Development of Software to Estimate Representative Surface Roughness Length in Korea

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1. Introduction

The surface of the earth can be comprised of various surface type such as bare land, forest, urban, waters and etc. Characteristics of land cover can be characterized by surface roughness and it is expressed by surface roughness length (z_0) or aerodynamic roughness length (z_0) mathematically. When performing off-site consequence analysis, surface roughness is one of the important factors as it influences on both atmospheric dispersion and deposition of radionuclides.

Gaussian plume model is the most frequently used for off-site consequence analysis as well as for many other areas. Typically, one representative value of surface roughness length can be an input and be used for the calculation of atmospheric dispersion and deposition for the whole region.

Vertical dispersion of atmosphere is expressed by vertical dispersion parameter (σ_z) when Gaussian plume model is used. Surface roughness influences on vertical dispersion following Eq. 1 [1].

$$\sigma_z = \sigma_{z,P-G}\left(\frac{z_0}{z_{0,P-G}}\right)^{0.2} \qquad (1)$$

Where
- σ_z: vertical dispersion parameter scaled accounting actual surface roughness length
- $\sigma_{z,P-G}$: vertical dispersion parameter of Pasquill-Gifford formulation
- z_0: actual surface roughness length
- $z_{0,P-G}$: surface roughness length of prairie grass (3 cm)

Dry deposition is characterized by dry deposition velocity (v_d) and surface roughness affects to dry deposition velocity by Eq. 2 [2].

$$\ln(v_d) = a + b(\ln d_p) + \mathrm{c}(\ln d_p)^2 + \mathrm{d}(\ln d_p)^3 + e \cdot z_0 + f \cdot V \qquad (2)$$

Where
- v_d: dry deposition velocity
- d_p: aerodynamic particle diameter
- z_0: surface roughness length
- V: wind velocity

Korea has complex topography because diverse types of surface such as mountains, urban area with high population density, agricultural area are mixed in small area relatively. However, default value of surface roughness length such as 10 cm was typically used without regarding complex terrain in Korea. Even though, it can be easily regarded that Korean NPP site has higher surface roughness length than default value which was originated from US NPP sites, there exists no method and tool to calculate the representative surface roughness length in Korea.

Accordingly, estimation of representative surface roughness is very important pre-process for off-site consequence analysis especially for the Korean site which is comprised of complex terrain. In this study, method and tool to estimate representative surface roughness length in Korea were developed.

2. Methods and Results

Area-weighted average was employed to calculate representative surface roughness length.

$$\frac{\sum_i (z_{0,i} \times a_i)}{\sum_i a_i} \qquad (3)$$

- $z_{0,i}$: surface roughness length of grid *i*
- a_i: area of grid *i*

Program comprising input module, calculation module and map drawing module was developed by using C# and C++ as programing languages. This program can be installed and used for PC installing Microsoft Windows 7 or upper version as an operating system.

Input and results can be managed by project save and load function. Fig. 2 shows main window of the program.

2.1. Input Module

2.1.1. Site location and coordinate conversion

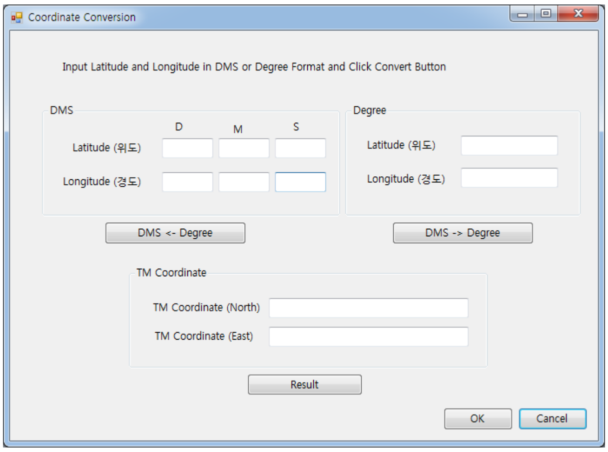

Fig. 1. Coordinate conversion tool

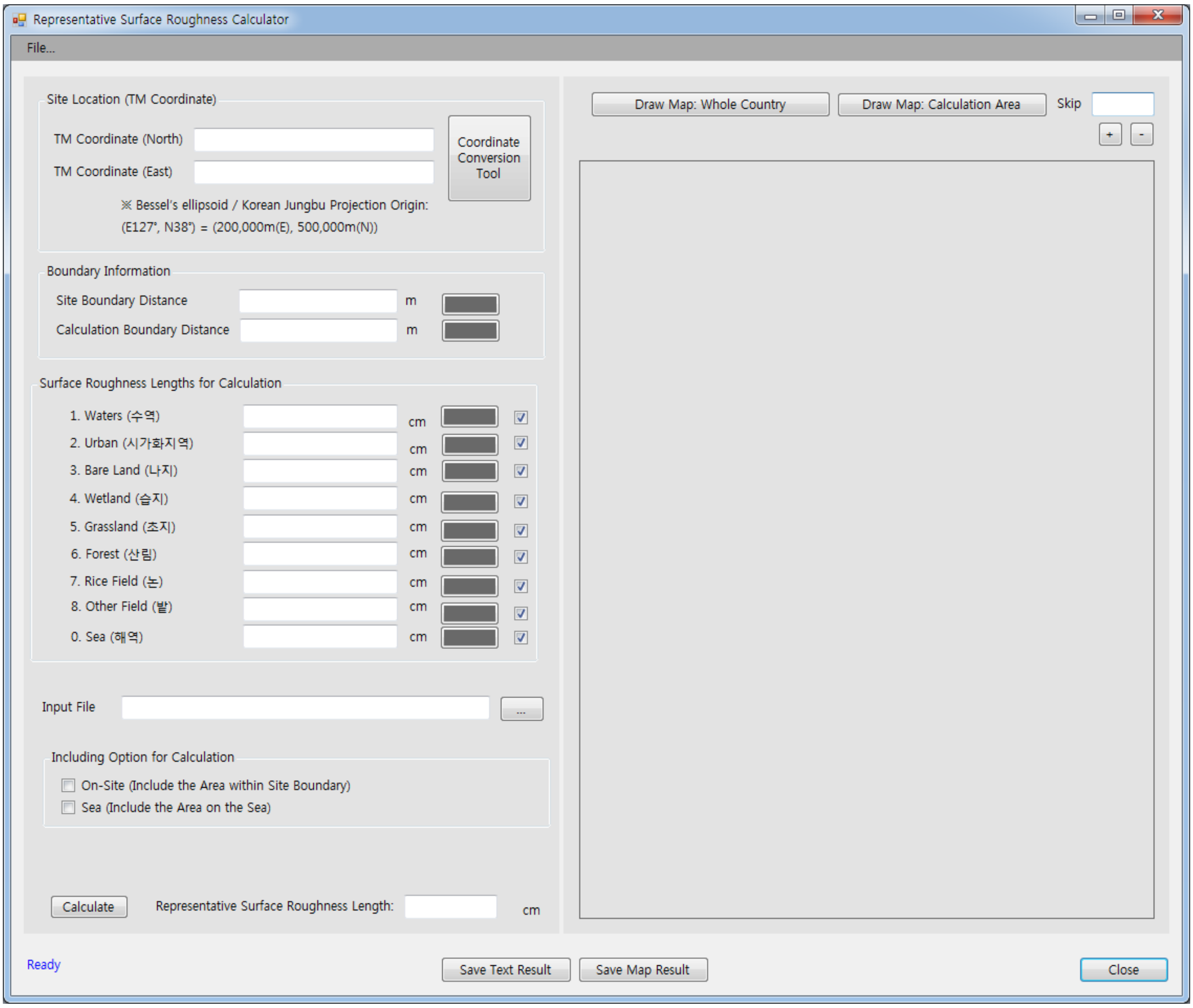

Fig. 2. Main window of the program

TM (Transverse Mercator) coordinate using Bessel's ellipsoid and Korean Jungbu projection origin was employed to handle the location of site and data. As latitude and longitude can be more familiar to users, coordinate conversion tool from latitude and longitude to TM coordinate was prepared following Standard Work Instruction for Converting Coordinate System of 1/1000 Digital Map [3]. User interface of coordinate conversion tool is presented in Fig. 1. Both DMS (degree-minute-second) and degree format of latitude and longitude can be input and be converted into each other and TM coordinate.

2.1.2. Boundary information

Program is designed to input both calculation boundary and site boundary. Decision of calculation boundary is necessary as only data within calculation boundary is included to calculate representative surface roughness length. Excluding the data within site boundary can be reasonable in some cases because on-site area is not the region of interest when performing off-site consequence analysis.

2.1.3. Surface roughness lengths

This program is designed to use eight land cover codes. Raw data should be categorized by land cover codes following below definition:

1) Waters
2) Urban
3) Bare Land
4) Waterland
5) Grassland
6) Forest
7) Rice Field
8) Other Field

User can input surface roughness length for each land cover code. Input of corresponding surface roughness length is matched to land cover code and used for calculation. The number of categories can be easily changed and updated when it is needed in the future.

2.1.4. Including option for calculation

As mentioned in Section 2.1.2, it is possible that user wants to exclude data inside site boundary to calculate representative surface roughness length for off-site consequence analysis. By clicking check box, user can easily choose whether including the data within site boundary for calculation or not.

In addition, including sea area can be a consideration for calculation. In order to deal with surface roughness of the sea, new land cover code (code number zero) was added for the sea.

0) Sea

User can assign the surface roughness length of the see by input and include or exclude sea area for calculation by checking checkbox when see area exists within calculation boundary.

2.2. Calculation Module

Code calculates representative surface roughness length by using user input and area-weighted average. In addition, code also performs simple statistical analysis such as counting each land cover code used for calculation and analyzing their fractions. User can save and read the analysis results by clicking "Saving Text Result" button.

2.3. Map Drawing Module

Map drawing module has two options. The first option is drawing map of whole country and the second option is drawing map of calculation area.

User can freely assign color to each land cover code and each color of land cover can be expressed on the map. User also can select land cover code to draw on the map by using checkbox. Fig. 3 shows examples of map result including only Waters and Urban (code 1 + code 2) individually and together respectively.

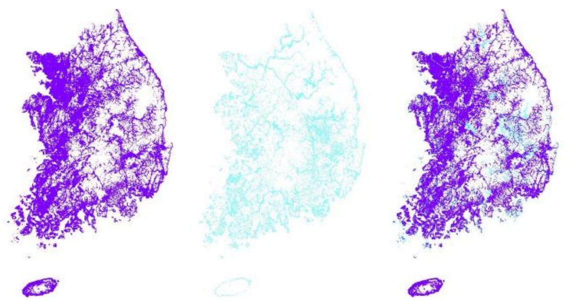

Fig. 3. Example map results including only urban area, waters, and both urban and waters (from left to right)

As raw data for testing is comprised of Korean land cover data with the resolution of 30m ×30m and eight kinds of land cover code, it costed lots of computing resources. Therefore, C++ was employed as supporting programing language additional to C# and skip option was also added. Skip option is skipping the data to draw map following the number input by user. If user input 100 for the skip option, next 100^{th} data is used for drawing map after skipping 99 data. User can input 1 in order to use every raw data. Two problems related with high resolution and huge size of raw data can be overcome by adding skipping option:

- Drawing time can be reduced,
- Map expression of overlapping eight surface roughness can be recognizable. Without skip option, drawing a land cover code overlaps and covers previous land cover code, and previous code becomes invisible. This phenomena does not appear in case of coarse grid, but it appears and becomes worse when raw data is very dense such as 30m ×30m grid for whole country. Fig. 4 shows the visibility by changing the number of skipping option when raw data is very dense. As program drew forest first and then draw rice field in this example, forest is covered by rice field after drawing rice field due to very high data resolution than the pixel of PC monitor.

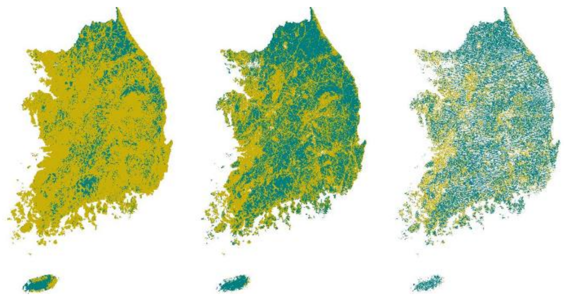

Fig. 4. Example map results including rice field (yellow) and forest (green) with skipping option 1, 100, and 500 (from left to right)

Regardless of skipping option, code include every raw data within calculation boundary for calculation of representative surface roughness length.

2.4. Validation and Verification of Code

2.4.1. Does code select appropriate data within calculation boundary?

As code provides the list of extracted data from raw data for calculation as a text file, user can check and confirm whether appropriate data was extracted and used. Moreover, by using the option of drawing map within calculation boundary explained in Section 2.3, code shows the region for the calculation graphically as described in Fig 5. Blue line is calculation boundary and red line is site boundary. User can change the line color of each boundary as well.

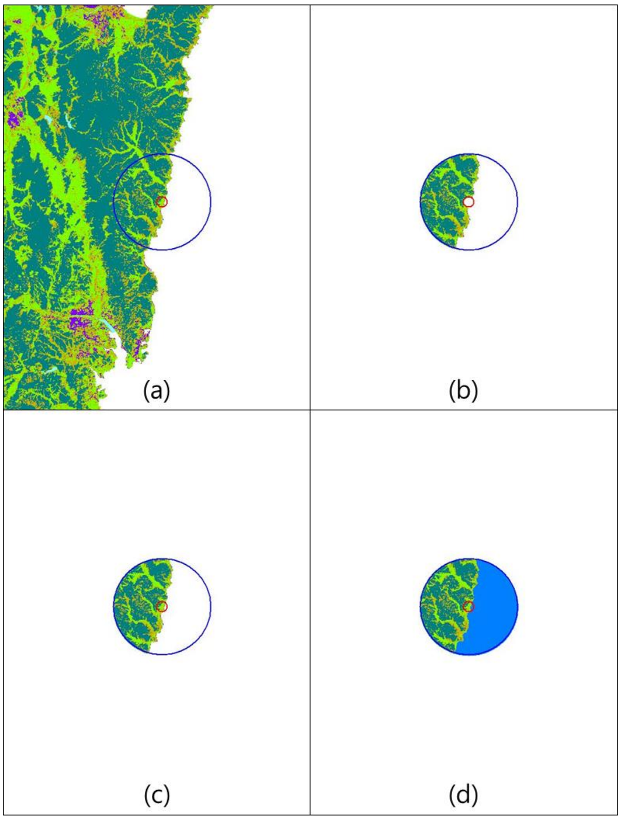

Fig. 5. Example map result using (a) "Draw Map: Whole Country" option (b) "Draw Map: Calculation Area" option without checking on-site (c) "Draw Map: Calculation Area" option with checking on-site (d) "Draw Map: Calculation Area" option with checking on-site and sea

2.4.2. Does code calculate accurate average?

Usually, grid size of raw data is identical for every grid. By using selected data inside calculation boundary, user can hand-calculated average surface roughness length by counting the number of each land cover code and compare it to confirm that calculation is correct.

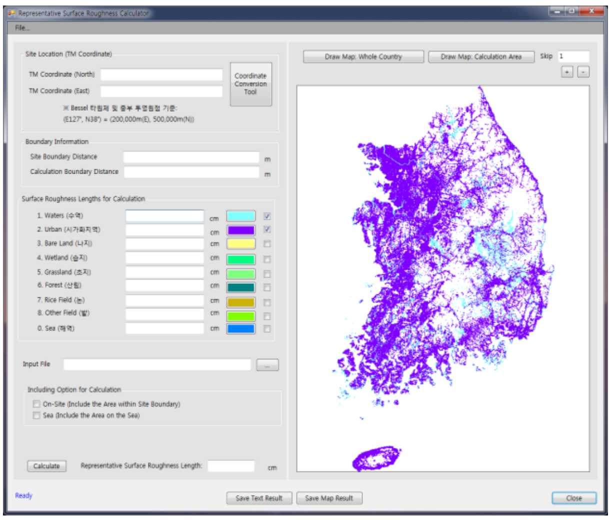

Fig. 6. Example window of developed program (checking only land cover code 1 and 2 with skipping option 1)

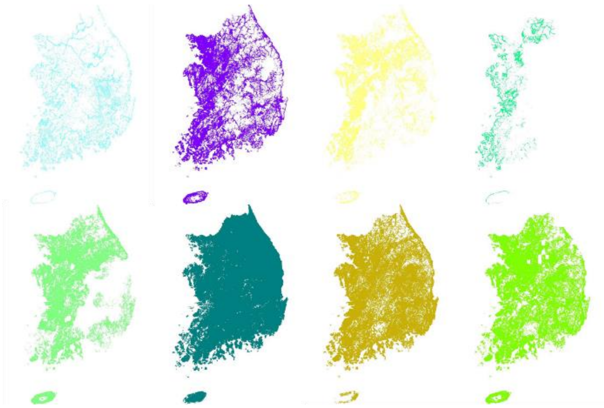

Fig. 7. Example map results of each land cover code with skipping option 1 (=without skipping) (from left to right and top to bottom)

3. Conclusions

In this study, method and tool for calculating representative surface roughness length was developed. It is expected that, this software can be used to estimate the representative surface roughness of each NPP site in Korea. Furthermore, using the representative surface roughness rather than default value which was originated from US NPP sites can reduce uncertainty and enable more realistic off-site consequence analysis for Korean NPP sites because surface roughness is one of very important factor which affects to both atmospheric dispersion and surface deposition.

From follow-up study using this tool, it was found that applying surface roughness of Korean complex terrain is influential to results of off-site consequence analysis.

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