Using the Spatial Data of Agroclimatic Elements and Soil to Define the Suitable Lands for some Industrial Crops in Tay Nguyen Highland of Vietnam

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Key words: spatial data, agroclimatic elements, suitable lands, industrial crops

SUMMARY

This report will present interpolation method to develop the spatial data that include temperature-related data, rainfall-related data and evapotranspiration (agroclimatic elements); with pH data, soil texture and some hydrological agricultural constants (soil-related). The agroclimatic elements were interpolated from observing data (from National Hydro-Meteorological Services - NHMS) and other factors such as longitude, latitude, altitude, coastal distance... The soil data was developed from the soil map of Tay Nguyen highland region of Vietnam (National Institute of Agricultural Project and Plan – NIAPP). The resulting layers were used to define the suitable lands for coffee, rubber and tea crops in this region with ecological characteristic of these crops and GIS techniques. The research contributes to help the land manager and agricultural planner to develop land use and agricultural plan in Tay Nguyen highland. The research was implemented in Centre for Agrometeorology (CAM) – National Institute of Meteorology, Hydrology and Environment (IMHEN).

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1. INTRODUCTION

Geographic Information System (GIS) plays an important role in many activities of human in the world. The applications of a GIS are vast and continue to grow. By using a GIS, scientists can research changes in the environment; engineers can design road systems; electrical companies can manage their complex networks of power lines; governments can track the uses of land; and fire and police departments can plan emergency routes. Many private businesses have begun to use a GIS to plan and improve their services. There were many researches and projects in GIS with many difference applications. In the field of hydrometeorology, the applications of GIS were also implemented, such as: *Assessment the damages induced by sea level rise of Vietnam's coastal, Applying GIS in management the information of meteorology and hydrology, applying GIS technology in management and exploit the database of temperature...* With the development of GIS, the spatial data infrastructures were developed in some nations and organizations. But in Vietnam, a developing country, spatial data infrastructure is a new concept and the important thing is developing the spatial data – the fundament of spatial data infrastructures. In the spatial datasets, the spatial climate data plays an important role because of its applicability in many fields. It is used in many climate calculations and models with the detail in the spatial distribution of climate elements. In applied climate, the spatial climate data is useful in many targets, in particularly of agriculture. In this paper, we present the interpolation method to develop the climate data to use in define the suitable land for some industrial crops.

2. INTERPOLATION METHOD TO DEVELOP SPATIAL CLIMATE DATA

2.1. Data and interpolation methods to develop rainfall maps for Tay Nguyen highland

To develop the rainfall maps for Tay Nguyen highland, we use the 35 stations from Tay Nguyen highland and coastal southern central that include 14 stations from Coastal Southern central and 21 stations from Tay Nguyen highland. All the data from these stations was supplied by the National Hydro-Meteorological Services with the time series from 1981 to 2005.

Because of the lack of data (only 35 stations), so the choice of interpolation methods is very important. In meteorology and climatology, geographical data plays a key role. The demand for these kinds of data can be considered from two aspects [4]:

- They are used in analyses, for various kinds of spatial interpolation and modelling, in which case the data are a factor that determine the spatial distribution of the analyzed meteorological phenomena or climate elements.
- They are used for visualizing the results of measurements or calculations, in which case they are used mainly as a background image for other data. Meteorological modelling takes advantage of climatic data, whereas climatic analyses are based on meteorological data and geographical data constitutes vital input information. In this case, geographical data concerns mainly elevation (with slope and exposure of the area), land cover (with parameters dependent on and independent of the season of the year)...

In this research, we collect a set of geographical data that include longitude, latitude, elevation, slope, facet direction and coastal proximity. These are the factors that have effects on the distribution of rainfall – the climate element for which we want to present the interpolation method.

- The influence of latitude on the climate of different mountain systems shows up in a variety of ways [8]. According to New at el (2001) [5], the rainfall is usually higher in the low latitude and lower in the high latitude.
- Climate varies strongly with elevation. Temperature typically decreases with altitude, and precipitation generally increases (Oke, 1978; Barry&Chorley, 1987) [7,1].
- Elevation is an excellent statistical predictor variable, because it is usually sampled at a far greater spatial density than climate variables and is often estimated on a regular grid [2].
- Because the data from meteorological stations in from Tay Nguyen highland and Coastal Southern centre, the coastal proximity is considered as an important factors. Depending on the types of terrain, effects of coastal proximity is various [3]. Remoteness from the sea tends to lead to low rainfalls, especially in the “rainshadow” of mountain ranges, where the air’s descent and consequent warming lead to the evaporation of any cloud. Other exceptions are found at tropical islands, many of which receive more rainfall inland than at the coast on account of uplift in the centre of fairly flat islands. On larger, mountainous islands, the increase of rainfall inland is due to orographic uplift behind the coastal plain. Moreover, when the wind blows from one prevailing direction, the downwind coast may be relatively dry.
- With facet direction, we pilot use it as a factor to interpolate the rainfall because the research area have a complex terrain. The importance of topographic facets in determining climatic patterns varies both spatially and temporally [2]. In this case, we use the slope and slope direction to determine the facet direction.

With all the meteorological data and the geographical data, we use the two interpolation methods including multivariable regression and inverse distance weighting (IDW) to develop the spatial data in this research according the following steps:

- All the area of Coastal Southern centre and Tay Nguyen highland is divided into 2520x5400 cells with the cell size is 0.1x0.1 km in the projection of UTM – 1983 with Zone 48.
- With the map of topography, we calculate the values of longitude, latitude, altitude, slope, facet direction and coastal distance, in which:
  - Longitude and latitude of the middle point in each cell are in the unit of degree (^{0})
  - Altitude of the middle point in each cell is in the unit of metre (m)
  - Slope of each cell is in the unit of degree (^{0})
  - Facet direction of each cell is in the unit of degree (^{0}) (from 0^0 to 360^0)
  - Coastal distance of the middle point of each cell is in the unit of kilometre (km)
- All the above calculations are computed in the ArcViewGIS 3.2 software with some extensions.
- After dividing the research area into cells, we assign the values of cell to station that belong to this cell.
- Base on a set of close stations, developing the multivariable regression equation with the format below:

  $$Y = f\{X1, X2, X3, X4, X5, X6)$$

  in which, Y is the interpolation variable (rainfall) and X1, X2, X3, X4, X5 and X6 are the interpolation factors (longitude, latitude, altitude, slope, facet direction and coastal distance). Choosing the set of close stations to use in regression equation was implemented in many steps with different datasets and the assessment of climate expert. Using the above regression equation, we calculate the values of Y (rainfall) for all of cells. After calculating, the first map with interpolation values is established.
- After that, we determine the errors of interpolation values of cells that have station with the real values of this station and use the inverse distance weighting (IDW) to interpolate all of the errors in the maps:

  $$f_0 = \sum_{i=1}^{k} \frac{1}{d_i^2} f_i \Big/ \sum_{i=1}^{k} \frac{1}{d_i^2}$$

  in which, f_0 is the value of interpolation point (error in point of 0), k is the number of interpolation points (k is equal to the number of station in the regression equation in the above step), d_i is the distance from the point of i to the point of 0, and f_i is the value of point of i (errors in point of i). After that, we have the second maps with the errors that re-interpolated.
- The last step is adding the second map to the first map to have the last interpolation map.
- All of the interpolation steps (from developing multivariable regressions to having the last interpolation maps) are programmed with the programming language of Microsoft Visual Fox Pro 9.0. In this process, the most important step is choosing the regression equation, our software calculated in many different set of point to determine the equation that have the highest correlation. Most of the equations for developing interpolation maps have the correlate index higher than 0.9.

2.2. Results and using it to define the suitable land for some industrial crops of Tay Nguyen highland

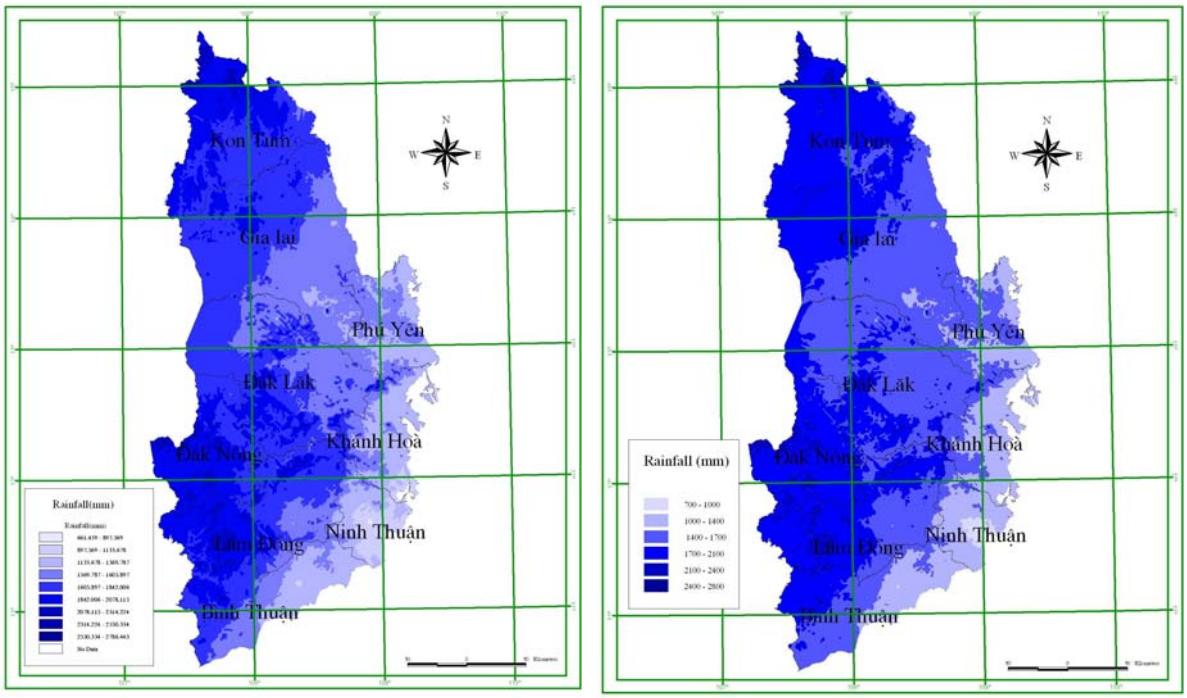

Figure 1. Map of annual average rainfall for Coastal Southern centre and Tay Nguyen highland (left is the grid map and right is the reclassified map)

The result maps from the above interpolation method was reviewed by the climate experts and was compare with different climate maps of this area that developed by traditional ways. In the frame of project "Developing the maps of drought and domestic water shortage for Coastal Southern centre and Tay Nguyen highland regions", we also establish a software to updating the meteorological database and auto-mapping the climate maps with the presented interpolation methods. All of the climate maps developed by this software were assessed that having the corresponding with the rules of climatology and geography. In fact, using the spatial data of climate element has an important signification in many applications. With this paper, we present the application of this spatial data to define the suitable land for some industrial crops (rubber, coffee and tea) of Tay Nguyen highland region. We use the indicators in the table 1. There are many factors of climate, soil and terrain that affect on the growth and development of crop, but in the limited paper, we only use the climate indicators. The aim of this research is demonstrating the key role of climate spatial data in particular target of defining the suitable land for some industrial crops. The result maps were presented in Figure 2.

Table 1. Climate indicators of crops [6]

Crop	Indicator	Very suitable	Suitable	Moderately suitable	Weakly suitable	Not suitable
Rubber	Annual average minimum temperature (^{0}C)	>20	20 - 18	18 - 16	16 - 14	<14
	Annual average temperature (^{0}C)	>25	25 - 22	22 - 20	20 - 18	<18
	Annual average maximum temperature (^{0}C)	>29	29 - 27	27 - 24	24 - 22	<22
	Annual average rainfall (mm)	>2000	2000 - 1700	1700 - 1450	1450 - 1250	<1250
	Slope (%)	0 - 4	4 - 12	12 - 23	23 - 38	> 38
Coffee	Annual average minimum temperature of the hottest month (^{0}C)	<18	18 - 19	19 - 20	20 – 22	>22
	Annual average maximum temperature of the hottest month (^{0}C)	<28	28 - 30	30 - 32	32 - 34	>34
	Annual average rainfall (mm)	> 2000	2000 - 1750	1750 - 1500	1500 - 1000	< 1000
	Slope (%)	0 - 4	4 - 12	12 - 23	23 - 38	> 38
Tea	Annual average minimum temperature of the hottest month (^{0}C)	<20	20 - 22	22 - 24	24 - 26	>26
	Annual average maximum temperature of the hottest month (^{0}C)	<28	28 - 30	30 - 34	34 - 36	>36
	Annual average rainfall (mm)	> 1800	1800 - 1500	1500 - 1200	1200 - 1000	< 1000
	Slope (%)	0 - 4	4 - 12	12 - 23	23 - 38	> 38

3. CONCLUSIONS AND RECOMMENDATIONS

The interpolation methods to developing climate spatial data that presented above were demonstrated in the project of "*Establishing maps of drought and domestic water shortage in Coastal Southern centre and Tay Nguyen highland regions"* – the project was finished in 2008 by Vietnam Institute of Meteorology, Hydrology and Environment (IMHEN). The result maps of this project are also got the agreement of many climate experts. For the progress of developing spatial data infrastructure in Vietnam, standardizing the spatial data is one of the most important missions. Inside of this, climate spatial data with the high resolution for Vietnam needed to put in the earliest mission that had to implement. With the finished projects, Vietnam Institute of Meteorology, Hydrology and Environment have the capacity of science, technology and human resources to develop and standardize the climate spatial data for Vietnam.

In hydrometeorological field of Vietnam, this is the first time that a software to update database and auto mapping was developed. The software is useful in monitoring and managing the hydrometeorological phenomena and is the new way not only in modernizing but also in commercializing the hydrometorological products. In particularly of agriculture where climate play a key role, the climate spatial data is useful in many research such as agricultural climate zoning, monitoring climate disasters in agriculture or like in this paper, define the suitable land for crop...

With all the advantages of it, we recommend to receive the interesting of stakeholders and the investment of Vietnam Ministry of Natural Resources and Environment (MONRE) as well as Vietnam Institute of Meteorology, Hydrology and Environment to develop the climate spatial data for all over Vietnamese territory.

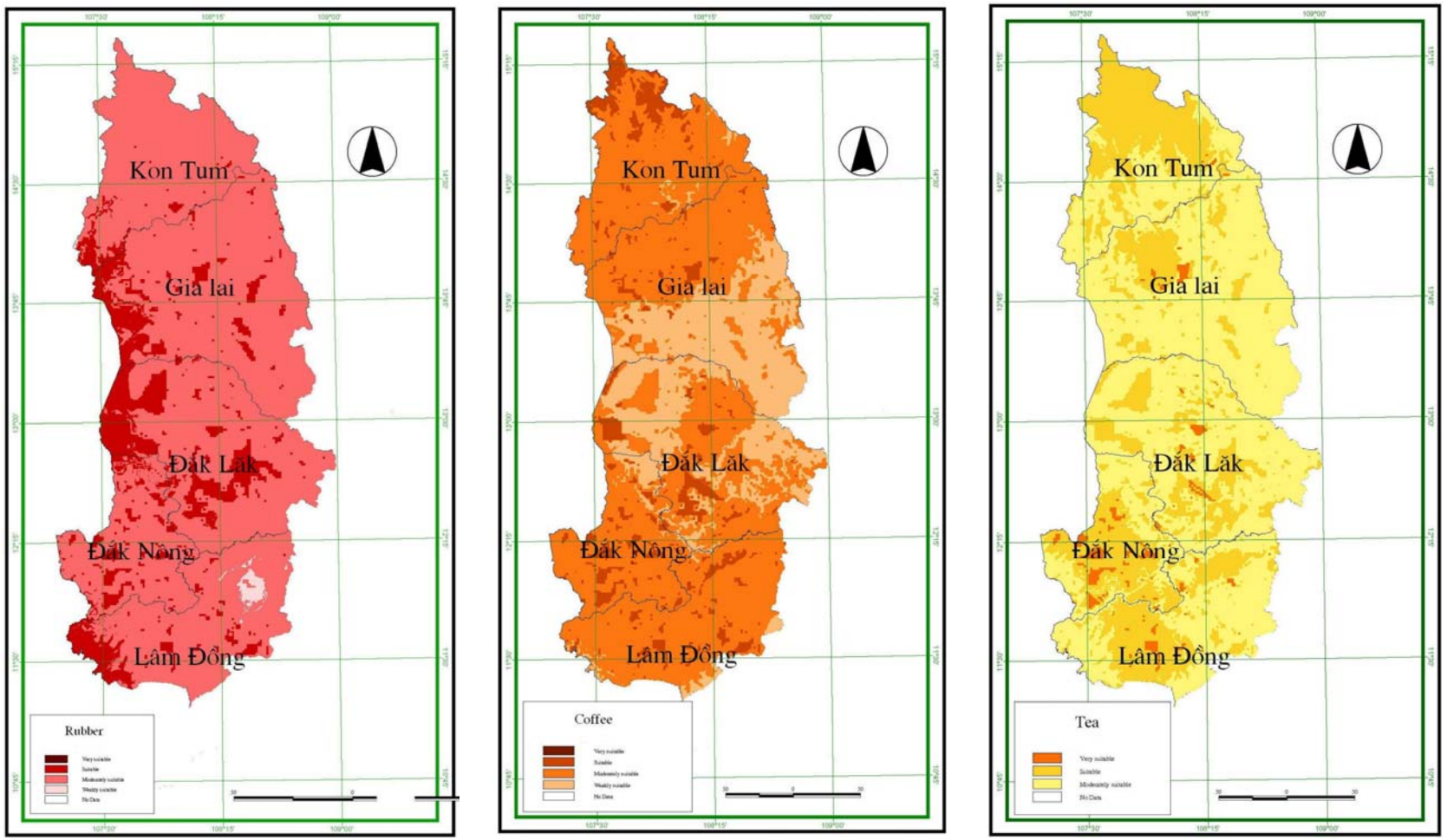

Figure 2. Maps of suitable lands for rubber, coffee and tea in Tay Nguyen highland of Vietnam

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APPENDIX – Table of legend for maps in the figure 2.