論　文　の　内　容　の　要　旨

論文題目　Urban runoff quality modeling with elaborated land-cover identification by IKONOS satellite imagery
(IKONOS 衛星画像を利用した精緻な地表面特性解析に基づく都市雨天時汚濁流出モデル)

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As surface conditions provide essential information for runoff simulation on the rainfall loss which is mostly occurred in the process of interception, storage and infiltration during the rainfall event, it is important to classify properly the surface into several types with the basis on the types of rainfall loss. Especially, urban region is covered with various surface types, like road, roof, vegetation, soil. Moreover, these surfaces are intricately distributed with each other. Hijioka *et al*. (2001) carried out landcover classification for urban runoff simulation with the landuse information data of 10m grid. They classified urban surface into roof, road and pervious area. Although, they succeeded in the dynamic runoff simulation for five rainfall events, there was a little disagreement between observed and simulated runoff hydrograph in early part of rainfall event because detailed distribution and size of vegetation-covered area including roof garden, street plants and plant zone within building sites were not quantitatively taken into account. Hence, the detailed information on distribution and size of pervious surface is required to enhance the model accuracy for runoff analysis, especially for non-point pollutant behavior. Cowen *et al*. (1998) proposed that the medium-scale image of which resolution is 1 to 5m need to be acquired in urban regions for interpretation of the landuse/landcover classification level III specified by the United States Geological Survey (USGS).

This study was conducted in being divided into three subparts to achieve the principal objective of the study which is to propose the robust method for improving the urban-runoff quality modeling based on accurate classification of pervious and impervious area.

The first subpart is to develop the accurate identification method of plant-covered area in urban region using high-resolution IKONOS satellite imagery. In this study, enhanced identification method of vegetation-covered area was investigated to overcome two limitations in the application of NDVI-based method to urban region, which were overestimation of vegetation area and misidentification of blue/green colored roofs. Being satisfied with accurate identification of vegetation and exclusion of other landcover, e.g. roof, road and soil, Urban Vegetation Index (UVI) was derived from reflectance properties of vegetation among visible red, green and near infrared ray band of IKONOS satellite imagery. The USVI is expressed as follows

$$USVI = (NIR\text{-}Green) / (NIR\text{-}Red) \quad (1)$$

Where, NIR, Red and Green represent the reflectance at near-infrared, visible red and visible green band, respectively. Vegetation area can be determined in the range of $0<USVI<1$ on the precondition of $NDVI>0$. Then the effectiveness of UVI for vegetation identification was verified by six ground truth data in terms of width and area (size) of identified vegetation. Finally, we achieved both high identification accuracy of urban vegetation and successful exclusion of green/blue colored roof through the application of UVI to the study area

The second subpart is to develop the separation method of grass area from entire plant-covered area because there are different rainfall loss/pollutant washoff pattern between grass and tree. This method was also derived from reflectance analysis with four multi spectral bands in IKONOS satellite imagery. As the value of (Green-Blue) showed remarkable contrast between shrubby and tree group, the dimensionless algebraic formula using relationship between (Green-Blue) and (NIR-Red) was proposed as the tree/shrubby separation method as follows;

$$Eq1 = (Green\text{-}Blue) / (NIR\text{-}Red) \quad (2)$$

where, Green, Blue, Red and NIR represent the reflectance at visible green, blue, red and near-infrared, respectively. This equation can be used in precondition of $0 < UVI <1$ as criterion of plant-covered area. Tree and shrubby area in whole plant-covered area identified with UVI can be separated in the range of $Eq1> 0.1$ and $Eq1 \leqq 0.1$, respectively.

Finally, runoff quality simulation was carried out using the advanced landuse parameters which were estimated with methods proposed in subpart 1 and 2 above. We could find out the different washoff pattern in two models of which landuse parameters were estimated from traditional and advanced landuse classification layers, respectively.

(地表面の状態を把握することは雨水流出解析において有効降雨を算定するために重要な情報を提供することから､地表面を雨水損失能によるいくつかの種類で適切に分類することは重要な課題である． 特に， 都市部は多様な土地利用と共に，これらの地表面は複雑に分布している．Hijiokaら(2001)は都市流出解析において 10m メッシュの詳細土地利用情報を利用して地表面を屋根,道路,不浸透面で三分類した報告を行っている．五つの観測降雨データに対し，精度高い流出解析が可能であったものの，都市内に分布する多様な浸透面,例えば屋上庭園，街路樹などの面積や分布を考慮することができなかったため，降雨強度の弱い雨降初期において，観測流量とシミュレーション流量が若干合わない部分が見られた．ノンポイント汚染源の流出及び挙動解析のためには弱い雨降に対する流出解析の精度を高める必要があり，そのため浸透域の精度高い算定が重要と判断される．Cowenら(1998)は都市内詳細構造を把握するためには 1mから 5m精度の解像度を持つ画像データが必要だと提案した．

本論文は小降雨時におけるノンポイント汚染源の精度高い流出解析のため，都市内詳細土地利用の分類方法を提案する目標を果たすため，以下に示す三つのsubpartに分けて構成された．

はじめに，都市内の重要な浸透域としての植生を正確に算定することである.衛星画像を利用した植生抽出方法の中で,もっとも一般的な正規化植生指数(NDVI)の都市部への適用において植生の過大算定や緑/青色の屋根まで植生として分類される限界を解決するため，新

たな植生域の抽出方法を提案した. IKONOS 衛星画像の赤,請,緑,近赤外の四つのバンド情報を利用して植生の分光特性を分析し,その特性から都市植生指数(UVI)を開発した.

$$USVI = (NIR-Green) / (NIR-Red) \qquad (1)$$

ここで, NIR, Red, Greenはそれぞれのバンドでの反射率である. 上記の式(1)を用い, 植生域はNDVI>0 を前提条件にして0<USVI<1として抽出可能である. UVIの精度検証は 6種のグラウンドトルス情報を利用して行った. UVIを利用した都市植生抽出は精度高い植生抽出が可能であり, NDVIの都市部への適用において問題であった緑/青色の屋根も除外することが可能になった.

次に, 全体の植生域を異なる雨水流出パターンを持つとされる芝や木グループで分類することである. 方法は植生抽出方法の開発と同様の流れで, IKONOS 衛星画像での二つのグループの分光特性を用いて提案した.6種の分光組合の中で (G-B)の関係で芝と木の異なる分布特性に着目し, 以下のような木と芝の分類のための式(2)を提案した.

$$Eq1 = (Green-Blue) / (NIR-Red) \qquad (2)$$

ここで, Green, Blue, Red, NIRはそれぞれのバンドでの反射率である. この式は植生の抽出条件である0 < UVI <1 を満足する植生域に対して適用され, 木と芝はEq1> 0.1 と Eq1 ≦0.1でそれぞれを区別した.

最後には新たに提案した都市部における土地利用分類方法を利用してノンポイント汚染物質の流出解析を行った. 従来の土地利用分類方法と本研究で提案した土地利用分類方法を利用した都市ノンポイント流出解析において異なる流出パターンが得られた.)