**Critical Analysis: Collaborative geodesign and spatial optimization for fragmentation-free land allocation**

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An increase in food production to feed a growing population will have adverse effects on soil and water quality. Best land management practices (LMPs) of agricultural land ensures the right balance between food production and water conservation by imposing constraints on water quality. One of the important criteria for land allocation is to avoid fragmentation- a process of dividing a particular agricultural land area into irregular and small shapes that prevent the usage of modern farm equipment. This paper aims to introduce solutions to the fragmentation-free land allocation problem through elegant approaches. The major contributions of this paper are as follows: (1) impose shape constraints and spatial contiguity to avoid fragmentation and (2) consideration of stakeholder design while performing spatial optimization. This paper also proposes a solution to the problem through the amalgamation of automated technology of spatial optimization and human response in terms of stakeholder design.

Land allocation in itself remains a particularly unsolved problem as LMPs adopted by farmers are motivated by economic profit whereas those by environmental agencies are focused on improving the water quality causing conflicts. With the addition of fragmentation-free constraints, this problem is exacerbated. The current optimization approaches for land allocation only solve the subproblems of optimizing space partitioning or finding LMPs (through combinatorial optimization) but are unable to solve both simultaneously. Furthermore, these approaches disregard the requirement of geometric regularity that the patches should be of specific shape (eg. circular, rectangular) and spatial contiguity that patches should be at least large enough to accommodate modern agricultural machinery.

In order to solve the aforementioned problems, the current paper suggests three different frameworks namely collaborative geodesign, spatial optimization, and a hybrid of the first two approaches. In collaborative geodesign, stakeholders such as farmers and watershed managers share their knowledge and design landscape together by reducing conflict within the group to provide a better balance of environment conservation and food production. The designed collaborative geodesign system can perform geoprocessing and provide visualization services for effectiveness. On the other hand, spatial optimization is completely automated and is solved through integer programming under given patch size and shape constraints. Although this approach performs better in terms of water quality parameters, it does not account for qualitative information that is difficult to identify such as landowner preferences, cultural values and so on. A hybrid approach to integrate the aforementioned two approaches is also suggested where the solutions from spatial optimization are considered by stakeholders during the design procedure.

The key concepts behind these approaches are namely watershed, land management practices, profit and cost, and spatial constraints. Watershed is always defined with respect to a point of interest on the stream. Let’s say we are interested in the watershed of the Mississippi River at Saint Anthony Falls. The watershed of that point will be all the area that contributes water arriving at Saint Anthony Falls through the overland flow (a portion of precipitation flowing over the land surface). Land management practices (LMPs) refer to all the activities/practices that are adopted to manage a given piece of agricultural land. For example, for farming in hilly regions, farmers adopt terrace farming to make the best utilization of the water availability and reduce soil erosion of the fertile top layer. Profit is defined based on the linear combination of multiple ecosystem service objectives whereas cost mainly refers to economic losses due to food production decrease and investment in changing LMPs. Spatial constraints refer to all the constraints imposed to provide ease in farming. For example, spatial constraints of rectangular patches might be necessary to easily operate agricultural machinery in straight lines such as in the midwestern US, whereas in dry areas such as in Nevada with a shortage of water, circular patches are efficient to use the pivot irrigation system that is highly water-efficient. Another spatial constraint of size may be necessary to impose for efficient use of large machinery.

The efficiency of the first two approaches is quantified through a case study conducted on Seven Mile Creek watershed, 25000 acres watershed located in southwest Minnesota. Recent intensive farming conducted on this watershed led to degradation in water quality making it a suitable candidate for redesign. The objective of this case study was to determine the best LMPs on this watershed under a given budget constraint. The advantage of this study is that it provides a concrete ground for testing of the aforementioned approaches with an urgent need for finding the best LMPs. But this study is limited by the application of the problem on a simple watershed. The only used parameter to identify the water quality used in this study is the sediment load. However, other water quality parameters such as phosphorus and sulfate are neglected which can significantly affect the aquatic habitat. With the addition of multiple water quality parameters, the feasibility of stakeholder design is in question as it might take the stakeholder indefinite amount of time to come to a single decision/conclusion. Furthermore, the watershed used in the case study is medium-sized and a large agricultural watershed will create a problem for the presented approaches - especially the collaborative geodesign. The assumption that the final design will be reached through iterations of design and discussions by the stakeholder may not hold true for a complicated/large agricultural watershed.

We suggest following revisions to this article:

* FF-LA will intuitively favor big farms at expense of diversity. Is it possible to measure and include “maintaining diversity in farming” as a constraint in spatial optimization.
* The paper doesn’t seem to address two issues of subdivisions and scattering prevalent in rural farms.
* Terrain may inherently favor small fragmented farms over large consolidated farms e.g. stepped farming prevalent in mountainous regions of rural India. Should terrain be included as a constraint in spatial optimization ?