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Urban food crop production capacity and competition with the urban forest

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ABSTRACT

The sourcing of food plays a significant role in assessing the sustainability of a city, but it is unclear how much food a city can produce within its city limits. In this study, we propose a method for estimating the maximum food crop production capacity of a city and demonstrate the method in Seattle, WA USA by taking into account land use, the light environment, and a mix of food crops necessary to supply a year-round vegetarian diet. By artificially removing trees from the city, we estimate the effect of tree shading on food crop production capacity. We find that at maximum food production, urban food crops can produce between 1% and 4% of the city's food needs under the most realistic land use scenarios, and that tree shading reduces food crop production capacity between 19% and 35%. We expand beyond the city Seattle limits to find that a buffer of 58 km around the city is required to meet 100% of the city's food needs.

With more than more than fifty percent of the global population living in urban areas (United Nations Food and Agriculture Organization, 2011), there is a growing interest in the long - term sustainability of urban and peri-urban ways of living (Grimm et al., 2008). A core question regarding urban sustainability is the sourcing and long-term supply of food to support a large, dense population. Considerable research and public interest has been focused on the locality of the food in a city dweller's diet (Born and Purcell, 2006; SFUSA, n.d.; Feenstra, 1997) and the security of the food supply (Godfray et al., 2010; Kremer and DeLiberty, 2011); consequently, there is interest in the ability of individuals and collectives to produce food within an urban environment. This type of food production, referred to here as urban agriculture, may be able to increase the sustainability of cities. While urban agriculture can encompass a wide range of food production techniques, such as aquaculture, livestock, and insect production (United Nations Development Programme, 1996), in this paper we focus solely on plants that can be grown in soil for food.

Many factors affect the quantity and quality of the food produced within a city, ranging from the geography of a city to the socioeconomic status of its residents (Orsini et al., 2013; Martellozzo et al., 2014). The maximum food crop production capacity (MFCPC) of a city, though, is based on available growing space, abiotic factors such as light, nutrients, water, and suitable temperatures, and biotic factors such as the suite of crops grown. Thus, each city has a unique MFCPC that can help to determine to what degree urban agriculture can support the sustainability of that city. Several studies have focused on aspects of estimating MFCPC. Land that is currently used for urban agriculture has been mapped in Chicago (Taylor and Lovell, 2012), areas of grass and bare soil within residential parcels that may be suitable have been mapped in Philadelphia (Kremer and DeLiberty, 2011), the land area available for vegetable production has been assessed in New York City (Ackerman et al., 2014) and globally at the country level (Martellozzo et al., 2014), while regional food sheds have been modeled using different combinations of remote sensing and GIS both in terms of current food production capacity and MFCPC (Peters et al., 2009; Morrison et al., 2011; Giombolini et al., 2011). A case study of Cleveland, OH, USA estimated the proportion of the city's needs for vegetables, fruits, poultry, meat, and eggs that could be met through urban agricultural on vacant lots, residential lots, commercial lots, and rooftops, although it did not examine the total nutritional needs of the city (Grewal and Grewal, 2012). These studies suggest that a geospatial framework is needed to assess the available land base for food production within a city, but we suggest that increased complexity is needed to arrive at a more comprehensive assessment of MFCPC that incorporates a key abiotic factor, light, and locally suitable crops.

In this study, we describe a geospatial methodology for estimating MFCPC, with an application of the method in Seattle, WA USA. We use remotely sensed data and geospatial analysis to derive land use, assess the light environment by taking into account

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three-dimensional structure within the city, and develop a mix of crops adapted to local conditions that are needed to supply a complete vegetarian diet. By modeling the virtual removal of trees from the city using three-dimensional information derived from remote sensing, we estimate the effect of tree shading on food production capacity. In addition, we expand the extent of the analysis to areas surrounding Seattle to estimate the foodshed required to meet 100% of the nutritional needs of the population.

1. Methods

1.1. Study area

Seattle, WA has a 2010 population of 608,660, a land area of 217.2 km^2 (U.S. Census Bureau, 2010), and is bordered by Puget Sound to the west and Lake Washington to the east. Mixed conifer forest dominated land cover before European Settlement in the

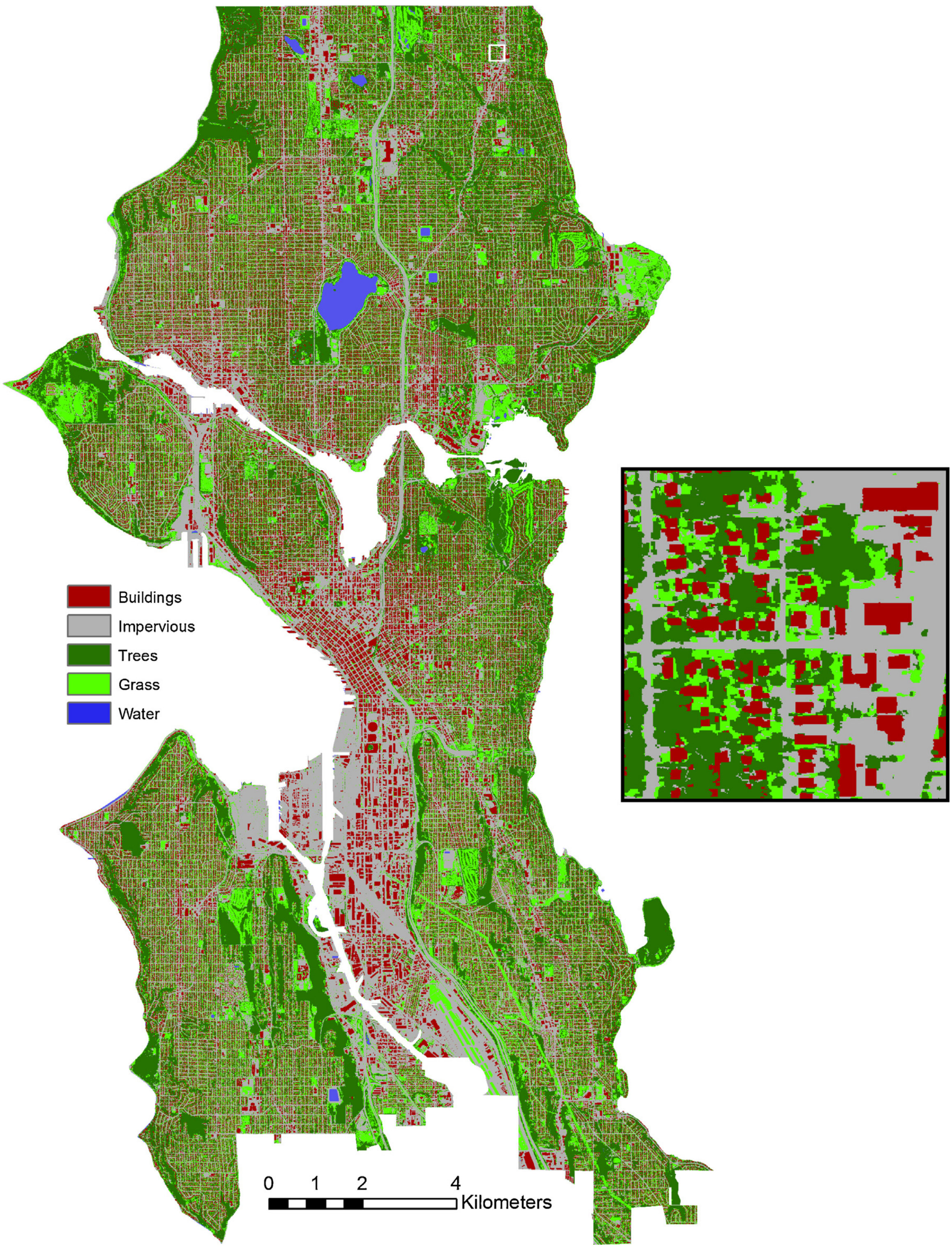

Fig. 1. Categorical raster of land use for Seattle, WA. The white box in the Northeast corresponds to the enlarged inset.