>

Exploration of Factors Impacting Grape Yield

Yuki Mitsuno
Department of Computer, Information, and Data Sciences, University of Wisconsin-River Falls
410 S 3rd St, River Falls, WI 54022

***Abstract* — Our main goal is to use satellite technology and GIS (Geographic Information Systems) for an exploration of grape vegetation, with a focus on understanding the factors influencing optimal grape production. In this research, several possible factors impacting grape yield in Michigan has been explored from the data between 2001 and 2011. First, the relationship between NDVI and temperature, precipitation, dew point, and wind speed has been examined. Second, the relationship between NDVI and the yield of grapes in Michigan has been investigated. A regression model has been developed for this purpose. Increase in NDVI during the summer season has been detected. The relationship between NDVI and temperature, precipitation, dew point, and wind speed turned out to be statistically not significant. Similarly, the relationship between NDVI and the yield of grapes has no significance statistically.**

***Keywords*—** NDVI, viticulture, concord grape, regression analysis

I. INTRODUCTION

NDVI stands for Normalized Difference Vegetation Index. It's a numerical indicator used in remote sensing to assess and measure the amount of live vegetation in a given area. NDVI is calculated using the reflectance of near-infrared and red light from the Earth's surface.

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Where:
NIR is the reflectance of near-infrared light.
Red is the reflectance of red light.

It's widely used in agriculture, forestry, and ecology to monitor vegetation health, growth, and coverage over time. Previous research by Schultze et al. (2014) has explored the impacts of climatic variability on grape production. This study explores cool climate viticulture in response to the observed trend of increasing temperatures on Earth. This research investigates the trends of NDVI and concord grape yield in Michigan. Additionally, it examines the relationship between NDVI and various climatic factors including temperature, precipitation, dew point, and wind speed. Furthermore, this study investigates the relationship between NDVI and the yield of concord grapes in Michigan.

II. METHODS AND DATA SETS

To analyze the relationships, several methods were employed. Initially, a multiple regression model was utilized to examine the relationship between NDVI and variables including temperature, precipitation, dew point, and wind speed. Subsequently, a linear regression model was developed to explore the relationship between NDVI and grape yield. A diagram illustrating these relationships has been constructed and is presented below:

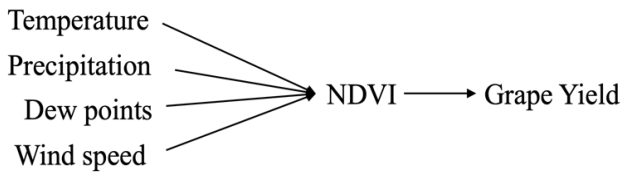

Fig. 1. First, the relationship between NDVI and temperature, precipitation, dew point, and wind speed, where NDVI is dependent variable and temperature, precipitation, dew point are dependent variable. Second, the relationship between NDVI and the yield of grapes, where NDVI is independent variable, and Grape Yield is dependent variable.

Initially, several studies have demonstrated a positive correlation between variables such as temperature and precipitation and NDVI (Raynolds et al., 2008). However, research investigating the connection between variables such as dew point and wind speed and NDVI has been limited. Therefore, this study considers the inclusion of these two variables.

Furthermore, Gozdowski et al. (2021) have reported a positive correlation between NDVI and crop yield in their research on the relationship between NDVI and yield of cereals in several European countries. Since research in the area of grapes associated with NDVI has been relatively scarce, this paper explores the analysis between these variables.

The concord grape yield data in Michigan from 2001 to 2011 were sourced from The National Grape Cooperative Network.

NDVI values were obtained using a multi-step process. Firstly, the shapefile of St. Julian vineyard in Michigan was extracted using QGIS software. Subsequently, these files were

>

imported into AppEEars, a web application provided by NASA, which allows users to select specific areas or import the shapefile, and access data from available satellites. For this study, data from the Terra and Aqua satellites were utilized. Additionally, the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, a satellite-based instrument for Earth observation, was employed. NDVI values were selected based on the grape bloom date and harvest completion date. To streamline data analysis, NDVI values were averaged to obtain yearly values based on the selected months.

Temperature and precipitation data were sourced from the National Weather Service by NOAA. Similar to NDVI values, data were selected based on specific months. For analysis, temperature values were averaged, while precipitation values were summed to obtain the total for the selected months. Dew point and wind speed data from the location were obtained from Weather Underground.

Table 1 presents all the values used to examine the relationships.

TABLE I

CALCULATED VALUES FOR THE VARIABLES

Year	Yield	NDVI	Temperture(°F)	Precipitation(mm)	Dew Point(F)	Wind Speed(mph)
2001	2.1	0.69646515	60.72857143	32.34	52.0171429	7.24
2002	2.8	0.73065	59.44285714	18.54	49.9028571	7.15285714
2003	5.3	0.71640186	58.82857143	26.83	49.6357143	7.06142857
2004	3.7	0.73101852	59.85714286	27.03	50.3871429	6.93
2005	7.1	0.71677	61.74285714	24.71	50.6642857	7.04571429
2006	1.6	0.72915833	60.02857143	28.41	49.2614286	6.65285714
2007	6.5	0.7543648	63.14285714	17.81	49.6885714	6.57857143
2008	4.9	0.75689444	60.1	28.58	47.4285714	6.68571429
2009	4.9	0.68626001	59.71428571	26.59	47.7857143	6.03714286
2010	2.0	0.7300792	62.74285714	26.46	50.9971429	6.66
2011	6.5	0.73079761	62.28571429	27.03	50.9085714	6.49428571

III. RESULTS AND DISCUSSION

TABLE II

RESULT OF THE MULTIPLE REGRESSION ANALYSIS

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.74634782
R Square	0.55703507
Adjusted R Square	0.26172511
Standard Error	0.0181859
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.00249536	0.00062384	1.88627257	0.23216622
Residual	6	0.00198436	0.00033073		
Total	10	0.00447973			

	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.39679795	0.31383968	1.26433328	0.25300354	-0.3711401	1.16473599	-0.3711401	1.16473599
Temperture(F)	0.01299221	0.00607263	2.13946821	0.07620631	-0.001867	0.0278514	-0.001867	0.0278514
Precipitation(mm)	-0.0005323	0.0015214	-0.3499046	0.73836536	-0.0042551	0.00319039	-0.0042551	0.00319039
Dew Point(F)	-0.0154443	0.00744648	-2.0740372	0.08342014	-0.0336652	0.00277661	-0.0336652	0.00277661
Wind Speed(mph)	0.04766118	0.02611632	1.82495789	0.11780831	-0.0162431	0.11156551	-0.0162431	0.11156551

First, a multiple regression analysis was utilized to examine the relationship between temperature, precipitation, dew point, and wind speed and NDVI. The result tells us that all p-values for temperature, precipitation, dew point, and wind speed resulted in p-value value of greater than 0.05. The p-value for the temperature resulted in 0.07 which was close to 0.05. Therefore, this leads us to conclude that these variables do not have significant effect on NDVI variable for the specified months and area of this study. Subsequently, Adjusted R Square value is 0.261, which is not high enough to conclude the independent variables explains the variation of data in dependent variable. The table 2 shows the result of the analysis.

To calculate NDVI, the values were averaged based on the selected months, typically ranging from May to November, covering the years 2001 to 2011. While significant fluctuations in NDVI between years were not observed, it is important to note that further research on grape vegetation and agricultural practices may be necessary to fully understand any potential effects on the results.

TABLE III

RESULT OF THE LINEAR REGRESSION ANALYSIS

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.16535535
R Square	0.02734239
Adjusted R S	-0.0807307
Standard Erro	2.06008036
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.07371093	1.07371093	0.25299914	0.62704943
Residual	9	38.19538	4.24393111		
Total	10	39.2690909			

	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-6.9205575	22.3344185	-0.3098607	0.76372152	-57.444522	43.6034074	-57.444522	43.6034074
NDVI	15.4816771	30.7792816	0.5029902	0.62704943	-54.145895	85.1092495	-54.145895	85.1092495

The linear regression model was applied to explore the relationship between NDVI and concord yield. The analysis revealed that the P-value for NDVI was greater than 0.05, indicating that the variable does not contribute significantly to concord yield. Furthermore, the Adjusted R Square value was found to be -0.080, suggesting that the model does not adequately explain the data.

These results were unexpected, as none of the variables were found to be significant. There are several potential explanations for these findings. Firstly, the lack of significant fluctuation in NDVI values may be attributed to the limited geographical scope of the vineyard in Michigan that was selected for the study. Therefore, it's possible that this limited area may not capture sufficient variation in NDVI values. Secondly, the selection of time periods, from bloom date to harvest date, may not be optimal for capturing the significant impact of vegetation index on concord grapes. Further research is needed to identify the specific time of year that has the most significant impact on the vegetation index of concord grapes. Thirdly, the selection of independent variables influencing NDVI could be refined. For instance, the regression results indicated negative coefficients for precipitation and dew points. While this does not necessarily imply a negative impact on NDVI, it suggests that these variables may not positively influence NDVI. Further investigation into the relationships between these variables and NDVI is necessary. Additionally, research on dew point and wind speed is essential to enhance the model's accuracy and comprehensiveness. Finally, conducting preliminary correlation analyses to evaluate the individual relationships with NDVI values would be beneficial. This step would provide insights into the strength and direction of each variable's association with NDVI, aiding in the refinement of the model.

V. CONCLUSION

Overall, I am grateful for the opportunity to conduct these analyses and learn how to develop the model. While the results were unexpected, they highlight the significant

>

potential for further refinement in the model and underscore the need for continued research on grape vegetation.

ACKNOWLEDGMENT

I would like to express my gratitude to Dr. Schulz at University of South Alabama, Prof. Wiesner and Prof. Hendricks at University of Wisconsin-River Falls for their invaluable support and guidance throughout this semester's research.

REFERENCES

[1] Panek, E.; Gozdowski, D. "Relationship between MODIS Derived NDVI and Yield of Cereals for Selected European Countries," Agronomy 2021, 11, 340. https://doi.org/10.3390/agronomy11020340

[2] Kawabata, A., Ichii, K., & Yamaguchi, Y. (2001). "Global monitoring of interannual changes in vegetation activities using NDVI and its relationships to temperature and precipitation." International Journal of Remote Sensing, 22(7), 1377–1382. https://doi.org/10.1080/01431160119381

[3] Schultze, S. R., Sabbatini, P., & Andresen, J. A. (2014). "Spatial and temporal study of climatic variability on grape production in southwestern Michigan," American Journal of Enology and Viticulture, *65*(2), 179-188. https://iris.unito.it/bitstream/2318/1930774/1/179.full.pdf

[4] National Oceanic and Atmospheric Administration (NOAA), National Weather Service. Available: https://www.weather.gov/wrh/climate

[5] TWC Product and Technology LLC, Weather Underground. Available: https://www.wunderground.com/

[6] National Aeronautics and Space Administration (NASA), Earth Data. Available: https://www.earthdata.nasa.gov/