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CLIENT-SIDE WEB MAPPING SYSTEM FOR VINEYARD SUITABILITY ASSESSMENT

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ABSTRACT:

Currently, several 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, we used open geospatial data to develop a client-side web mapping system for assessment of site suitability for vineyards. As the research area for testing the system, we selected Nagano Prefecture, where many farmers recently started viticulture. The data used in the system are geology, soil, slope gradient, slope aspect, annual mean temperature, and annual maximum and minimum temperatures. These data were converted to a Grid PNG tile, which was developed by The Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology. FOSS4G tools, such as QGIS, TileMill, and MBUtil were used to prepare Grid PNG tile data. Map algebra functions were implemented using the WebGL. Web mapping systems developed in this research do 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.

1. INTRODUCTION

1.1 Status of client-side web mapping

Currently, several kinds of geospatial data are provided as open data/or map tile data. This implies that geospatial data have become easier to obtain and use than older data with traditional licenses and formats. By combining map tile data with Web Mapping clients, such as Open Layers and Leaflet, users can browse maps of any location without complicated procedures, i.e., downloading data, transforming coordinate systems, extracting an area of interest, and installing software. These web mapping technologies have been developed in the field of human interpretation of map images.

In addition, technologies have been developed for using map tiles not only as background images for web mapping but also for visualizing and processing data in a client-side web browser. The Geological Survey of Japan (GSJ) has proposed Data PNG and related formats (The Geological Survey of Japan, 2021) for distributing data as map tiles. This format provides data in the PNG format which allows for retaining numerical attributes such as temperature, elevation, and geological classification. It is also possible to develop web applications with good responsiveness to user requests and that promote a diverse use of data (Nishioka, 2019). The GSJ published a demonstration site for the Data PNG tile (The Geological Survey of Japan, 2019, 2020). Kitao (2020) developed a Web application for visualizing and mapping point cloud data provided as Data PNG. Mapbox Terrain-RGB provides elevation data in PNG format and Mapbox GL JS visualizes these data as a 3D map. Furthermore, development of data visualization and analysis tools in web browsers for large-scale geospatial data, such as Deck.gl and kepler.gl, has become increasingly popular.

These applications were implemented with the capabilities of WebGL. WebGL is a cross-platform, open web standard JavaScript API for 2D and 3D graphics in modern web browsers that allows the GPU-accelerated usage of image processing without the use of plug-ins. Thus, there are many applications for client-side data visualization using WebGL. However, the implementation of data analysis using WebGL, especially the map algebra function, has not been progressively developed.

1.2 Suitability assessment of vineyard and *Fuudo Sangyou*

Recently, “Japan Wine,” made exclusively from grapes grown in Japan, has been gaining international recognition, and new wineries in Japan are increasing. Thus, there is an urgent need to provide information to support the selection of appropriate vineyard sites and grape cultivars. There have been attempts to assess the suitability of agricultural fields for crop production applying Geographic Information Systems (GIS). For example, Kato (1988) made a suitability map of vineyards based on a combination of soil categories and regional climatic conditions in Yamanashi Prefecture.

Despite these efforts, suitable site evaluation of vineyards has not been fully disseminated owing to the lack of the following components: (1) sufficient quality, quantity, and accuracy of information necessary to determine suitable sites; (2) appropriate criteria for evaluating site suitability based on this

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information, and (3) methods for providing evaluation results to consumers such as new farmers.

Traditional agriculture in Japan has emphasized *Tekichi-Tekisaku* (the right crop for the right place), which means to produce crops suited for the local environment. The same concept is used for assessing site suitability. Katsue Misawa, 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). Now in the 21st century, practicing agriculture as *Fuudo Sangyou* is becoming increasingly important in Japan. Approximately 40% of Japan's agriculture is in mountainous regions where large-scale management is difficult. Additionally, the problems of an aging and declining population and an 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.

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 such crop is the wine grape. As there are about 10,000 varieties of *V. vinifera*, and the suitable environment for each cultivar differs, there has been a long tradition of *Tekichi-Tekisaku* for wine grape production. In other words, each wine grape cultivar is grown 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. Thus, there is an urgent need to provide information to support the selection of appropriate vineyard sites and grape cultivars, and to promote *Tekichi-Tekisaku*.

1.3 Purpose of research

GIS effectively evaluates suitability of lands for vineyards, especially using the map algebra function (Kato, 1988). Recently, many types of environmental information required for suitability assessments 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 the distinct types of data necessary for evaluating the suitability of land and develop suitable site-evaluation methods.

To solve these problems, we considered client-side web mapping technology to be an effective solution. Client-side technology enables users to easily obtain data and conduct various GIS operations. In this study, we developed a prototype of a vineyard suitability assessment tool as a client-side web mapping system that enables new farmers to evaluate the suitability of sites for vineyards, without requiring GIS skills.

2. DEVELOPMENT OF A CLIENT-SIDE WEBMAPPING SYSTEM FOR VINEYARD SUITABILITY ASSESSMENT

2.1 Study area

In this study, a vineyard suitability assessment system was developed for Nagano Prefecture, Japan (Figure 1). Nagano prefecture occupies the central area of Honshu Island, Japan (approximately 37°1′49″ to 35°11′55″ N, 137°19′29″ to 138°44′22″ E), with a north-south width of 210 km and an east-west width of 120 km. The topography is steep, with a maximum altitude of 3,190 m and a minimum altitude of 280 m. Rural and agricultural areas are distributed in basins and on an alluvial fan. In Nagano city, the prefectural capital, mean annual precipitation is 965.1 mm and the average annual sunshine is 1969.9 h/y (Japan Meteorological Agency, 2021). Mean annual, maximum, and minimum temperatures are 12.3, 17.8, and 7.9 °C, respectively. However, weather conditions in Nagano prefecture reflect the differences in altitude within the prefecture (Figure 2). Furthermore, such variation in weather conditions can exist within a single municipality. Therefore, a local agricultural administration member remarked that within a single village there is a potential to produce a cultivar of wine grapes.

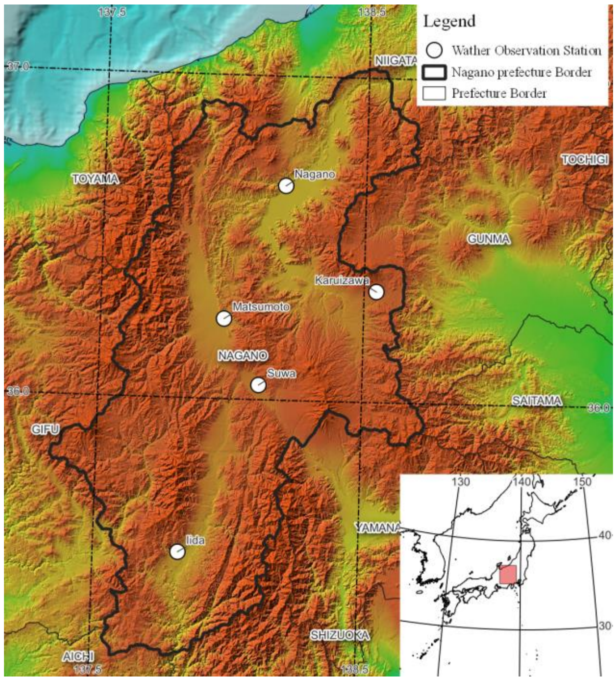

Figure 1. Study area

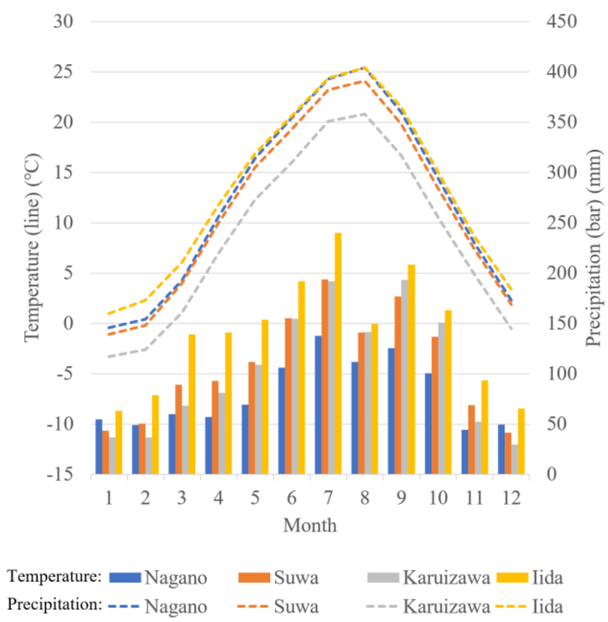

Figure 2. Weather conditions for Nagano Prefecture

Nagano Prefecture is one of the most prosperous regions of viticulture and winery in Japan. There are 66 wineries and 11 Wine Structural Reform Special Zones. Farmers new to viticulture and wineries are also increasing. Nagano local government has encouraged viticulture and wineries in the prefecture. Nagano prefecture has four regions, each of which is in one of the main basins. The Nagano local government named these regions the "Shinshu Wine Valley" and prepared "the Shinshu Wine Valley Plan" to promote viticulture and wine industry in the region. With ideal environmental and social conditions, it is one of the best regions in Japan for prototyping a vineyard assessment system.

2.2 Preparing a Grid PNG tile and implementation map algebra function

2.2.1 Grid PNG tile for suitability assessment: A variety of environmental information is required for assessing vineyard suitability. In this study, we converted spatial information about geology, soils, topography, and meteorology, available as open data, to the Grid PNG tile format for conducting the suitability assessment. Grid PNG tile is a subcategory of Data PNG. It includes the Numeric PNG format, which contains numeric data such as altitude and temperature, and the Pallet PNG format, which contains categorical data such as soil and geological classifications.

Table 1 shows the original data used to create the map set for the Grid PNG tile. The geological data tile map was created as a PNG Palette Tile by directly obtaining data from the Seamless Geological Map of Japan at a scale of 1:200,000 (The Geological Survey of Japan, 2017) disseminated by the GSJ, National Institute of Advanced Industrial Science and Technology. 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 (The National Agriculture and Food Research Organization, 2021) and converted to a PNG Palette Tile using FOSS4G tools, such as QGIS (QGIS Development Team, 2022), TileMill, and MBUtil. For the topographic Grid PNG tile map, we obtained the PNG Elevation Tiles from the GSI Tiles provided by the Geospatial Information Authority of Japan (GSI) (The Geospatial Information Authority of Japan, 2021) and converted them to a PNG Numerical Tile of slope angle and slope direction. The meteorological data tile containing annual mean temperature and annual minimum and maximum temperatures was created from the Japanese Standard Grid Meteoritical Data published by the NIAES (Sudo *et al*., 2010).

2.2.2 Map algebra functions using the WebGL and WebGIS interface: WebGL is a cross-platform, open web standard JavaScript API for 2D and 3D graphics in modern web browsers that allows the GPU-accelerated usage of image processing without the use of plug-ins. In the system, we used the GPU acceleration capability for the map algebra functions. We implemented the following functions:

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

The formulae used in each evaluation and visualization process can be input when the target data tile layer is selected. It is also possible to input formulae prepared as samples.

The interface of the suitability assessment tool was developed using Leaflet. We implemented 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.

3. PROTOTYPE OF THE VINEYARD SUITABILITY ASSESSMENT TOOL AND ITS USAGE

3.1 Overview of the vineyard suitability assessment tool

A prototype of the vineyard suitability assessment tool is available at the following URL: https://wata909.github.io/web-map-algebra/index_e.html. Source code for the assessment system is available in the GitHub repository: https://github.com/wata909/web-map-algebra/tree/main/src/v01. Figure 3 shows the initial screen of the prototype tool. The system is a web mapping application with a 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 Leaflet. The system can perform suitability assessments using seven factors prepared as Grid PNG tile maps: geology, cultivated soils, slope gradient, slope direction, annual mean temperature, and annual maximum and minimum temperatures. The layer designation used for these evaluations is defined in "DEFINITION_e.js." The user interface is defined in "initialize_e.js." By editing these scripts, it is possible to easily add new layers and change the interface. The web algebra function is defined in L.Webgllayers.js.

3.2 Evaluation of vineyard suitability using the assessment tool

Figure 4 shows the initial screen of the assessment formula input panel. In the initial status, no factors are selected. To apply an evaluation factor, one must select the checkbox to the left of the item. Then, the background color of the relevant condition and the text color of the "Formula" button will turn

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	Calculates slope gradient and direction
Meteorology	NIAES Basic Grid Square Meteorological Data	Calculates annual mean temperature, and annual mean maximum and minimum temperatures

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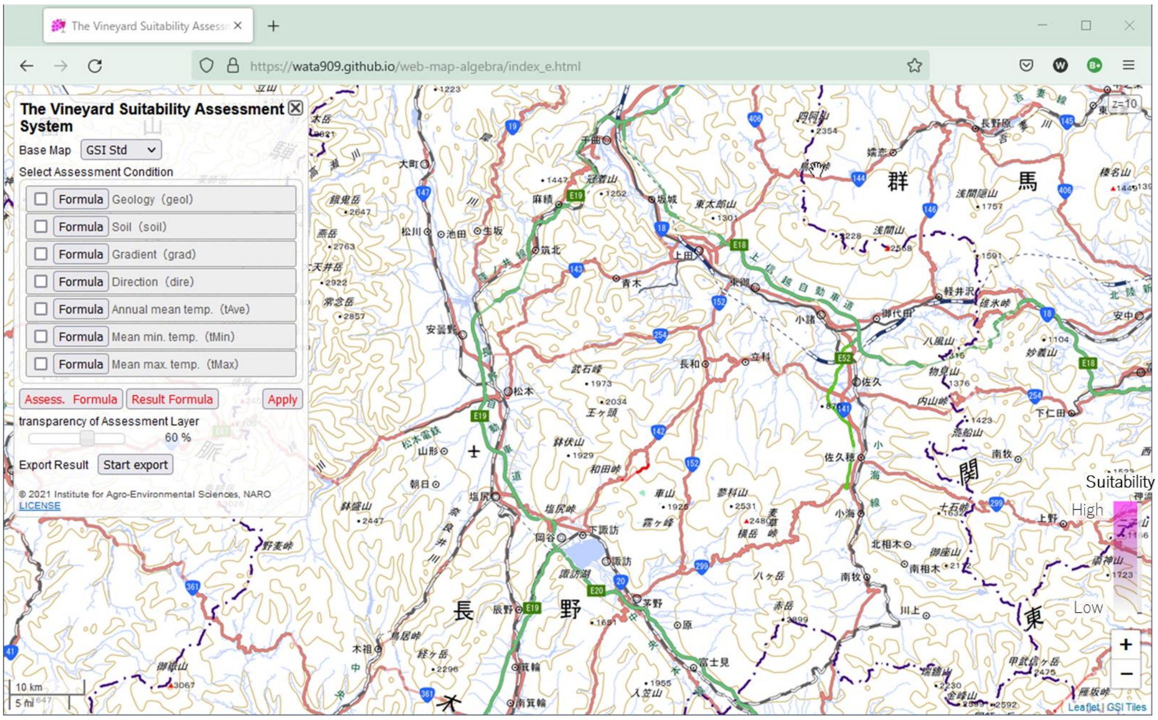

Figure 3. Start-up screen of The Vineyard Suitability Assessment System

red (Figure 5a). 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 a sample formulation by clicking on the "Sample formula" button (Figure 5b). 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 (Figure 5c). 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 must enter the "Assess. Formula," used to calculate the comprehensive assessment value (Figure 5d), and the "Result Formula," which evaluates the suitability of vineyard (Figure 5e).

After all the formulae have been entered, the "Apply" button in red can be clicked. Then, the suitability assessment result is

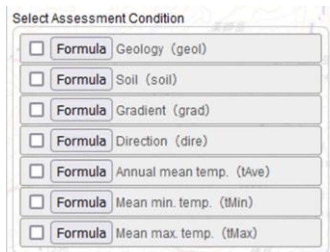

Figure 4. Panel for the assessment formula input

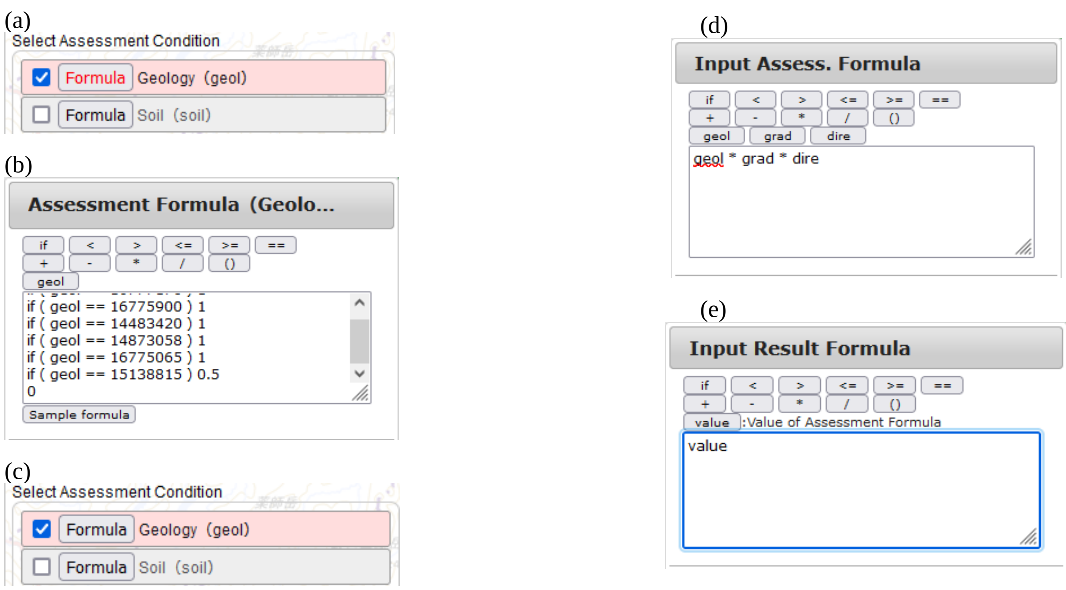

Figure 5. Example of assessment formula input

displayed on a map (Figure 6). Suitability is assessed using the GRID PNG tile corresponding to the displayed zoom level. When the zoom level is changed, the assessment is refreshed to correspond to the new zoom level. The suitability assessment result is displayed as a pink gradient, with darker gradients indicating higher suitability. To export an evaluation result, one must click the "Start export" button and specify the map area to be exported (Figure 7).

The tool enables the assessment of vineyard suitability based on environmental conditions and using a client-side a web browser without additional data or software.

4. CONCLUSION

In this study, we developed a client-side web mapping system for vineyard suitability assessment. In this mapping system, data used for the assessment are provided as Grid PNG tiles. A map algebra function is performed by WebGL on a client-side platform. Unlike many other web mapping systems, our system

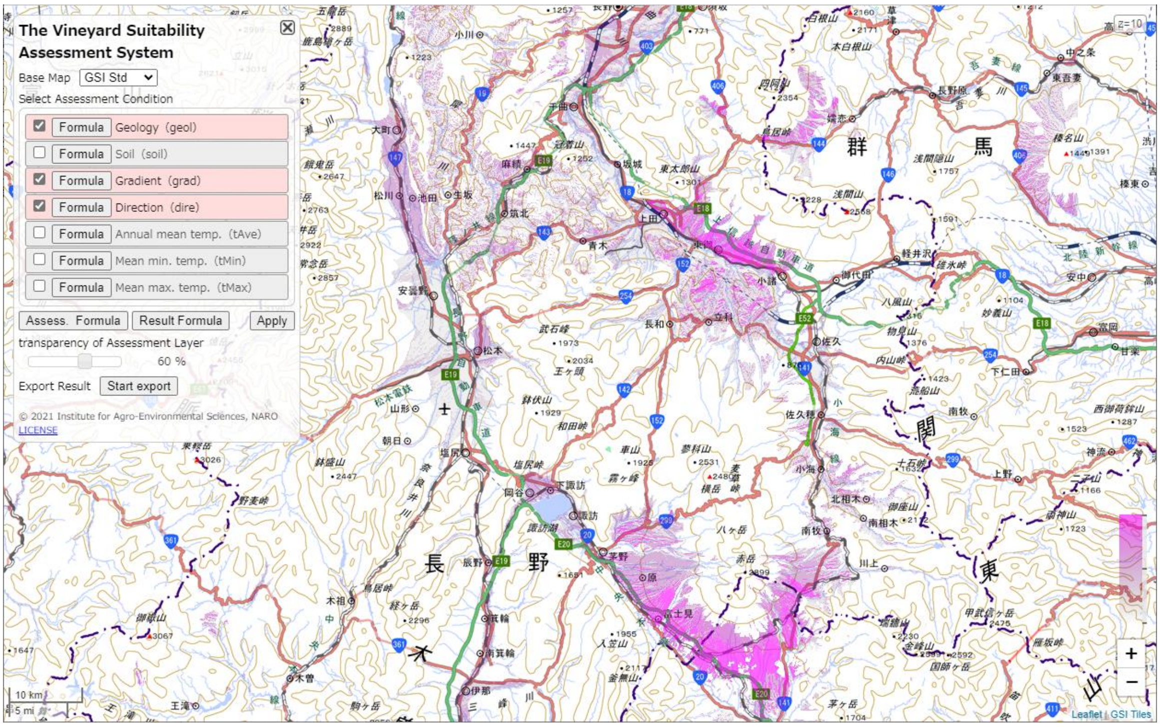

Figure 6. Example of a vineyard suitability assessment

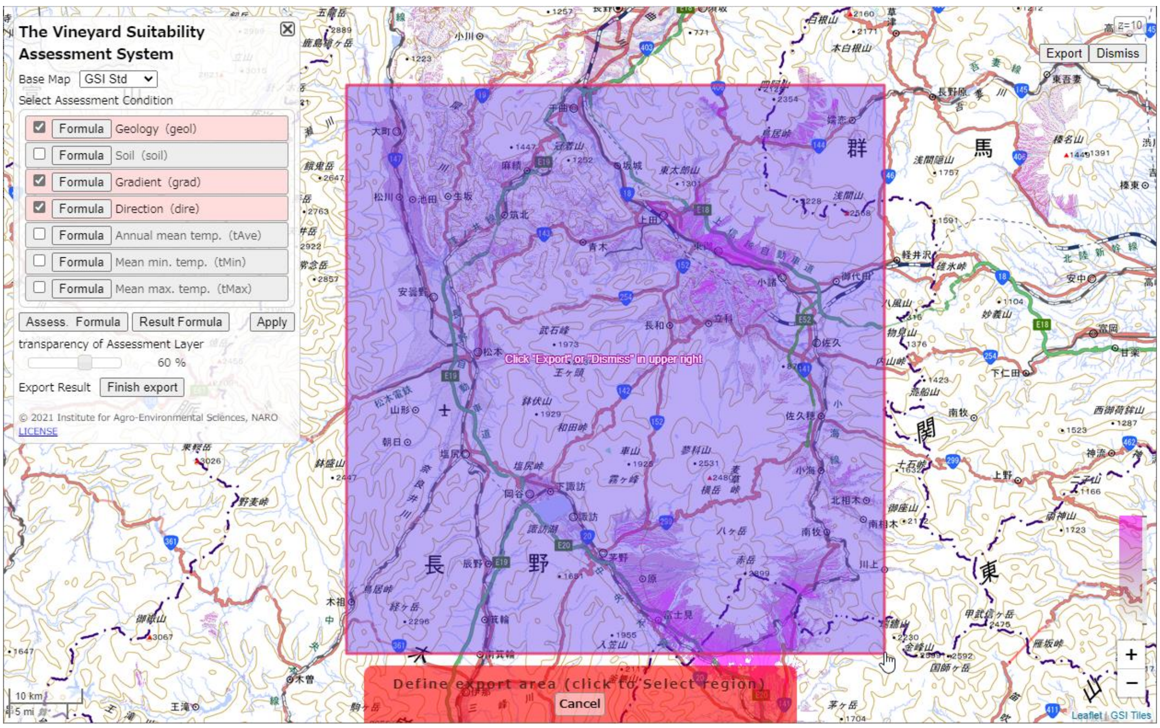

Figure 7 Exporting an evaluation result

does not require server-side systems and/or middleware and can be operated using only a web browser. This means that several 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 many 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 the system is not capable of implementing the complex model calculations required for highly realistic assessment. The conditions selected for assessment formulation depend on the experience and knowledge of the user. Therefore, for new farmers to find a suitable site for a vineyard using this tool, it must be improved as a GIS tool with additional evaluation methods to determine site suitability for viticulture.

We are currently constructing a suitability assessment model using machine learning, information about the distribution of vineyards obtained from field surveys in upper river basin of Chikuma river which include "Chikuma river wine valley," 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 Sangyou*. This will contribute to the establishment of *Smart Fuudo Sangyou*, which enhances the sustainability of the environment and provides for data-driven agricultural practices utilizing newer information and communication technology tools and methods, such as artificial intelligence and sensor networks.

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