Short Versus Long-term Urban Planning Using Multi-objective Optimization

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ABSTRACT

In this paper, we consider the short-term versus long-term urban planning problem as a bi-objective optimization problem. Two conflicting objectives considered are (i) maximization of compact urban development and (ii) minimization of good quality agricultural soil. In such problems, decision-making becomes an important task, which we highlight. Such problems usually involve an astronomically large search space, which must be negotiated well by an optimization algorithm. In this paper, we discuss the importance of using optimization and decision-making procedures in urban planning task in Switzerland and a future paper will demonstrate the results obtained.

CCS CONCEPTS

•**Computing methodologies → Optimization algorithms;**

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1 INTRODUCTION

Globally large amounts of urban land are developed on land previously used for agriculture, which has far-reaching impacts on ecosystem services and the soilfis capacity for agricultural production [1, 2]. To reduce these impacts, it is possible to find urban patterns that are less detrimental to the environment [3]. However, identifying urban patterns that best preserve ecosystem services and at the same time include economic objectives like reducing infrastructure costs is a difficult task. The process in which urban planners try to identify urban patterns that might account best for several conflicting criteria, is usually called zoning. To support urban planners in the process of finding good solutions to such problems like optimal location of new building zones, a large variety of tools and approaches has been developed. Recently, a variety of studies has proposed to use multi-objective optimization in order to provide decision support in an a posteriori decision making process [4]. However, to our knowledge, there are no studies so far that deal with the problem whether to plan for shorter or longer periods considering that there is uncertainty in the demands for new urban areas.

In this study, we use a multi-objective optimization procedure to maximize compact urban development while minimizing the loss of good quality agricultural soils due to urban soil sealing. Reducing the loss of fertile agricultural soils while allowing compact urban development are two important aims of the Swiss planning legislation. As they are causing a strong trade-off [3], the results from a multi-objective optimization can provide decision-makers with a set of different options and information about the form of the Pareto Front (i.e., the trade-off), which may strongly enhance the decision-making process. However, we do not only optimize the urban pattern for just one scenario, but for several different scenarios in which we simulate short-and long-term urban planning.

2 METHODS

Our study areas were a small artificial landscape and the municipality of Uster, which is situated in the canton of Zrich in Switzerland. To solve our multi-objective optimization problem, we used the elitist Non-dominated Sorting Genetic Algorithm [NSGA-II, 5], due to its modularity, freedom from parameters and population approach. We modified the recombination and mutation operators to suit our specific optimization problem and implemented the algorithm using the python framework fiDistributed Evolutionary Algorithms in Pythonfi [DEAP, 6]. To simulate short-and long-term planning, we use the same optimization algorithm. However, we define different demands for new urban areas and apply a stepwise optimization procedure to simulate short-term planning. For both short-and long-term planning, the optimization starts based on the land-use pattern in 2010. For the stepwise short-term planning process, we optimize the allocation of new building zones from 2010 until 2030. From the obtained non-dominated front we select one pattern and use it as the new starting pattern for the optimization from 2030 until 2050. For each pattern selected from the non-dominated front produced for the year 2030, we produce a new non-dominated front in 2050. For the long-term planning process, we produce only one

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non-dominated front for the year 2050 as there is only one starting pattern, which is the one from 2010 and is based on the Swiss Area Statistics [7].

3 RESULTS AND DISCUSSIONS

Short-term urban planning can result in non-optimal solutions in comparison to long-term planning. This can happen due to the non-linear combinatorial nature of the problem. In contrast to the problem situation for the artificial landscape, we found that short-term planning didnfit result in non-optimal solutions when optimizing the urban pattern in the municipality of Uster in Switzerland. The most compact patterns resulting from the long-term simulations until 2050 and the short-term simulation until 2030/2050 are very similar. This indicates that short-term planning didnfit result in non-optimal solutions. Thus, urban planners could be recommended to develop a zoning plan for 2030 first and afterwards to create a second plan for 2050. If they would instead do only the zoning plan for 2050, they might designate too many agricultural cells to future urban areas (oversized zone), if the prediction on the demand for urban areas was overestimated. However, urban planners will try to avoid oversized zones because they often result in unforeseen and non-optimal urban patterns, as the allocation of urban areas within zones is strongly driven by economic factors and not accounting for externalities [8]. As short-term planning didnfit result in non-optimal solutions, the task of finding optimal patterns for the year 2050 could be split into smaller problems in order to reduce the computational effort. For example, when placing 212 new urban cells onto 1164 agricultural cells in the municipality of Uster, which corresponds to long-term planning, there are approximately $2(10)^{238}$ possibilities. However, when first allocating 106 new urban cells and doing more optimization runs, there are only approximately $6(10)^{152}$ possibilities. This means that the solution space could be reduced by a very large number of possibilities, which might result in better solutions within a smaller amount of search time. However, the spread of the non-dominated front simulating long-term planning is slightly larger than a combination of all the fronts from the short-term simulation is. This is rather surprising, as the genetic algorithm was dealing with a smaller solution space when performing the short-term simulations and would be expected to produce better results. A possible explanation is that we used many fewer generations when doing the short-term simulation.

The simulation of the short-term planning reveals that a chosen preference, expressed as the weight for the two objectives, strongly determines which solutions we are able to reach in the long run. Selecting a preference early will allow us to reach a wider range of solutions than when selecting the preference in a later stage . This could mean that if there is uncertainty about the right preferences, short-term planning may be more reasonable, as an early adjustment in preferences may have a larger effect than later adjustments.

4 CONCLUSIONS

In this study, we have considered an urban growth planning problem including two conflicting criteria: (i) compact urban development and (ii) reduction of loss of good quality agricultural soils. After formulating the resulting two-objective optimization problem, we have used an efficient modification to the existing NSGA-II procedure for the urban growth planning problem. In order to simulate short-term planning, we split the optimization task into two steps. Finally, we compared short- and long-term planning in order to give a recommendation to urban planners on the optimal length of a planning period.

For the artificial landscape we designed, long-term planning seems to be preferable over short-term urban planning. However, in contrast to that, we showed that short-term planning might be recommended for the urban planning problem in the municipality of Uster in Switzerland. The methodology we developed could help planners to identify the right planning horizons for a large variety of spatial planning problems.

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