

Global Stability via the Forced Global Warming Equation, Fire Control with Joint Fire Fighting Resources and Optimal Forestry

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Abstract:

Our world presently contains several severe conflicts and sources of instability. We face large scale geopolitical tensions with local and global disturbances such as the covid-19 pandemia, large streams of refugees, global warming and expanding wild fires. The technology options of energy systems and environmental problems rapidly develop. International control, such as global taxes on CO₂, are discussed and environmental initiatives of many kinds are introduced in different regions. Combined heat and power expands in the Nordic countries. New ways to continuously and sustainably manage the global forest resources have been developed that not only optimize profits but also contribute to the CO₂ management problem. Furthermore, carbon capture and storage can make several kinds of energy systems sustainable. In six new scientific articles, fundamental processes and optimal solutions have been defined, derived and presented.

#1. The fundamental theory of the CO₂ level in the atmosphere, under the influence of changing CO₂ emissions, is modeled as a first order linear differential equation with a forcing function, describing industrial emissions. 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. 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. 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. 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.

#2. & #3. Reduced 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. 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. We 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. 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. 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.

#4. Forest fires cause severe problems in many countries. Forest fire areas in nine European countries are investigated with respect to yearly averages, standard deviations and correlations between nations. In the region IFPS (Italy, France, Portugal and Spain), the average yearly burned area during the years 2010 to 2018 was 313.4 kha and in FGLNS (Finland, Germany, Latvia, Norway and Sweden) the corresponding area was only 7.6 kha. The correlations between the regions are strictly negative and the correlations within the regions are strictly positive. Since forest fires usually do not occur in every country at the same time, there is a potential expected gain from

international cooperation, where easily mobile firefighting resources such as water bombing airplanes are moved between nations. A general stochastic dynamic programming approach to adaptive moves of such resources is defined and suggested. General properties of the solution are derived. A particular version of the model is created and analytical derivations are performed. It is demonstrated that the expected objective function value, the expected present value of total costs, is a strictly increasing function of the fire correlation between nations. Adaptive moves of mobile resources between the regions IFPS and FGLNS have the advantage of negative correlations between these regions. Some adaptive moves can also be motivated within the regions even with positive correlations, thanks to the low costs of short moves.

#5. The average relative burned area has been studied, as a function of different conditions, in 29 countries. Detailed international statistics of forest fires, published by FAO and European Commission, are used as empirical data. A multivariate fire area function with empirically very convincing statistical properties is defined, tested, and estimated. A set of hypotheses was created based on three fundamental factors. The hypotheses could not be rejected on statistical grounds, and the estimated parameters obtained the expected signs with very low P-values. The residual analysis supports the selected functional form. Future fire areas are predicted for 29 countries, conditional on three alternative levels of global warming conditions. The estimated fire area function can explain the forest fire areas in different countries via three fundamental factors. Global warming is predicted to make future forest fire problems even more severe.

#6. Forests, sensitive to fires, cover large parts of our planet. Rational protection of forests against fires, forest fire management, is a very important topic area. Our planet is facing the serious problem of global warming. The probabilities of long dry periods and strong winds are increasing functions of a warmer climate. Heat, dry conditions and strong winds increase the probabilities that fires start. Furthermore, if a fire starts, the stronger winds make the fires spread more rapidly and the destruction increases. Under the influence of global warming, we may expect more severe problems in forestry caused by wild fires. For all of these reasons, it is essential to investigate and optimize the general principles of the combined forestry and wild fire management problem. In this process, we should integrate the infrastructure and the firefighting resources in the system as decision variables in the optimization problem. First, analytical methods are used to determine general results concerning how the optimal decisions are affected by increasing wind speed. The total system is analyzed with one dimensional optimization. Then, different combinations of decisions are optimized. The importance of optimal coordination is demonstrated. Finally, a particular numerical version of the optimization problem is constructed and studied. The main results, under the influence of global warming, are the following: In order to improve the expected total results, we should reduce the stock level in the forests, increase the level of fuel treatment, increase the capacity of firefighting resources and increase the density of the road network. The total expected present value of all activities in a forest region are reduced even if optimal adjustments are made. These results are derived via analytical optimization and comparative statics analysis. They have also been confirmed via a numerical nonlinear programming model where all decisions simultaneously are optimized.

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Biography of presenting author (should not exceed 100 words)

Professor Dr. Peter Lohmander focuses his research on optimization, optimal control and applications to decision problems in different sectors. Since 2015, Peter Lohmander is president of his own research company, Peter Lohmander Optimal Solutions. Optimization of real dynamic and stochastic decision problems, in particular via stochastic dynamic programming and stochastic dynamic control theory, has gained considerable attention in the research projects. Application areas are economics, natural resource management, forestry, logistics, global warming, bioenergy, the military and other areas. Peter Lohmander was full professor of forest management and economic optimization, SLU, faculty of forest sciences, Umea, Sweden, 2000 - 2015.

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