RATIONAL AND SUSTAINABLE UTILIZATION OF FOREST RESOURCES WITH CONSIDERATION OF RECREATION AND TOURISM, BIOENERGY, THE GLOBAL WARMING PROBLEM, PAPER PULP AND TIMBER PRODUCTION: - A MATHEMATICAL APPROACH

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Abstract:
Sustainable utilization of the forest resources of our planet is necessary for our survival. The resources can be used in many different ways, and for several purposes, that all are important to a sustainable world. This paper contains an optimization model that considers sustainability in the following dimensions: Recreation and tourism, a controllable climate, renewable bioenergy supply, supply of timber and pulpwood and economic profits. Forests can be managed in many different ways. In some countries, only continuous cover management is legal. In other countries, the law forces the forest owner to harvest all or nothing. Even with such constraints, there are many different ways to control the forest over time, dynamically changing the size and species structure. Forest management decisions influence the value of the forest for recreation and tourism and, at the same time, changes the flow of bioenergy, the flow of timber and pulpwood, the economic results and the effects on the global warming problem. The system optimization models defined in this paper make it apparent that new mathematical functions with empirical support are needed in several cases. For instance, it is important to determine parameters of mathematical functions that describe how the value of recreation is affected by the properties of the forest stands.

1. Rational coordination of the decisions in the forest industry, infrastructure, energy industry, recreation and tourism sectors, with consideration of climatic effects

Let the activities in the sectors “forestry and forest industry”, infrastructure, energy, and recreation (including tourism), be denoted F, I, E & R. We also consider the future climate C. A very general approach is to investigate the function $U = U(F, I, E, R, C)$ where U is the total utility as a function of all activities in the different sectors already described (possibly including even more sectors) and the climate. In general, C is affected by the activities in all sectors. Furthermore, dramatic changes in C influence the possible activities, and results of such activities, in all sectors. There are several strong links between all sectors. Let the present values of the profits in the sectors be denoted Π_F, Π_I, Π_E & Π_R. $\Pi = \Pi_F(F) + \Pi_I(I) + \Pi_E(E) + \Pi_R(R)$. One computationally feasible, but certainly not *completely* general, alternative to the very general problem of maximizing U is to try to maximize $W = \Pi(F,I,E,R) + \Phi(C(F,I,E,R))$, where Φ is a function describing the "direct" utility effects of the climate and where the climate, is a function of the activities in the different sectors. In the simplified approximation, we assume that the changes in C are close to zero and hence do not influence the present value function $\Pi(F,I,E,R)$.

Different optimization methods have different advantages and disadvantages, when they are applied to solve problems with long horizons and large numbers of dependencies. Lohmander (2007) presents some adaptive optimization approaches that are possible to use, in cases when the risk and/or uncertainty is relevant, considerable and important, and when processes such as the climate and the market prices can be described as stochastic Markov processes. The adaptive approaches, such as stochastic dynamic programming, however sooner or later, reach the upper dimensionality limit in problems with many dependent activities. In cases when the investigated systems include large numbers of dependent activities, linear and quadratic programming methods are usually the only computationally feasible approaches. Quadratic programming is more general than linear programming and can also handle quadratic approximations of nonlinear functions in a simple way, which is usually very relevant and important in problems of the kinds discussed in this paper. Hence, the best choice of optimization method is a function of the relative importance of these factors: Risk and uncertainty in the most relevant processes, the number of activities that have to be coordinated and the possibility to handle nonlinear functions.

Recent studies of optimal combinations of decisions in the forest and energy sectors with consideration of the global warming problem are found in ECOFOR (2008), IISD (2008) and in Lohmander (2008a & 2008b).

Decisions concerning the activities in the different sectors can be determined, and sometimes optimized, in several different ways. In different historical periods and in different parts of the world, alternative approaches have been used. There are several reasons for this. In some countries, the forests are owned and/or controlled via more or less detailed forest acts, by the governments. In other countries, large numbers of individual forest owners control the activities in the forests almost independently. Furthermore, large forests are owned and controlled by industrial companies that also own saw mills, pulp mills and paper mills. In some regions of the world, such as Sweden, energy corporations presently increase the use of biomass from forests. Such biomass can come from branches and tops (GROT), from stem wood of any dimension and from stumps. A preliminary plan for a global research programme with the title "Rational and sustainable international policy for the forest sector - with consideration of energy, global warming, risk, and regional development" is presented in Lohmander (2009d).

Below, six alternative ways to define the optimization problems with strong links to the forest resources are described. The optimal management activities in the forests are strongly dependent on how the optimization problems are defined. In general, the final results can be improved if the relevant links between the dependent sectors are consistently considered.

Johansson (1987) focuses on a general theory of environmental benefits. Such theories must however be integrated in the relevant and often complex and multidimensional resource management problems. Hull and Buhyoff (1986) is an example of the interest in explicit functions that describe how individuals like forests with different properties. The functions presented in that article are however not exactly the kind of functions that are needed in order to optimize the relevant multi sector problems where the forest plays a key role. The system optimization models defined in this paper make it apparent that new mathematical functions with empirical support are needed in several cases. For instance, it is important to determine parameters of mathematical functions that describe how the value of recreation is affected by the properties of the forest stands. It is necessary that these functions can be included in the relevant systems that we should optimize. For this reason, and since the most general problems with large dimensions should be possible to solve, nonlinear functions, in particular quadratic approximations, are recommended. Then, quadratic programming can be used to handle the large and relevant system that contains all of the sectors “forestry and forest industry”, infrastructure, energy, and recreation (including tourism).

1.1 Forest sector optimization

You maximize Π_F , the present value of the activities in the forest sector, including forest management and the forest products industry, selecting the decisions in this sector, F . The decisions must belong to the feasible set, S_F , which is a function of the parameters a , and the exogenous infrastructure, I_0 . $\Pi_F^* = \max_F \Pi_F(F) \quad s.t.\; F \in S_F(a, I_0)$

1.2 Forest sector and infrastructure optimization

Π_I , the present value of the infrastructure sector, is also considered in the objective function. The feasible set $S_{FI}(a)$ is less constrained than S_F with respect to F . Furthermore, the infrastructure decisions are optimized with consideration of both sectors. The optimal result based on this formulation is $\max_{F,I} \Pi_{FI} = \Pi_F(F) + \Pi_I(I) \quad s.t.\; (F, I) \in S_{FI}(a)$ Some ideas concerning optimal and coordinated expansion of the forest sector and infrastructure in Russian federation based on this approach are found in Lohmander (2009b & 2009c).

1.3 Forest sector, infrastructure and energy optimization

Now, also the energy sector activities are included in the problem definition. $\max_{F,I,E} \Pi_{FIE} = \Pi_F(F) + \Pi_I(I) + \Pi_E(E) \quad s.t.\; (F, I, E) \in S_{FIE}(a)$. Recent studies of optimal combinations of investment and production plans in the forest industry and energy industry sectors are reported by Lohmander (2009c).

1.4 Forest sector, infrastructure and energy optimization plus conditional free access recreation valuation

R_M is the recreation activity combination that is a consequence of free independent decisions by all “recreation actors” and the decisions in the other sectors and includes “wild” tourism. This does usually not maximize the present value of recreation. Here, the present value of the recreation sector is not considered when the decisions in the other sectors are optimized.

$$\Pi = \Pi_{FIE}^* + \Pi_R(R_M(a, F, I, E))$$

$$\Pi_{FIE}^* = \max_{F,I,E} \Pi_{FIE} = \Pi_F(F) + \Pi_I(I) + \Pi_E(E) \quad s.t.\; (F, I, E) \in S_{FIE}(a)$$

1.5 Forest sector, infrastructure, energy and conditional free access recreation optimization

Here, the present value of the recreation sector is considered when the decisions in the other sectors are optimized. However, it is still assumed that the recreation activities are consequence of free independent decisions by all actors.

$$\max_{F,I,E} \Pi = \Pi_F(F) + \Pi_I(I) + \Pi_E(E) + \Pi_R(R_M(a,F,I,E)) \quad s.t. \, (F,I,E) \in S_{FIE}(a)$$

1.6 Forest sector, infrastructure, energy and recreation optimization

Here, all sectors are considered and all decisions are optimized.

$$\max_{F,I,E,R} \Pi = \Pi_F(F) + \Pi_I(I) + \Pi_E(E) + \Pi_R(R) \quad s.t. \, (F,I,E,R) \in S(a)$$

Here, the R that is optimal with consideration of all sectors, replaces R_M.

2. Proof that wild tourism is not economically optimal

Here, a quadratic model of tourism in two areas is defined. Some numerical assumptions are made in order to illustrate a hypothetical case of relevance. It can easily be generalized to many areas and general parameter cases. We are interested in the total utility of tourism, U. n_1 and n_2 are the numbers of visitors in the areas 1 and 2. The total number of visitors is 20. (We can imagine that the visitors are counted in the unit "thousands of persons" or some other scale.) The utility of a visitor, visiting area 1, $u_1(n_1)$, is a decreasing function of the number of visitors to that area. The utility of a visitor, visiting area 2, $u_2(n_2)$, is assumed to be insensitive to the number of visitors to that area. This is clearly relevant but it is not the standard assumption in economics, when a "consumer surplus" is calculated. We may consider area 1 to be a sensitive area. With many visitors, the animals and vegetation get disturbed and the area is degraded.

$$U = u_1(n_1)n_1 + u_2(n_2)n_2$$

$$n_1 + n_2 = 20$$

$$u_1(n_1) = 200 - 20n_1$$

$$u_2(n_2) = 20$$

2.1. The case of free access ("Wild tourism")

With free access to both areas, every individual will independently select destination.

If $u_1(n_1) > u_2(n_2)$, n_1 increases and n_2 decreases until $u_1(n_1) = u_2(n_2)$.

If $u_1(n_1) < u_2(n_2)$, n_1 decreases and n_2 increases until $u_1(n_1) = u_2(n_2)$.

In spatial equilibrium, $u_1(n_1) = u_2(n_2) = 20$ and $U = 20*20 = 400$

and $\left[200 - 20n_1 = 20\right] \Rightarrow \left(n_1 = 9\right) \Rightarrow \left(n_2 = 11\right)$.

2.1. The case of optimally controlled tourism

$$\max_{n_1} U = u_1(n_1)n_1 + u_2(n_2(n_1))n_2(n_1)$$

$$\max_{n_1} U = (200 - 20n_1)n_1 + 20(20 - n_1)$$

$$\max_{n_1} U = 400 + 180n_1 - 20n_1^2$$

$$\left(\frac{dU}{dn_1} = 180 - 40n_1 = 0\right) \Rightarrow n_1 = 4.5$$

$\frac{d^2U}{dn_1^2} = -40 < 0$. Hence, the derived optimum will be a unique maximum.

$$U^* = \max_{n_1} U = 400 + 180n_1 - 20n_1^2 = 805$$

We conclude that the optimally controlled access to the sensitive area means that the number of visitors to that area should be 4.5. In the case of wild tourism, the number of visitors to that area will become 9. Furthermore, the free ("wild") tourism will give the total utility 400 and the optimally controlled access will give a total utility that is more than 100% higher, namely 805. Hence, wild tourism will not only degrade the environment but also reduce the potential total utility of recreation and tourism. Of course, with a suitable price system, substantial parts of the total utility can be transformed to profits and present values.

Conclusions

Sustainable utilization of the forest resources of our planet is necessary for our survival. The resources can be used in many different ways, and for several purposes, that all are important to a sustainable world. Forest management decisions influence the value of the forest for recreation and tourism and, at the same time, changes the flow of bioenergy, the flow of timber and pulpwood, the economic results and the effects on the global warming problem. For this reason, recreation and tourism should not be studied in isolation. They should, and can, be optimized as a part of the total system, with consideration also of "forestry and forest industry", infrastructure, energy and climate. The system optimization models defined in this paper make it apparent that new mathematical functions with empirical support are needed in several cases. For instance, it is important to determine parameters of mathematical functions that describe how the value of recreation is affected by the properties of the forest stands. Let our research move in this direction!

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