ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

OPERANDUM
OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks

Cost-Benefit Analysis of continuous cover forestry and buffer zones as Nature Based Solutions to preserve water quality level in Lake Puruvesi and in its sub-catchment area.

SUMMARY: This study focuses on evaluating the cost effectiveness of Continuous Cover Forestry (CCF) and buffer zones as Nature-Based solutions (NBS) in the study area of Lake Puruvesi. This cost-effectiveness is assessed within the framework of Cost-Benefit Analysis (CBA). Cost items from CCF were derived by constructing forest owners profit maximization problem. These costs were compared to recreation values that local residents, tourists and weekend home visitors obtain from the area. The resulting Net Social Benefits from the project were positive, and thus project should be recommended. However, there were large assumptions made regarding effectiveness of CCF and buffer zones as NBS, so one should treat this result cautiously, as more quantified research from the impacts is needed to justify the results.

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AIM OF THE STUDY:
The aim of the study was to evaluate economic performance of continuous cover forestry (CCF) and buffer zones as NBS to promote the water quality in the study site of Lake Puruvesi in Eastern Finland (Map 1.) and evaluate what kind of costs and benefits these NBS could impose to recreational visitors and forest owners. The main research question of this research is: Is it economically feasible to implement continuous cover forestry and buffer zones as nature-based solutions to mitigate nutrient loading in research area so that the water quality will stay at least at the current level in the future?

STUDY AREA:
Lake Puruvesi is part of Lake Saimaa and it is located in the eastern part of Finland between Southern Savonia and North Karelia. The water quality of the lake is generally good. The aim is to keep it at least on the current level and perhaps increase the quality in the parts where water quality is average/poor.

METHODS:
Main method of the study is Cost-benefit analysis where the aim is to monetize the costs and the benefits that NBS implementation will cause. If the net social benefits after analysis are positive, the project should be recommended.

BENEFITS:
In this study recreation values from the study site were obtained by utilizing pre-existing valuation studies made by Finnish Natural Resource Centre where the consumer surplus and visit frequency was divided between different user classes and water quality scenarios. (Fig.1) The consumer surplus for each visit and the visit frequency was adjusted with three different visitor (Map.2) scenarios to the lake which yielded annual benefits for each scenario.

COSTS:
Costs on the other hand were derived by using size-structured forest optimization model for the sample forest created to simulate the study area. The economic loss for forest owners is the difference between their optimal forest management choice, and the optimized solution, where clearcutting is restricted. In the buffer zone case optimization was similar but the costs from buffer zones are directly the maximized profits from forest as the buffer zone is completely left out from any forestry
Cost and benefit items were combined to obtain NPV for each visitor and water quality scenario. (Fig.2)

Figure 1. Recreation values. (Pouta et al., 2019)

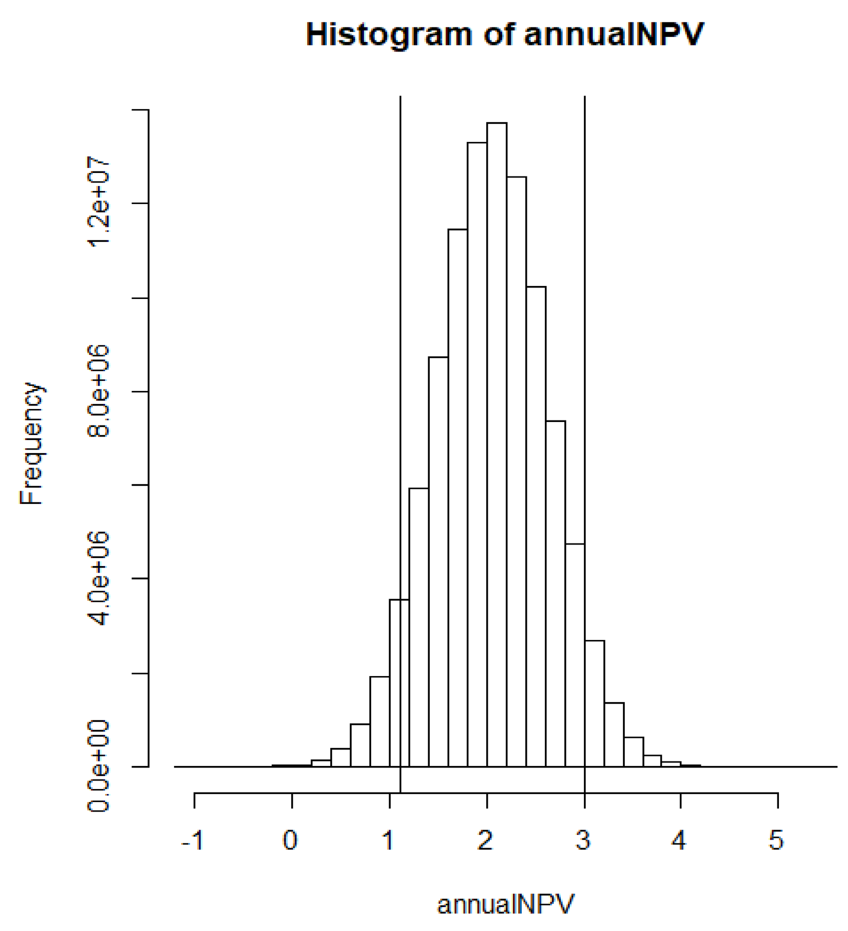
	Class 1			Class 2			Class 3				
								Cycling/ walking		Other	
	Visits per year	CS, €	Annual CS, €	Visits per year	CS, €	Annual CS, €	Visits, per year	CS, €	Annual CS, €	CS, €	Annual CS, €
Level A	43	110	4725	4	370	1481	217	5,2	1128	116	25231
Level B	39	110	4286	3	370	1111	209	5,2	1087	116	24300
Level C	28	110	3077	2	370	741	192	5,2	998	116	22323
Level D	18	110	1978	2	370	741	128	5,1	652	78	10000

	Scenario A	Scenario B	Scenario C	Scenario D
Water clarity	Over 8 meters	6 meters	4 meters	2 meters
Blue-green algal blooms	None	1–4 days	5–10 days	More than 10 days
Sliming	None	Slight	Some	Abundant
Quantity of reeds on the beach	None	Individual stems	Patchy	Abundant
Muddiness of the beach	No mud	Under 2 cm	3-10 cm	Over 10 cm

Figure 2 NPV for each water quality and visitor scenario.

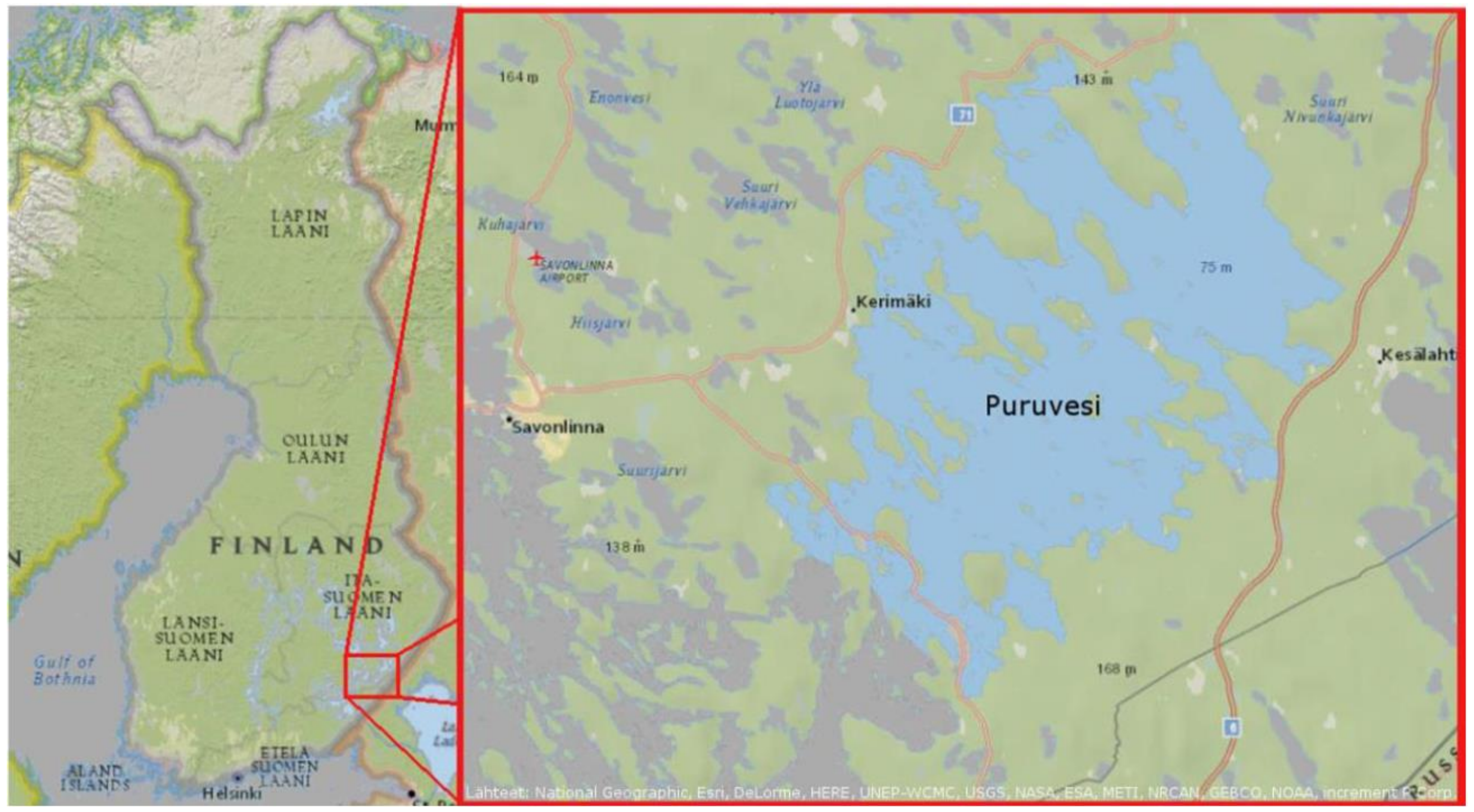
NPV				
Visitor scenario 1: Benefits from sub-catchment area of Kuonanjoki (€)			Costs	
Water quality scenario	Total annual CS (mil.€)	Perpetuity (mil.€)	Total costs (mil.€)	NPV (Million €)
A	1.81	60.39	0.90895884	59.48
B	1.59	53.12	0.90895884	52.21
C	1.18	39.35	0.90895884	38.44
D	0.83	27.93	0.90895884	27.02
Visitor scenario 2				
Scenario				
A	12.26	408.66	0.90895884	407.75
B	10.79	359.51	0.90895884	358.60
C	7.99	266.31	0.90895884	265.40
D	5.67	189.03	0.90895884	188.13
Visitor scenario 3				
Scenario				
A	18.81	626.86	0.90895884	625.95
B	16.54	551.47	0.90895884	550.57
C	12.26	408.51	0.90895884	407.60
D	8.70	289.97	0.90895884	289.06

Figure 3. Monte-Carlo simulation. (Pouta et al., 2019)

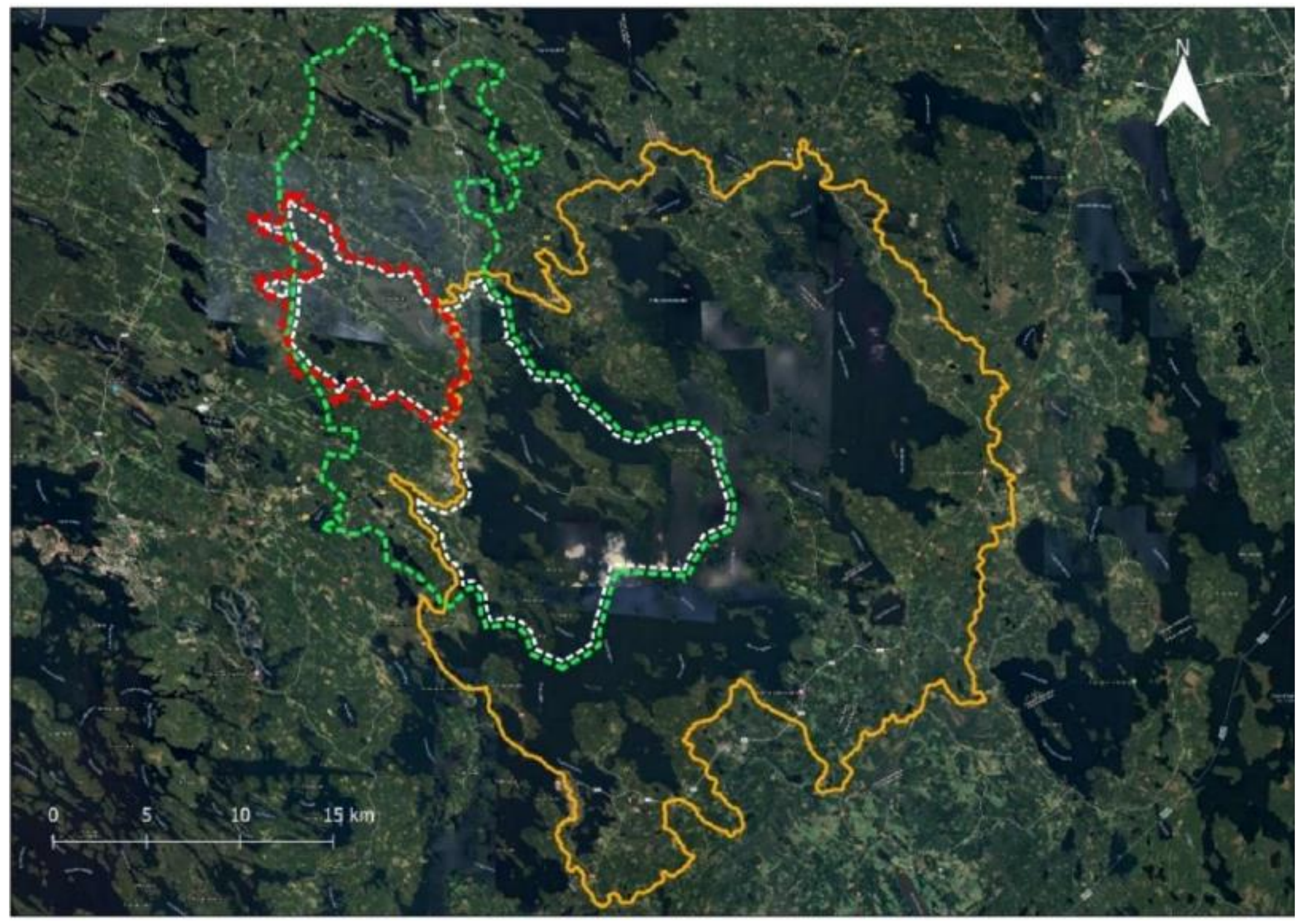


RESULTS AND CONCLUSIONS:
Uncertainty of the CBA was assessed by running Monte-Carlo simulation. Figure 3 shows the annual NPV that is generated, if the water quality changes from water quality scenario D to C. Simulation yielded mean of 2.052867 million euros for annual NPV with quantiles of 5% = 1.104241; 95% = 3.001261.

In both cases CCF was the optimal forest management regime for the sample forests. When these costs were compared to the benefits this study produced positive net social benefits and therefore CCF and buffer zones should be recommended as NBS in the study site. **However**, there are quite large assumptions made in this study regarding effectiveness of NBS, and further modelling of nutrient flow in study site is required. The real quantified impact of nutrient flow model is still under progress in OPERANDUM, and for this reason it is impossible to take the nutrient model within the scope of this thesis. This model can have an significant impact for the results of this thesis in the future, as currently impacts of NBS's are backed up by the findings of previous scientific literature, but the actual spatial, hydrological, geological and ecological interactions of the study site are still unclear. Therefore, the reader should interpret the resulting NPV and recommendation with this precaution in mind.



Map 1. Study area location (Tienhaara et al., 2018)



Map 2. Visitor scenarios: Scenario 1 = red line, Scenario 2 = white line, Scenario 3 = green line.