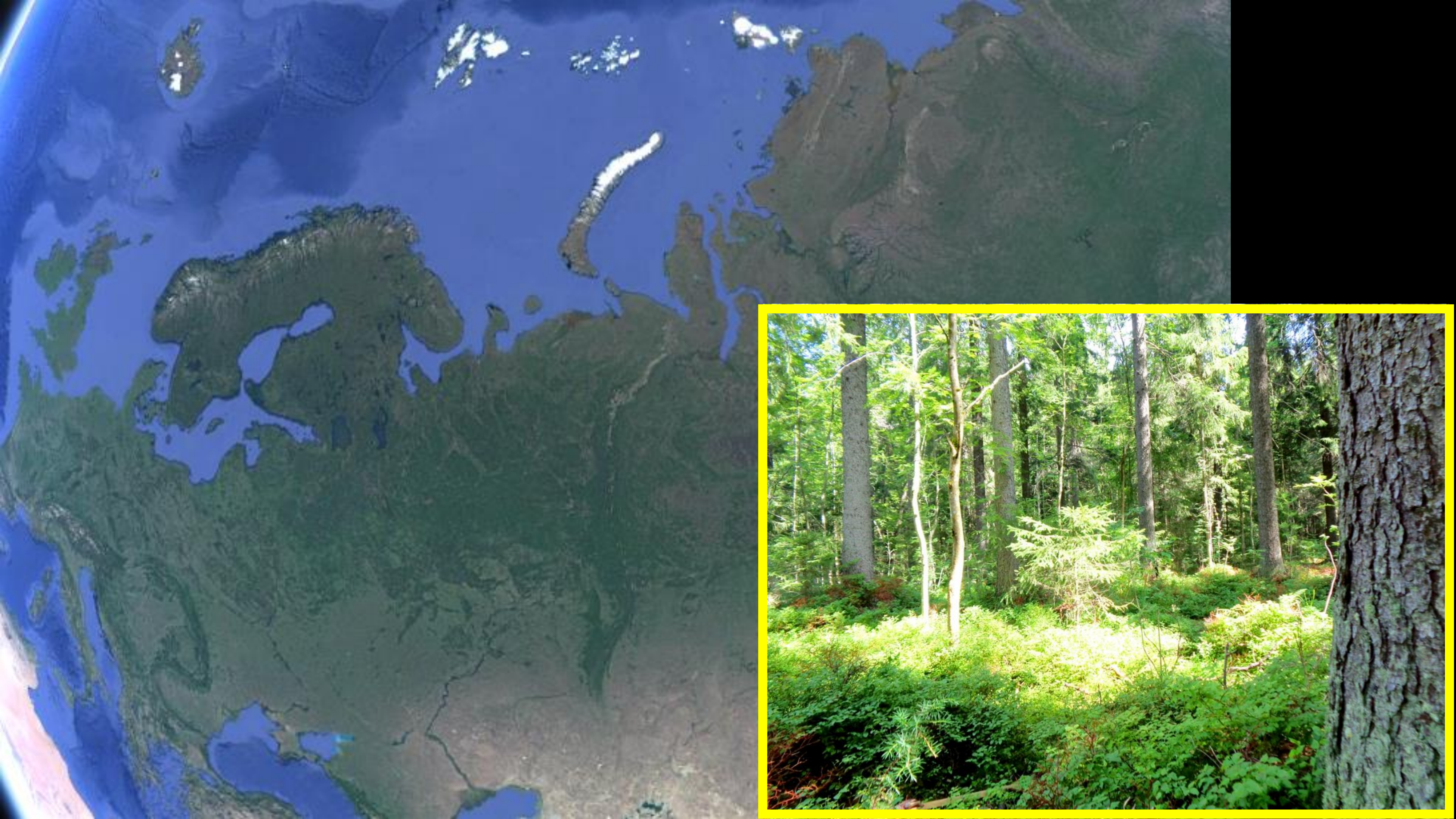
Lohmander, P., Optimization of continuous cover forestry expansion under the influence of global warming, International Robotics & Automation Journal, Volume 6, Issue 3, 2020, 127-132.
https://medcraveonline.com/IRATJ/IRATJ-06-00211.pdf
https://medcraveonline.com/IRATJ/IRATJ-06-00211A.pdf

According to FAO, 2020, the world presently has at least 1.11 billion ha of primary forest. In these primary forests, of particular interest and relevance to the analysis developed in the later part of this paper, there are practically no human activities such as forest harvesting.

The forests are almost undisturbed by human industrial projects and have native forest species and original ecological processes. In the three countries Brazil, Russian Federation and Canada, we find 61% of these primary forests, which represents approximately 677 M ha.

Our world contains very large areas of mixed species forests with trees of different sizes.

By Phil P Harris. - Own work, CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=717267



Abstract part 2(4)

Parts of these natural forests may be transformed to continuous cover forests, which mean that the absorption of CO2 increases so that the CO2 level in the atmosphere can be further reduced. This transformation can be made without severely damaging the environmental conditions.

The analysis in this paper shows how to define an optimization problem with two objectives with different weights in the objective function. These objectives are the economic present value of profits and the utility of the climate.

Lohmander, P., Optimization of continuous cover forestry expansion under the influence of global warming, International Robotics & Automation Journal, Volume 6, Issue 3, 2020, 127-132.
https://medcraveonline.com/IRATJ/IRATJ-06-00211.pdf
https://medcraveonline.com/IRATJ/IRATJ-06-00211A.pdf

Continuous cover forest harvesting in the Swedish mountains, December 2014

Multi objective optimization

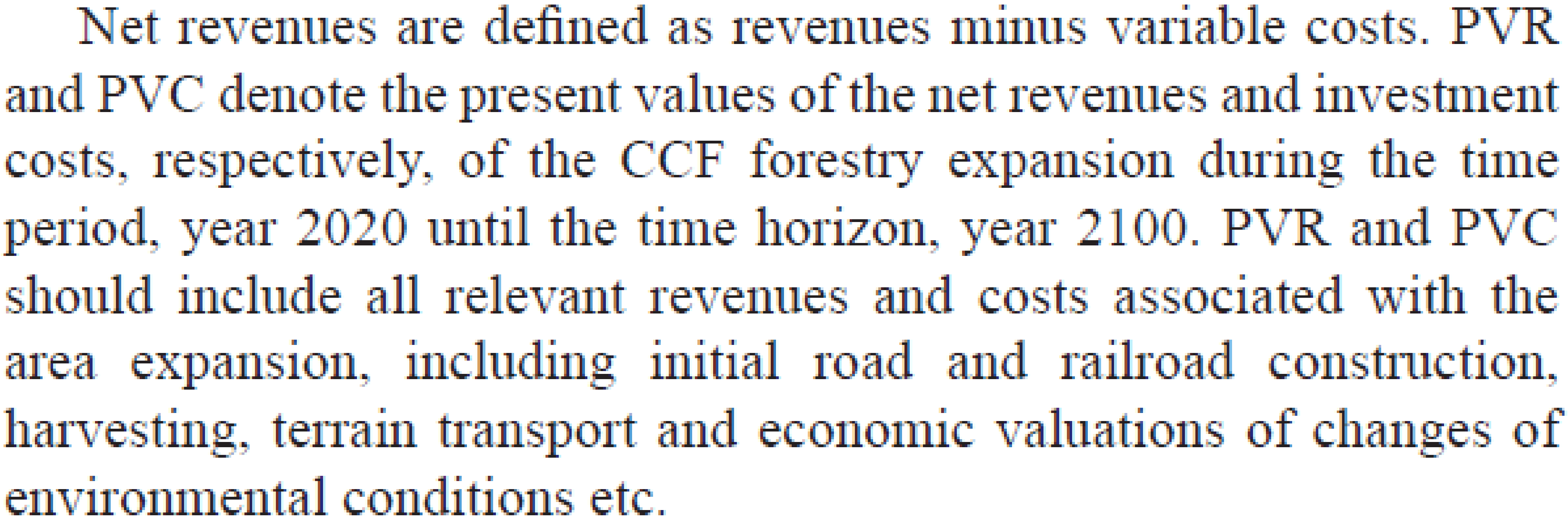
The optimization problem contains the objective function OBJF:

$$OBJF = \boxed{kW * W} + \boxed{kR * PVR - kC * PVC}$$

Present value of all profits

Time is denoted by t, in years. t = 0 in year 2020. The analysis is concerned with the time interval year 2020 until year 2100, which means that t goes from 0 to 80. The time horizon is denoted T. T = 80.

W(t) is the utility of the climate as a function of time. W = W(T), is the utility of the predicted climate at the time horizon, T. The utility is assumed to be a strictly concave function of the CO_2 concentration in the atmosphere. This utility function has a unique maximum at the CO_2 level 280 ppm, which is assumed to be the "preindustrial level".



Net revenues are defined as revenues minus variable costs. PVR and PVC denote the present values of the net revenues and investment costs, respectively, of the CCF forestry expansion during the time period, year 2020 until the time horizon, year 2100. PVR and PVC should include all relevant revenues and costs associated with the area expansion, including initial road and railroad construction, harvesting, terrain transport and economic valuations of changes of environmental conditions etc.

Abstract part 3(4)

The analysis shows how the optimal transformation of natural forests to managed continuous cover forests is affected by the relative weights of the utility of the climate and of the present value of the profits.

If the relative weight of the utility of the climate increases, the optimal area of natural forests that should be transformed to managed continuous cover forests increases.

Lohmander, P., Optimization of continuous cover forestry expansion under the influence of global warming, International Robotics & Automation Journal, Volume 6, Issue 3, 2020, 127-132.
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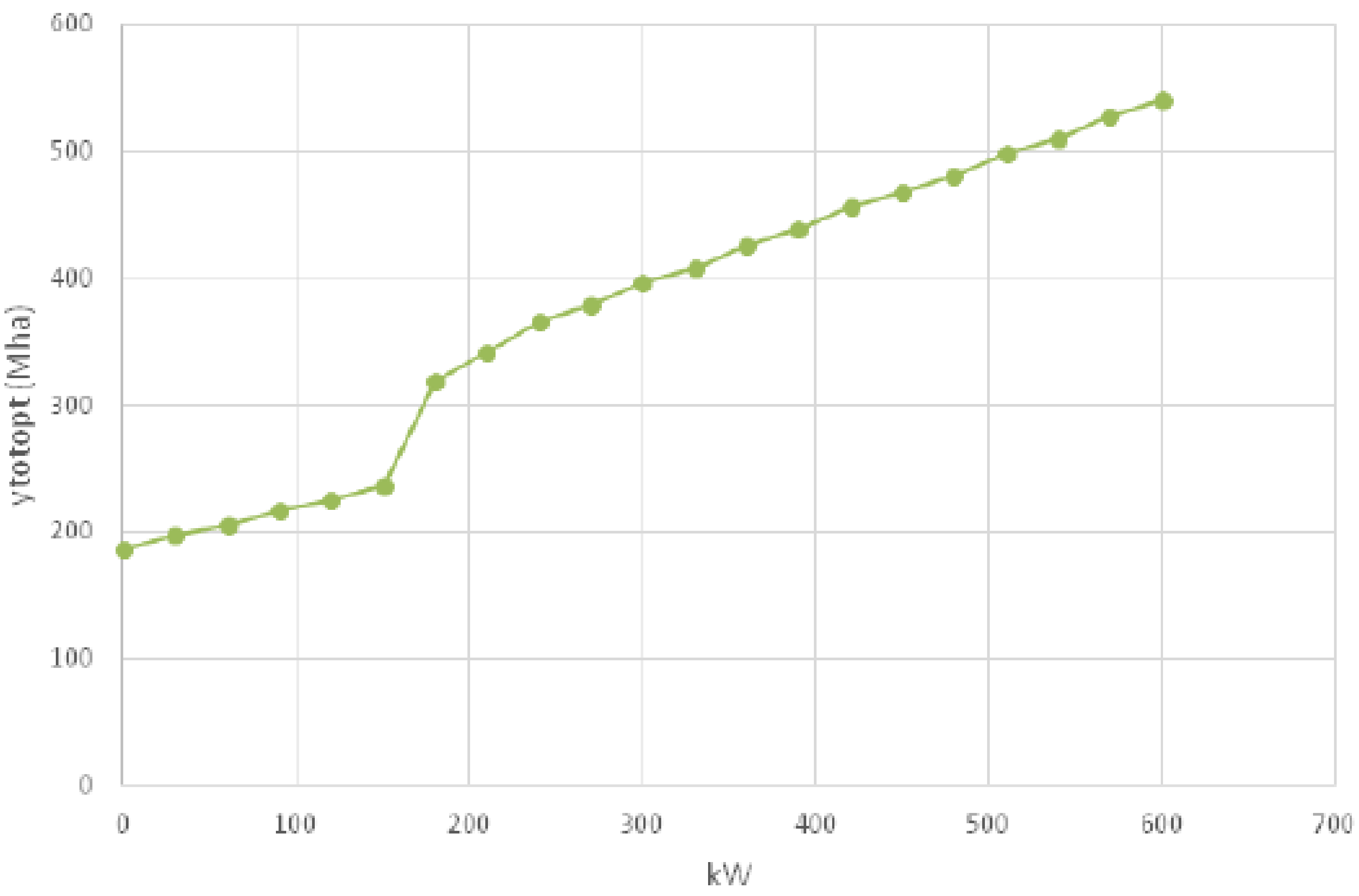
```
FOR y1 = 0 TO 10 STEP 0.1          (y1 = CCF area expansion per year)
    FOR yt = 10 TO 60 STEP 0.1     (yt = number of years of CCF area expansion)

        Determinations of the CO2 differential equation parameters and solutions from year 2020 until 2100.

        Derivations of forestry profits and forest dependent CO2 change during 80 years via the solution to the differential equation.

        Selection of the optimal combination of y1 and yt based on the objective function parameters.

    NEXT yt
NEXT y1
```

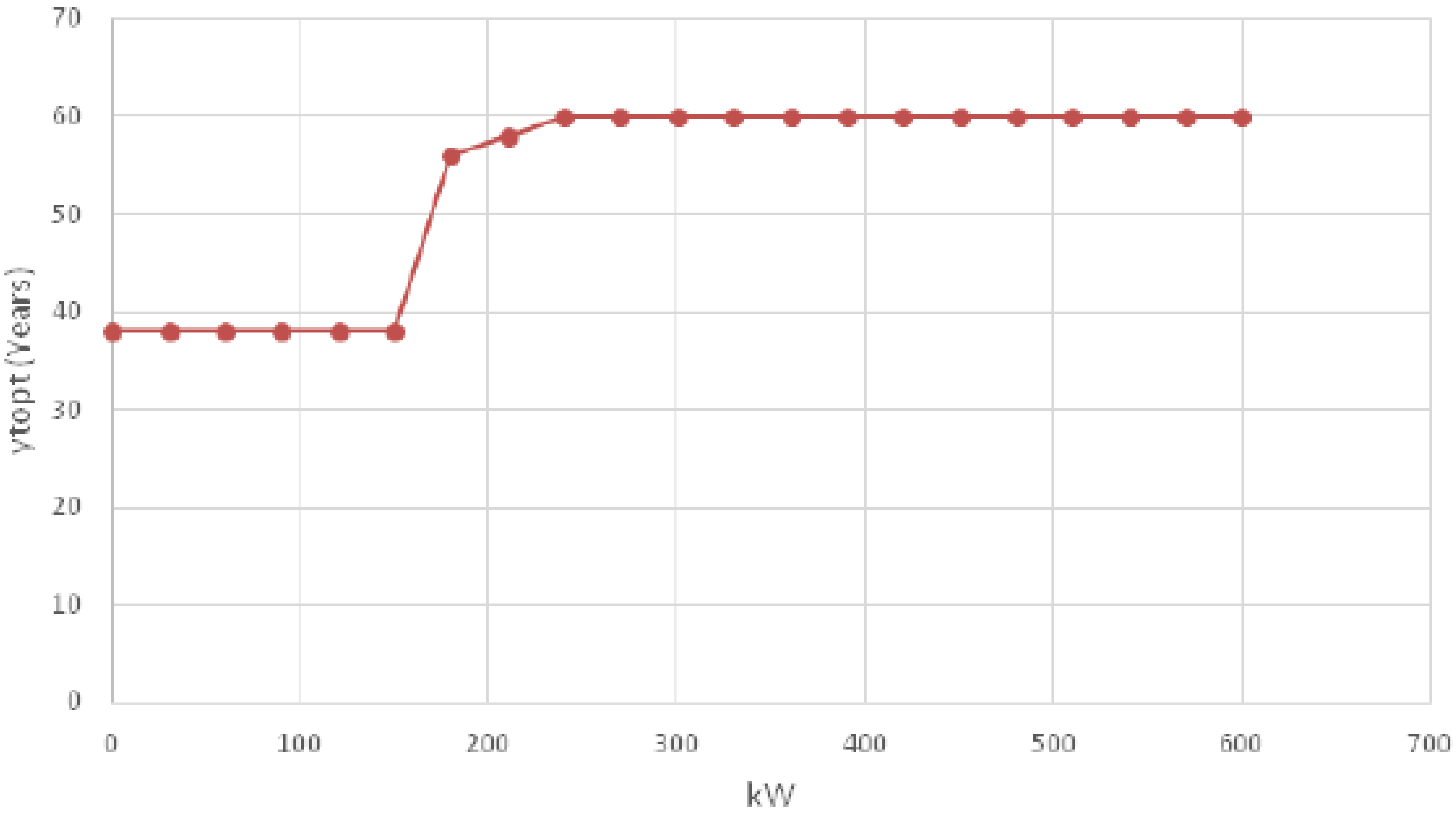
Optimal Total Area Expansion (Mha)



kW

Figure 1 ytotopt, the optimal total area of CCF expansion, as a function of kW, the weight of W in the objective function. ytotopt is a function of ytopt and y1opt. These are found in Figures 2 & 3.

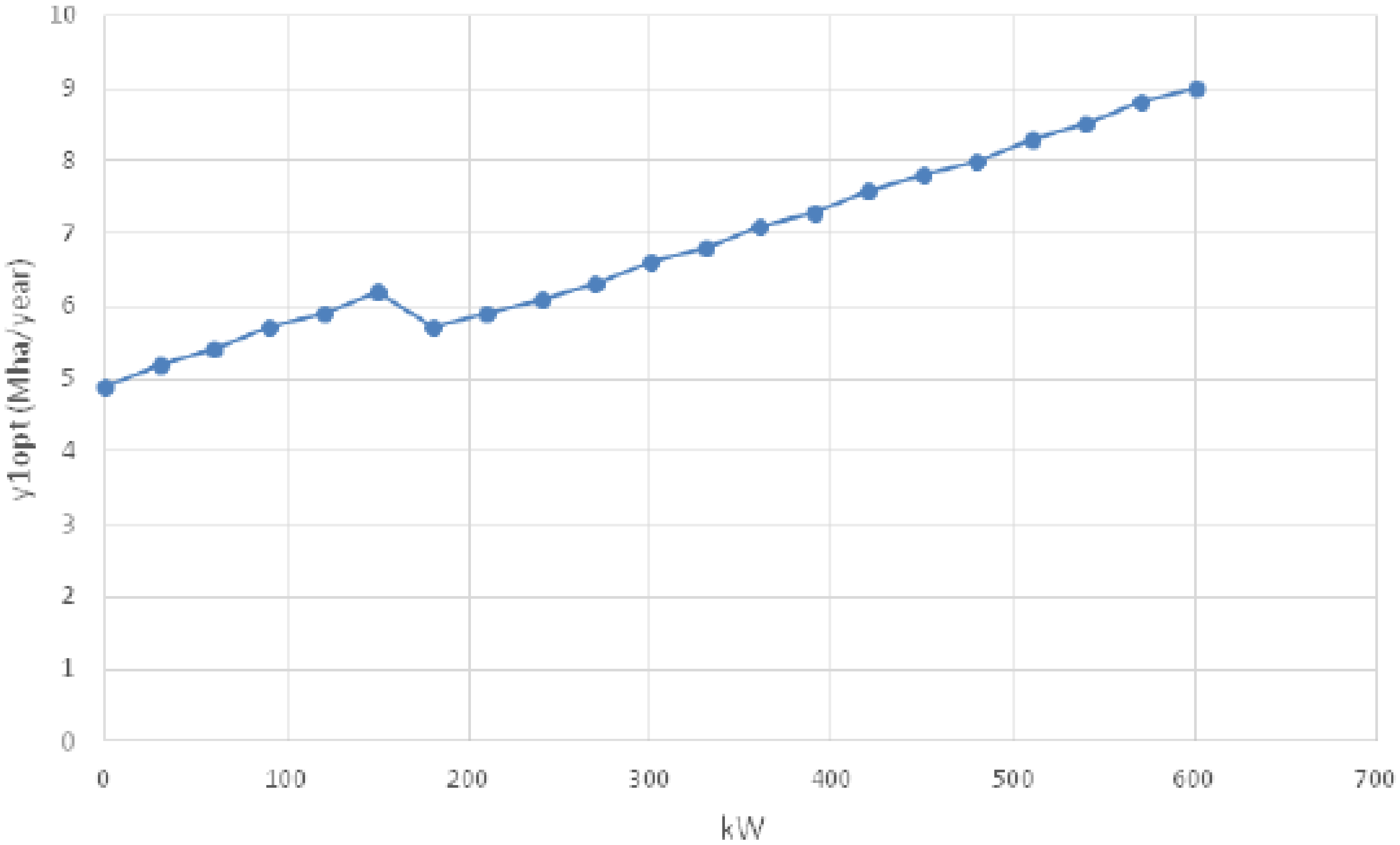
Optimal time of area expansion (Years)



kW

Figure 2 ytopt, the optimal number of years to continue the CCF expansion, as a function of kW, the weight of W in the objective function.

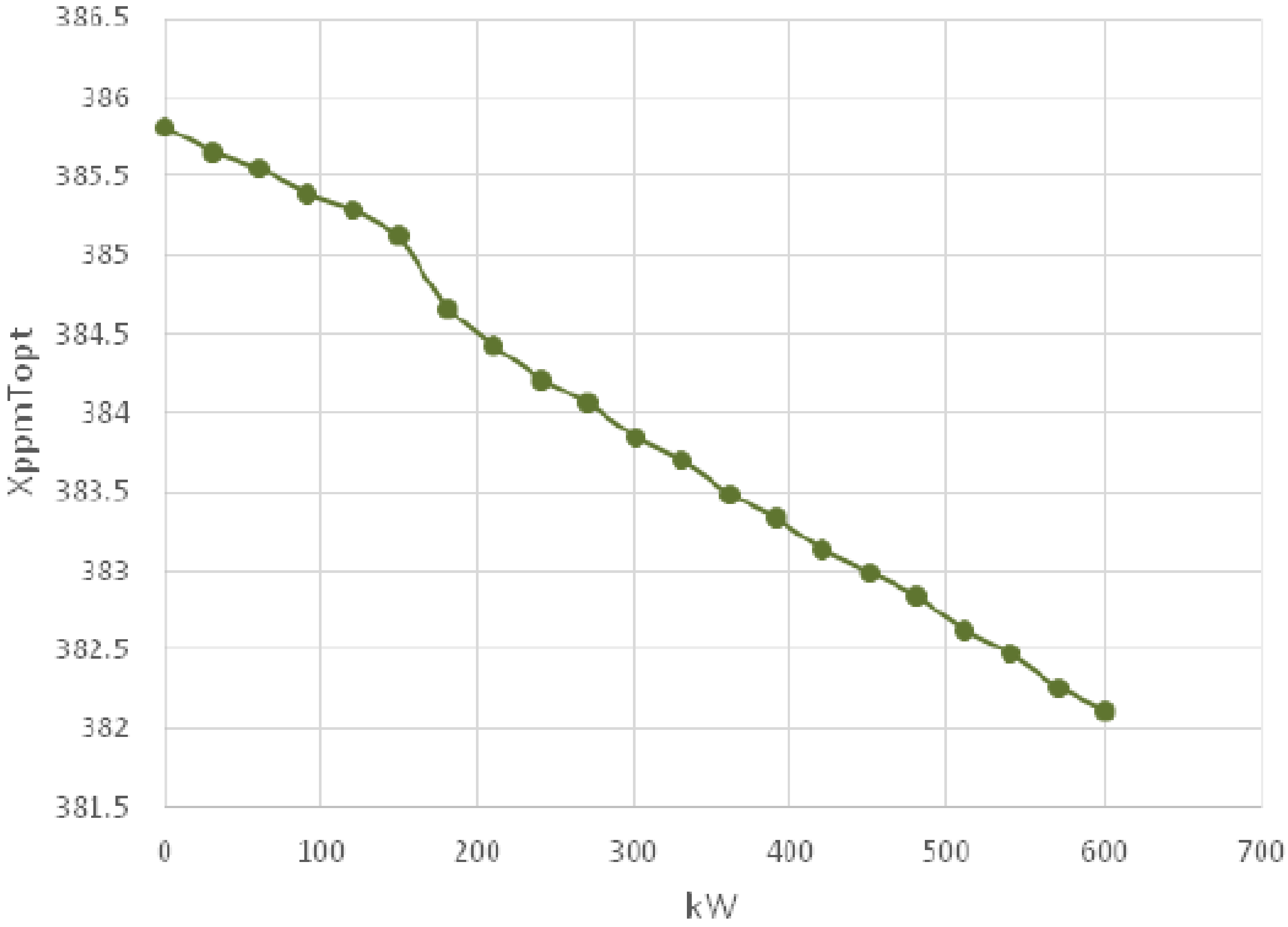
Optimal area expansion per year (Mha/year)



kW

Figure 3 y1opt, the optimal area expansion of CCF per year, until year ytopt, as a function of kW, the weight of W in the objective function.

Optimal CO2 level in year 2100 (ppm)

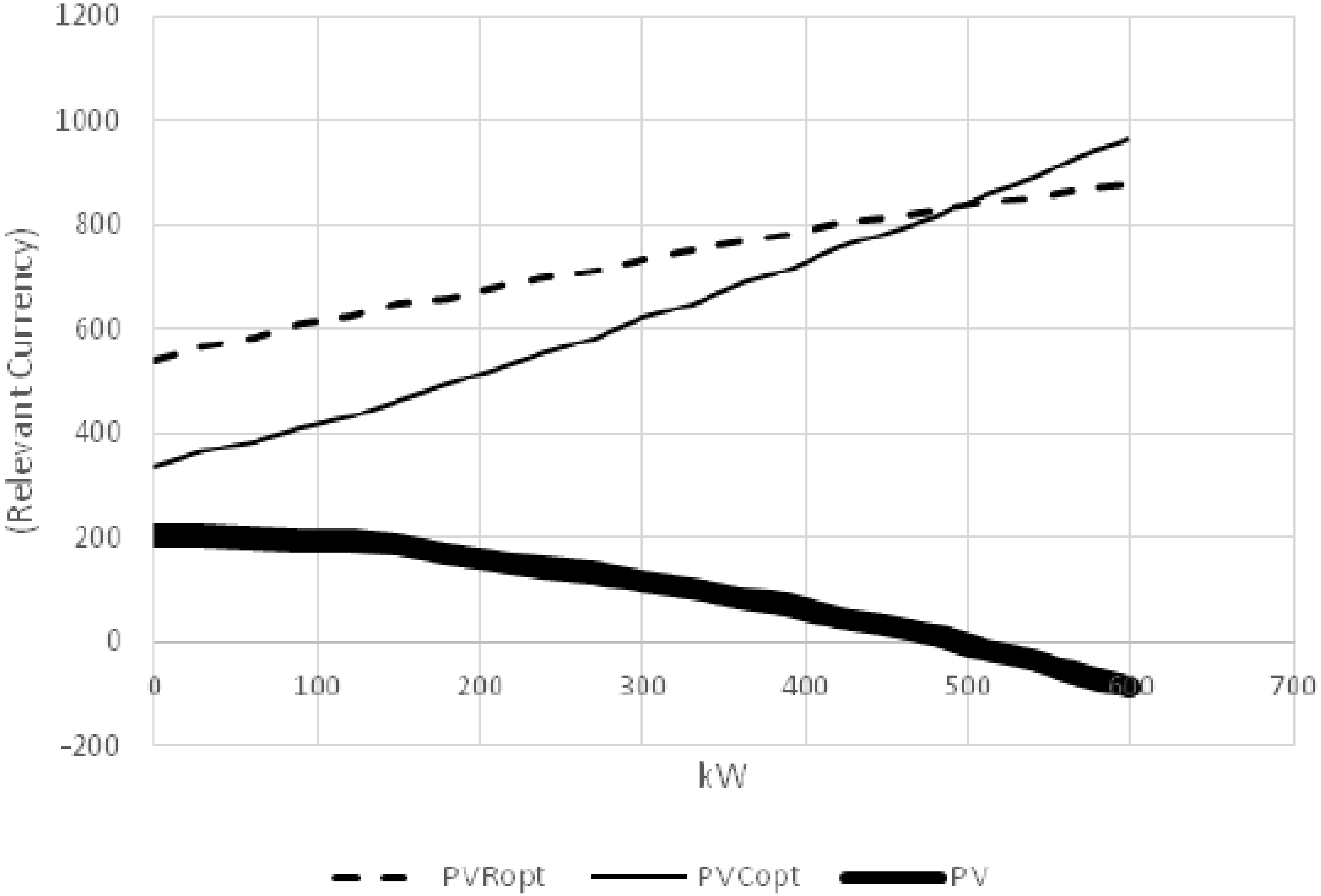


kW

Figure 4 XppmTopt, the optimal ppm value of CO_2 at time T, (the year 2100), as a function of kW, the weight of W in the objective function.

Present values of optimal revenues, costs and profits (Relevant currency)

PV

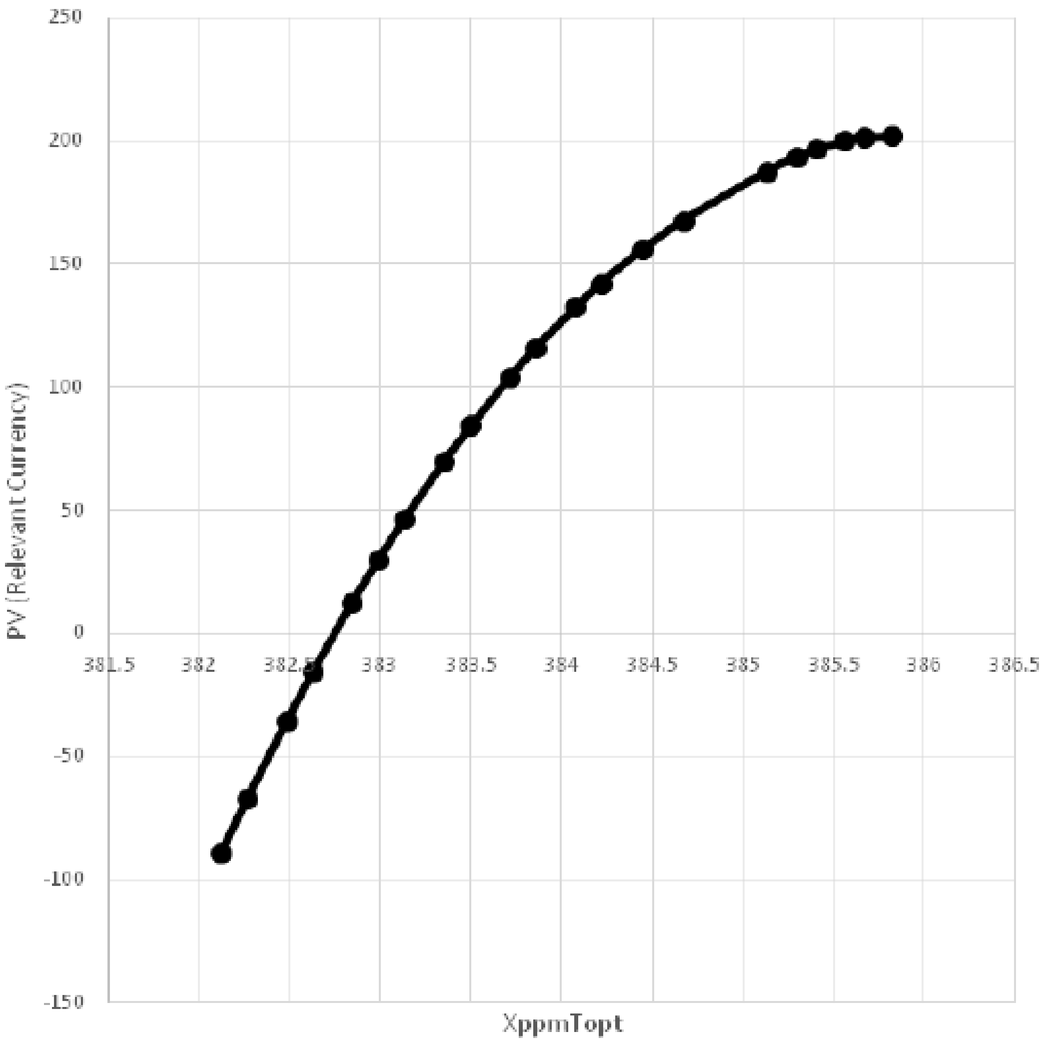


kW

Figure 5 PVRopt, The optimal present value of net revenues, PVCopt, the optimal present value of investment costs and PV, the optimal present value of the profits, as functions of kW, the weight of W in the objective function.

The frontier of optimal combinations of the present value of total profits and the CO2 level in year 2100 (Relevant currency & ppm)

PV



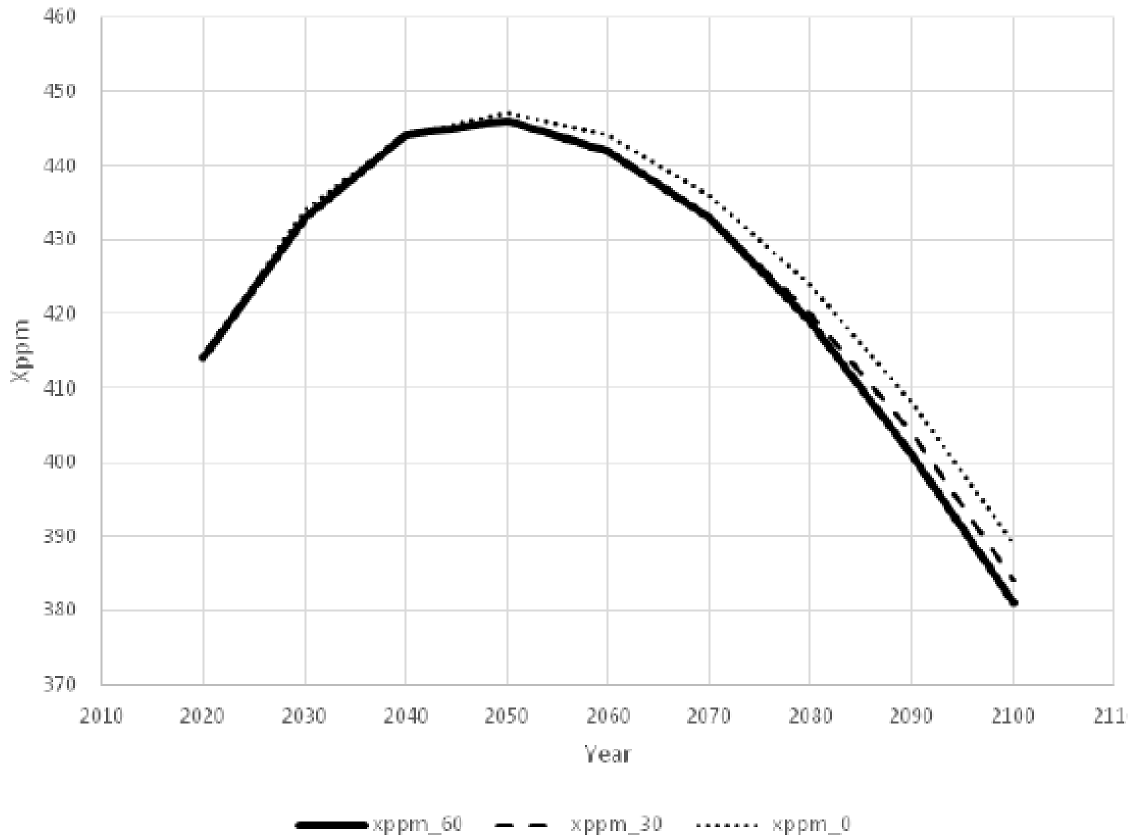
X(t=80) (ppm)

Figure 6 The frontier of optimal combinations of PV, the present value of the profits, and XppmTopt, the concentration of CO_2 in the atmosphere at time T (year 2100). In different points along the curve, the relative weights of the different objectives in the objective function are different.

The time path of the CO2 level as a function of the number of years of area expansion. (ppm)

(In all three cases in the graph, The expansion per year is 10 Mha.)

X
(ppm)

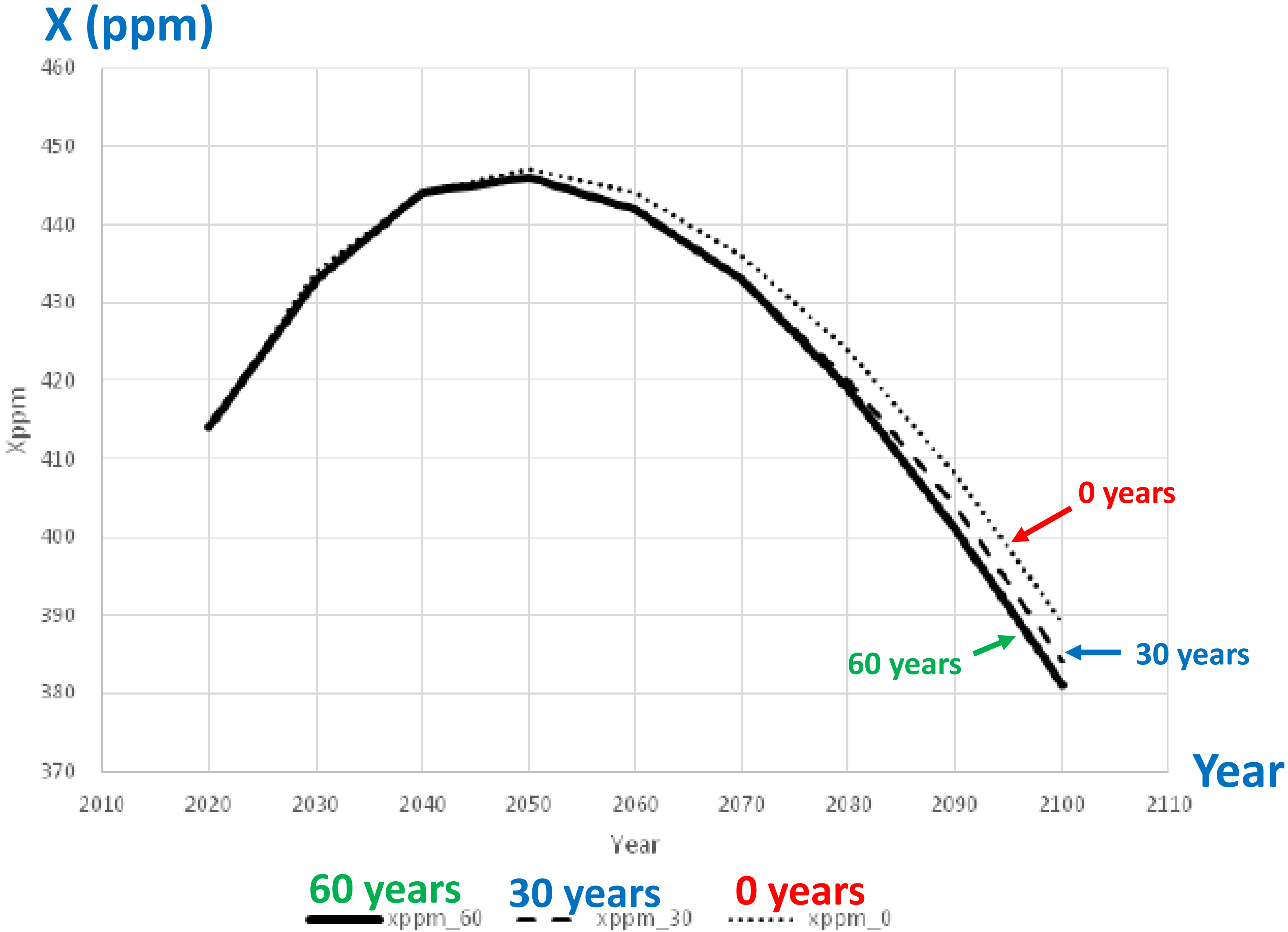


Year

Figure 7 The time path of the CO_2 concentration in the atmosphere, Xppm, over time as a function of yt, the number of years with CCF expansion. Three cases are illustrated. In all cases, the CCF expansion per year is 10 Mha, until the expansion stops. In xppm_0, the CCF expansion instantly stops (it never starts), in xppm_30, the CCF expansion stops after 30 years (in year 2050) and in xppm_60, the CCF expansion stops after 60 years (in year 2080). All cases reported in this graph are based on a particular general global emission reduction case defined in Lohmander P, 2020.[1] The emission reduction per year, in this case, from year 2020, is constant until year 2100. In year 2100, the emissions are zero.

The time path of the CO2 level (ppm) as a function of the time of area expansion. (years).

(In all three cases in the graph, the area expansion per year is 10 Mha.)



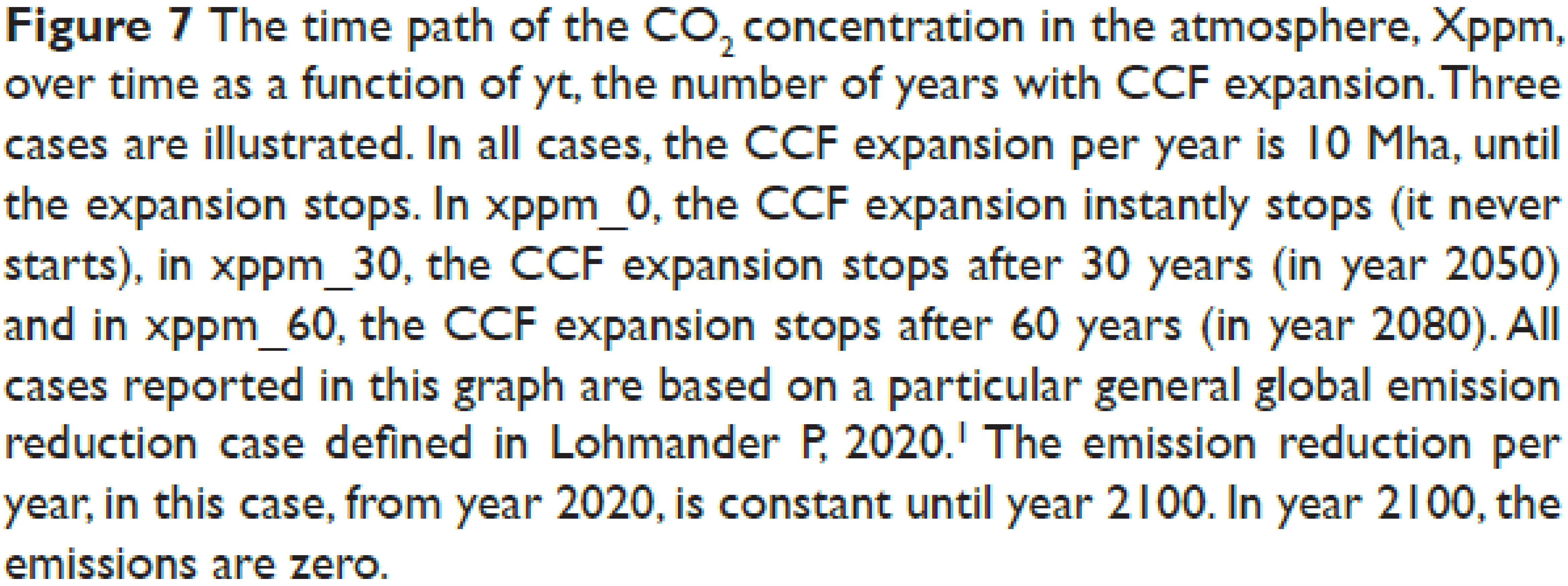


Figure 7 The time path of the CO_2 concentration in the atmosphere, Xppm, over time as a function of yt, the number of years with CCF expansion. Three cases are illustrated. In all cases, the CCF expansion per year is 10 Mha, until the expansion stops. In xppm_0, the CCF expansion instantly stops (it never starts), in xppm_30, the CCF expansion stops after 30 years (in year 2050) and in xppm_60, the CCF expansion stops after 60 years (in year 2080). All cases reported in this graph are based on a particular general global emission reduction case defined in Lohmander P, 2020.[1] The emission reduction per year, in this case, from year 2020, is constant until year 2100. In year 2100, the emissions are zero.

Abstract part 3(4)

The analysis shows how the optimal transformation of natural forests to managed continuous cover forests is affected by the relative weights of the utility of the climate and of the present value of the profits.

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Abstract part 4(4)

**If 600 M hectares are transformed during 60 years,
from 2020 until 2080,**

**then the concentration of CO2 in the atmosphere
can be reduced by 8 ppm until the year 2100.**

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Conclusions 1(2)

#1. Now, it is possible to understand the dynamics of the CO2 level of the atmosphere, under the influence of global emissions.

#2. A first order differential equation with emission forcing has been able to explain the development of the dynamics of the CO2 level in the atmosphere, with very high precision.

#3. The function shows that the CO2 equilibrium level, before the industrial revolution, was 280 ppm, which confirms earlier empirical research.

#4. The model has predicted how the global CO2 level can be dynamically changed via different emissions strategies.

Conclusions 2(2)

#5. Large areas of primary (natural) forests do not contribute very much to the net absorption of CO2. They may be transformed to CCF.

#6. Then, the absorption of CO2 increases and the CO2 level in the atmosphere can be reduced. This transformation can be made without severely damaging the environmental conditions.

#7. If the weight of the utility of the climate increases, the optimal area of natural forests that should be transformed to CCF increases.

#8. If 600 M hectares are transformed during 60 years, from 2020 until 2080, the CO2 level in the atmosphere is reduced by 8 ppm year 2100.

This presentation is based on the following articles:

Lohmander, P., Dynamics and control of the CO2 level via a differential equation and alternative global emissions strategies, International Robotics & Automation Journal, Volume 6, Issue 1, 2020, pages 7-15. https://medcraveonline.com/IRATJ/IRATJ-06-00197.pdf

Lohmander, P., Optimization of continuous cover forestry expansion under the influence of global warming, International Robotics & Automation Journal, Volume 6, Issue 3, 2020, 127-132.
https://medcraveonline.com/IRATJ/IRATJ-06-00211.pdf
https://medcraveonline.com/IRATJ/IRATJ-06-00211A.pdf

Connected articles:

Lohmander, P., Fundamental principles of optimal utilization of forests with consideration of global warming, Central Asian Journal of Environmental Science and Technology Innovation, Volume 1, Issue 3, May and June 2020, 134-142. doi: 10.22034/CAJESTI.2020.03.02
http://www.cas-press.com/article_111213.html
http://www.cas-press.com/article_111213_5ab21574a30f6f2c7bdc0a0733234181.pdf

Lohmander, P., Adaptive mobile firefighting resources, stochastic dynamic optimization of international cooperation, International Robotics & Automation Journal, Volume 6, Issue 4, 2020, pages 150-155.
https://medcraveonline.com/IRATJ/IRATJ-06-00213.pdf

Lohmander, P., Forest fire expansion under global warming conditions: multivariate estimation, function properties and predictions for 29 countries, Central Asian Journal of Environmental Science and Technology Innovation, Volume 1, Issue 5, 2020, 134-142. doi:10.22034/CAJESTI.2020.05.03.
http://www.cas-press.com/article_122566.html

Lohmander, P., Optimization of forestry, infrastructure and fire management,
Caspian Journal of Environmental Sciences (Forthcoming. Accepted for publication).

Global Warming

Forest Fire

↑ Increases Forest Fires

↑ Total Forest Area

↑ Average Temperature

↓ Decreases Forest Fires

↑ Population Size

Climate change under CO2 emission control and optimal forestry

Webinar on Forest Management and Climate Changes

University of Guilan- Faculty of Natural Resources

February 15th, 2021, 13:00-14:30 (Iran time), 10:30-12:00 (CET)

Prof. Dr. Peter Lohmander

http://www.lohmander.com/Information/Ref.htm

Peter@Lohmander.com

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Forest Management and Climate Changes

مدیریت جنگل و تغییرات اقلیم

Optimal Solutions

Peter Lohmander

Professor Dr. Peter Lohmander
Optimal Solutions in cooperation with Linnaeus University, Sweden
Title: Climate change under CO_2 emission control and optimal forestry
Time: 13:00-13:30

Professor Dr. Luis Santos
Polytechnic Institute of Tomar, Portugal
Title: Forest fire risk assessment methodology, a climate change mitigation strategy
Time: 13:30-14:00

Professor Dr. Soleiman Mohammadi Limaei
University of Guilan, Iran
Title: Climate smart forest management considering economics and carbon dynamic
Time: 14:00-14:30

February 15th, 2021
13:00-14:30 IRST
۲۷ بهمن ۱۳۹۹
ساعت ۱۳:۰۰ تا ۱۴:۳۰

Webinar Link: لینک وبینار:

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University of Guilan- Faculty of Natural Resources
دانشگاه گیلان، دانشکده منابع طبیعی

Contact details:

Prof. Dr. Peter Lohmander
Optimal Solutions
Hoppets Grand 6
SE-903 34 Umea
Sweden

Peter@Lohmander.com
Peter.Lohmander@icloud.com

http://www.lohmander.com/Information/Ref.htm