GEOGRAPHICAL REPORTS
OF TOKYO METROPOLITAN UNIVERSITY 57 (2022) 79–85

PROTOTYPE OF AN ASSESSMENT SYSTEM FOR VINEYARD SUITABILITY

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Abstract Currently, various types of geospatial data are provided as open data and/or map tile data. This implies that geospatial data have become more barrier-free than older data with traditional licenses and formats. In this study, using open geospatial data, we developed a map algebra system usable with a web browser for evaluating areas suitable for vineyards. We selected Nagano Prefecture as the research area for testing the system where many farmers recently started viticulture. The data used in the system are geology, soil, slope gradient, slope aspect, annual mean temperature, and annual mean maximum and minimum temperatures. These data were converted to the Data Tile Map format, which was developed by The Geological Survey of Japan, AIST (National Institute of Advanced Industrial Science and Technology), Japan. FOSS4G (Free and Open Source Software for Geospatial) tools, such as QGIS, TileMill, and MBUtil were used to prepare the data tiles. Map Algebra functions were implemented using the WebGL™ API (Application Programming Interface). The system was published in Github.

Keywords: Vineyard Suitable Area, Data Tile Map, WebGL, FOSS4G (Free and Open Source Software for Geospatial)

1. Introduction

Traditional agriculture in Japan emphasized *Tekichi-Tekisaku* (right crop for right place), which means to produce crops as per the local environment. Katsue Misawa, who was a geographer and high school teacher in Nagano Prefecture before World War II, defined industries suited to the local climate and topography as *Fuudo Sangyou* (industry based on natural features) and encouraged them, especially in agriculture (Misawa, 1941). Practicing agriculture as *Fuudo Sangyou* is becoming increasingly important in Japan in the 21st century. About 40% of Japan's agriculture is carried out in mountainous regions where large-scale management is difficult. Additionally, the problems of an aging and declining population and increase in abandoned land in rural areas are particularly serious. Therefore, enabling *Fuudo Sangyou* in the field of agriculture based on cultivation of the right crops on the right land is expected to ensure sustainable use of rural areas and contribute to regional revitalization.

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There have been attempts to assess the suitability of agricultural fields for crop production applying Geographic Information Systems (GIS), which became popular in the late 1980s. For example, Kato (1988) made a suitability map of vineyards based on the combination of soil categories and regional climatic conditions in Yamanashi Prefecture, Japan.

Despite these efforts, suitable site evaluation of vineyards has not been fully disseminated due to the lack of the following components: (1) sufficient quality, quantity, and accurate information necessary to determine the suitable site; (2) appropriate criteria for evaluating suitable sites based on the information, and (3) methods for providing evaluation results to consumers, such as new farmers. To revitalize *Fuudo Sangyou* in mountainous regions, it is necessary to solve these problems.

When the quality and quantity of crops, as well as the price of the products, depend on the natural environment, the benefits of *Tekichi-Tekisaku* become more significant. One of such crop is wine grape. As there are about 10,000 varieties of *V. vinifera,* and the suitable environment for each variety differs, there has been a long tradition of *Tekichi-Tekisaku* for wine-grape production. In other words, each wine-grape variety is cultivated under suitable conditions in terms of climate, weather, temperature, solar radiation, precipitation, wind, geology, soil, and topography. This has also led to the establishment of "Terroir," which is a unique concept of viticulture. In recent years, "Japan Wine," made exclusively from grapes grown in Japan, has been gaining international recognition, and new wineries in Japan are also increasing. Thus, there is an urgent need to provide information to support the selection of appropriate vineyard sites and grape varieties, and promote *Tekichi-Tekisaku*.

GIS effectively evaluates suitability of lands for vineyards, especially using the map algebra function (Kato, 1988). In recent years, various types of environmental information, which are required for suitability assessment, have been available as open data and are becoming easier to obtain. Additionally, Free and Open Source Software for Geospatial (FOSS4G), such as QGIS, has become popular and easier to use. However, it is still difficult for most new farmers to prepare various types of data necessary for evaluating the suitability of land and develop suitable site-evaluation methods.

Therefore, we developed a system that enables new farmers to evaluate suitable sites for vineyards without using any GIS skills, and contributes to the establishment of *Smart Fuudo Sangyou*, which is a data-driven agricultural practice utilizing newer information and communication technology (ICT) tools and methods, such as artificial intelligence and sensor networks. We report the development of a prototype of an assessment system for the suitability of vineyards using only a web browser without any special skills and specific software.

2. Development of the vineyard suitability assessment system

Preparation of Data Tile Maps for suitability assessment

A variety of environmental information is required for assessing vineyard suitability. In this report, we converted spatial information about geology, soils, topography, and meteorology, which is available as open data, to the format of Data Tile Map for suitability assessment. Data Tile Map is a data format developed by the Geological Survey of Japan (GSJ), the National Institute of Advanced Industrial Science and Technology (AIST). This format provides data in the PNG format which allows us to retain numerical attributes, such as temperature, elevation, and geological classification. It is also possible to develop web applications with good responsiveness

to user requests and promote diverse data use (Nishioka, 2019).

Table 1 shows the original data that were used to create the map set of Data Tile Map. The geological data tile map was created as PNG Palette Tile by directly obtaining data from the Seamless Geological Map of Japan at the scale of 1:200,000 disseminated by the GSJ, AIST. The Soil Data Tile Map was obtained as the shape file format from the Japan Soil Inventory published by the Institute for Agro-Environmental Sciences, NARO (NIAES) and converted to PNG Palette Tile with FOSS4G tools, such as QGIS, TileMill, and MBUtil. For the topographic data tile map, we obtained the PNG Elevation Tiles from the GSI Tiles provided by the Geospatial Information Authority of Japan (GSI) and converted to a PNG Numerical Tile of slope angle and slope direction. The meteorological data tile containing annual mean temperature and mean minimum and maximum temperatures was created from the Japanese Standard Grid Meteoritical Data published by the NIAES (Sudo et al., 2010).

Table 1 Data categories and source to create Data Tile Map for vineyards' suitability assessment

Category	Source	Description
Geology	1/200K Seamless Digital Geological Map of Japan, Geological Survey of Japan, AIST	
Soil	1/50K Digital Map of Cultivated Soil in Japan, Japan Soil Inventory, NARO	
Topography	PNG Elevation Tile, GSI Tiles, GSI	Calculate slope gradient and direction
Meteorology	NIAES Basic Grid Square Meteorological Data	Calculate annual mean temperature, and annual mean maximum and minimum temperatures

Development of map algebra functions of data tile maps using the WebGL™ and WebGIS interface

WebGL™ is a cross-platform, open web standard JavaScript API (Application Programming Interface) for 2D and 3D graphics in modern web browsers that allows the GPU (Graphics Processing Unit) -accelerated usage of image processing without the use of plug-ins. In the vineyard suitability assessment system, we used the GPU acceleration capability for the map algebra functions. We implemented the following functions:

1) Generate assessment values from a data tile map layer by performing quadrature calculations, specifying the order of operations using parentheses, and classification based on logical operation formulae.
2) Comprehensive assessment function that performs quadratic calculation, specifies the order of operations using parentheses, and classification based on logical operation formulae between the layers generated by the above procedure.
3) Vineyard suitability visualize function based on the comprehensive assessment.

The formulae used in each evaluation and visualization process can be inputted when the target data tile layer is selected. It is also possible to input formulae prepared as samples. The interface of the WebGIS was developed using Leaflet, which has a graphical interface to input map algebra

formulae and a function to display and export the image of vineyard suitability based on the comprehensive assessment result described above.

Demonstration site of the vineyard suitability assessment system and its usage

A prototype of the vineyard suitability assessment system is available in the following URL: https://wata909.github.io/web-map-algebra/index_e.html . Fig. 1 shows the startup screen of the prototype system.

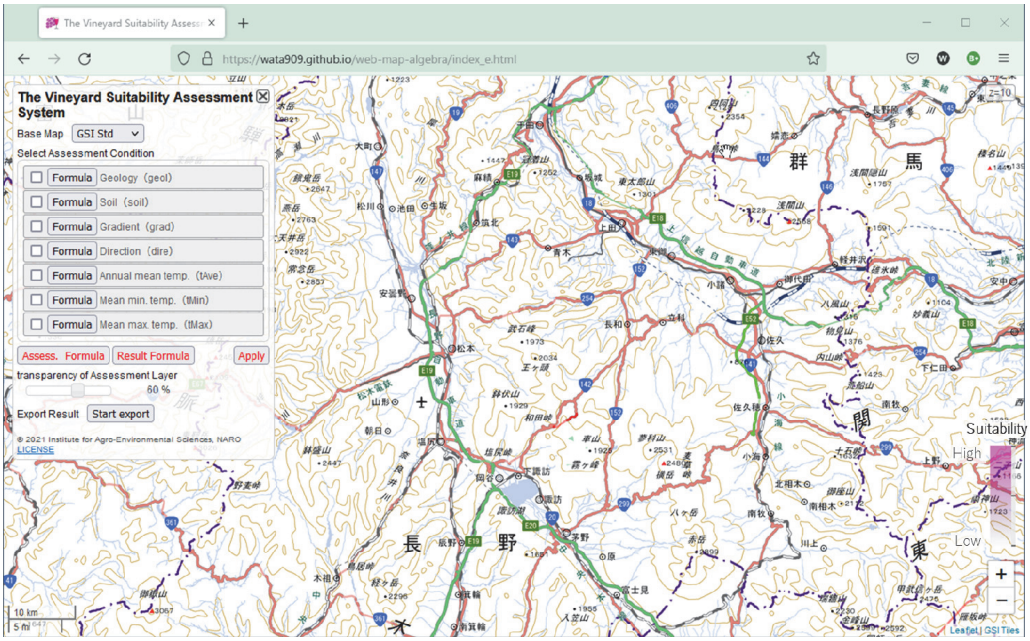

Fig. 1 Startup screen of the vineyard suitability assessment system

The system is a web map application with full size display in a browser. The input of formulae for the assessment of vineyard suitability is performed from the operation panel located in the upper left corner. The map operations are implemented using the Leaflet function. Regarding general web map application, it is possible to move the map by dragging the mouse, and zoom in and out by using the "+" and "-" marks located in the lower right corner. The system can perform suitability assessment using seven factors prepared as data tile maps: geology, cultivated soils, slope gradient, slope direction, annual mean temperature, annual mean maximum temperature, and minimum temperature.

Fig. 2 shows initial screen of the assessment formula input panel. In the initial status, no factors are selected. To apply the evaluation factor, one must select the checkbox to the left of each item. Then, the background color of the relevant condition and the text color of the "Formula" button will turn red [Fig. 3(a)]. The red text on the "Assessment Formula" button indicates that the evaluation formula for the selected factor has not been entered. After checking the items used for assessment, one must click on the "Formula" button to display the assessment form in the modal window. Here, one must enter the assessment formula in the text area. It is possible to enter sample formulation by clicking on the "Sample formula" button [Fig. 3(b)]. After completing the input of

the evaluation formula and clicking the apply button, the background color of the condition will remain red, and the text color of the "Assessment Formula" button will become black [Fig. 3(c)]. For the format of the assessment formula, please refer to the sample available at the demonstration site.

After entering the "Assessment Formula" of the factors to be used, one has to enter the "Assessment Criteria Formula," which is used to calculate the comprehensive assessment value, and the "Result Formula," which evaluates the suitability of vineyard. After all the formulae have been entered, the "Apply" button in red can be clicked. Then the suitability assessment result can be seen on the map (Fig. 4). As described above, the system enables the assessment of vineyard suitability based on environmental conditions using a web browser without any other data and software.

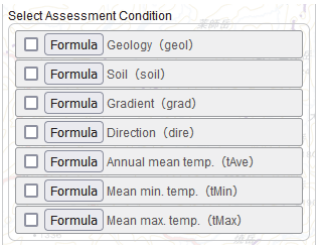

Fig. 2 Initial screen of the assessment formula input panel

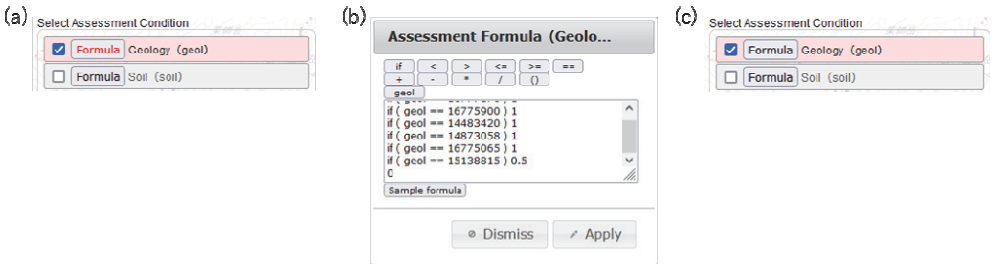

Fig. 3 Example of assessment formula input

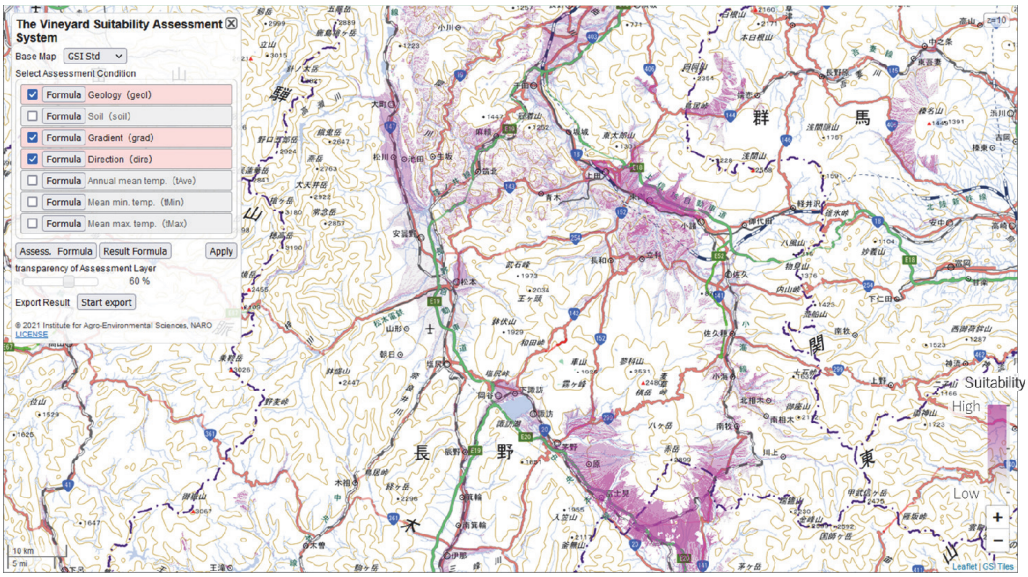

Fig. 4 Example of a vineyard suitability assessment result

3. Conclusion

In this study, we described the development of a prototype of the vineyard suitability assessment system. In this system, data used for assessment are provided by data tile maps, and map algebra function is performed by WebGL™ in the browser. In other words, unlike many other WebGIS systems, our system does not require server-side systems and/or middleware, and can be operated using only a web browser. This means that various entities can be operated on the same system at low cost or on a free web service, such as GitHub pages. Additionally, the functions implemented in this system can be applied to various evaluations using the map algebra functions.

However, our system contains only seven items for assessing suitable locations, which is not sufficient. The arithmetic functions of the system are limited to four arithmetic and logical operations, and it is not capable of implementing the complex model calculations required for highly realistic assessment. We are currently constructing a suitability assessment model using machine learning, information on the distribution of vineyards obtained from field surveys, and various environmental factors derived from field monitoring and published open data. In the future, we will use these data to improve the system and make it more practical. Additionally, we would like to disseminate the improved system and contribute to the realization of *Tekichi-Tekisaku* and *Smart Fuudo Sangyo*.

Acknowledgments

On the occasion of Professor Makiko Watanabe's retirement from Tokyo Metropolitan University, this report is dedicated to her, in appreciation of her kindness and supervising.

This work was supported by the JSPS KAKENHI Grant Number 20H03121.

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(*: in Japanese, **: in Japanese with English abstract)