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# Assessing impervious area ratios of grid-based land use classifications on the example of an urban watershed

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**Abstract**

When applying a distributed hydrological model in urban watersheds, grid-based land use classification data with 10 m resolution are typically used in Japan. Land use classifications into 17 categories are made without taking into account their impermeable properties. Thus, for such a grid-based urban hydrological model, the estimation of the Impervious Area Ratio (IAR) of each land use classification is a crucial factor for accurate runoff analysis in urban watersheds. However, so far IAR of each classification is estimated very roughly and applied in the corresponding hydrologic models almost empirically. Thus in order to assess the IAR accurately, we created a set of vector-based “urban landscape GIS delineation” data for a typical urban watershed in Tokyo using detailed land use recognition, which exactly delineated the pervious and impervious features into 20 land use types in the watershed. These vector data are used to improve the impervious area depiction of grid-based land use classifications. By superimposing the vector-based delineation map on the grid-based map, the IAR of each grid-based land use classification was estimated with very little uncertainty, after calculating the IARs of all grid cells in the entire urban watershed. As a result, we were able to calculate the frequency distribution of IAR for each land use classification as well as the spatial distribution of IARs for the urban watershed.


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*Keywords:* impervious area ratio; grid-based hydrologic model; land use classification; urban landscape GIS delineation; urban watershed; 10 m resolution

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## 1. Introduction

From a process description point of view, watershed hydrological models for different purposes can be classified into lumped and distributed models (Singh, 1995 [1]). Distributed models take explicit account of the spatial variability of processes, inputs, boundary conditions and watershed characteristics. In most distributed models, raster-based approaches for land-use characterization using Digital Elevation Model (DEM) have been developed (e.g. SHE (Abbott et al., 1986 [2]), GSSHA (Downer & Ogden, 2004 [3]), PCRaster (Karssenberg et al., 2010 [4])). The advantages of grid-based distributed models are their simple model structure and their use of watershed information that is generally readily available. Because of these advantages, grid-based distributed models are widely used. Especially in urban applications, direct runoff in each grid cell is usually calculated based on estimated fractions of impervious area or estimated runoff coefficients in different land use categories (e.g. Niehoff et al., 2002 [5]; Choi & Ball, 2002 [6]; Park et al., 2008 [7]). The Impervious Area Ratio (IAR) is the most important index representing the direct runoff characteristic of grid-based hydrological models. A proper estimation of the IAR of a grid cell (or of each land use category) is therefore crucial for accurate runoff simulation in urban systems, with their high degree of imperviousness (Leopold, 1968 [8]).

In Japan, grid-based hydrological models typically utilize readily available "digital map information data" published by the Geospatial Information Authority of Japan. In metropolitan regions, grid-based land use classification data on 10-m resolution are generally used for urban watershed hydrological models as the only source of basic data. However, as these data were established for the purpose of city planning, the impermeable properties of the grid cells are not taken into account. Each 10-m resolution grid cell is assigned only one dominant land use classification out of the 17 categories. Then, the IAR of the grid cell is set automatically according to its land use classification. Even in a small 10 m × 10 m grid cell, however, there may exist a wide range of pervious and impervious features, especially in urban watersheds in Japan (Amaguchi et al., 2012 [9]). This makes it more difficult to accurately estimate the IAR of each land use classification, let alone estimate the IARs of all the grid cells in the entire watershed. So far, no papers/reports have been published on accurately estimating IARs for the land use classifications and for all grid cells in the target urban watershed, because no reference GIS data exist for that purpose in Japan.

A number of studies have been published during the past few decades that try to identify the impervious surface areas in urban watersheds using remote sensing techniques such as satellite imagery and/or aerial photos. These studies proposed various methods (e.g. Slonecker et al., 2001 [12]; Thomas et al., 2003 [13]; Yang, et al., 2003 [14]; Yuan et al., 2008 [15]; Weng, 2012 [16]; Sugg et al., 2014 [17]). However, their methodologies need the highly accurate and precise calibration and validation surface data (i.e. the ground truthing data) of the watershed to be compared with in order to assess their estimation errors. The IAR estimates of a target urban watershed by remote sensing data generally involve not a small uncertainty (Civaco et al., 2006 [18]; Chabaeva et al., 2009 [19]).

Furthermore, indirect assessments of impervious surface via remote sensing data can be reasonably robust, but these generally require a ground truthing level-of-effort similar to manual methods (Yang 2002 [20]).

On the other hand, the recent advances in GIS technology, as well as data availability, open up new possibilities concerning urban runoff modelling. A few non-raster-based models have been developed from an urban morphology viewpoint that allow consideration of individual features in the urban environment. In contrast to current modelling approaches, which are generally based on grid data (e.g. Hsu et al., 2000 [21]; Ettrich et al., 2005 [22]; Dey and Kamioka, 2007 [23]; Cuo et al., 2008 [24]), we proposed and developed a new approach to simulate urban storm runoff and flood inundation with a vector-based watershed description that exactly delineated the pervious and impervious land surface features for a typical urban watershed in Tokyo, Japan (Amaguchi et al., 2012 [9]). This urban watershed-based methodology employs so-called "urban landscape GIS delineation" that faithfully describes the complicated urban land use features in detail (see Section 2.3).

In this study, we focused on the uncertainty of a model parameter IAR involved in grid-based distributed models. In order to assess the IARs of grid-based land use classifications in an urban watershed, we created a set of vector-based "urban landscape GIS delineation" data for a sub-watershed of the Kanda River, a densely-populated typical urban watershed in Tokyo, Japan. Taking full advantage of the vector-based data that exactly delineate the pervious and impervious features into 20 land use types in the watershed, we accurately estimated the IAR of each grid-based land use classification with 10-m resolution for the first time in Japan, after assessing the IARs of all grid cells in the