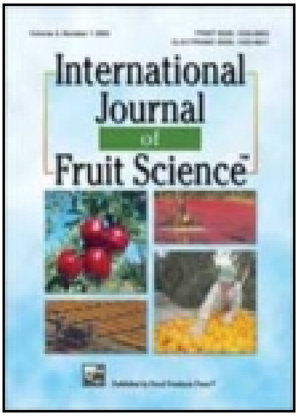

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Utilizing GIS Technologies in Selection of Suitable Vineyard Sites

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Utilizing GIS Technologies in Selection of Suitable Vineyard Sites

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ABSTRACT. Geographic information system (GIS) technologies and a weighted linear indexing model were used for suitability analysis of potential vineyard sites in Illinois. The model included a macroscale climate variables layer (40 points), a mesoscale climate variables layer (40 points), a soil properties layer (10 points) and a current land use variables layer (10 points) for a possible 100 points. Macroscale climate variables, growing degree day summation for a 33-year period (1969-2002) and occurrence of −26°C were interpolated using thin plate smoothing splines over the Illinois terrain using 100 m^2 resolution digital elevation models (DEM). Using the same DEMs, absolute elevation, slope, and aspect were reclassified using surface analysis of the terrain to model the effects of mesoscale climate variables in Jackson and Union Counties in Illinois (study area). Locations in the study area above 259 m in absolute elevation (above sea level), with gently rolling slopes (5 to 10%), and facing North, East, or Northeast received the most points within the mesoscale climate layer. Soils that drained well or moderately well with moderate organic matter content (2 to 3%) received the most

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points in the soil properties layer. Lands that promoted ease of conversion to vineyards were assigned the most points in the current land use layer. The resulting four layers were arithmetically summed and suitability maps with 760 m^2 resolution were developed. In the study area, over 18,155 hectares of land highly suitable or suitable for viticulture were identified. A portion of the existing orchard and vineyard acreage (223 ha) in the study area were surveyed with a global positioning system. Of the surveyed vineyard acreage, over 81% lies within the suitable or better ranking according to the model. Of the surveyed orchard acreage, over 50% lies within the suitable or better ranking. doi:10.1300/J492v06n03_07 *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com>*

KEYWORDS. Cartographic model, continental climate, digital elevation model, extension, topography, weighted linear indexing

INTRODUCTION

Grapes grown in Illinois are exposed to biotic and abiotic stresses that reduce crop yields and quality or can kill grapevines. Damaging winter temperatures, spring frosts, and higher than optimal growing season temperatures occur regularly within the state. Despite these challenges, viticulture can be a successful enterprise in many areas of the state. Vineyard site selection therefore is a determining factor that affects crop yields, quality, and sustainability. Climate is the major limiting factor for viticulture sustainability in Illinois. Macroclimate refers to the prevailing climate of a large geographic region. Illinois is subject to a continental macroclimate where temperature and precipitation patterns are modified by large land masses (Janick et al., 1981). Air temperatures fluctuate on a day-to-day basis, because the land does not buffer air temperatures. Mesoclimate, also referred to as topoclimate, is more specific than macroclimate. Horizontal distances as little as 152 m, such as opposing aspects or hillsides in hill and valley terrains may affect mesoclimates (Boyer, 1998). Vineyard mesoclimate is influenced by its elevation, slope, aspect, and physical and chemical properties of the soil.

Due to the relative youth of the industry in Illinois, much of the terrain remains uncharted for viticultural purposes. Viticulture has recently emerged as an alternative crop in the state only after private entrepreneurs started investing in vineyards and wineries many decades after prohibition uprooted the industry. Present and future enterprises will be more likely to prosper if only superior sites are used for vineyards.

In Illinois, youth of the industry, coupled with the continentality of the climate increases the hazard of vineyard site selection based solely on cold hardiness and soil maps currently in use. Topography and soil properties were modeled using GIS to define viticultural regions in Virginia (Boyer, 1998; Boyer and Wolf, 2001), Pennsylvania (Wu et al., 2004) and in New Zealand (Badcock, 1998). The use of GIS to define viticulturally suitable regions can reduce the time for trial and error process to chart optimum viticulture regions, which took over millennia to identify in Europe. The GIS approach can be utilized in Illinois where a Spatial Decision Support System (SDSS) can arithmetically define a region's suitability for viticulture using climate, topography, and soil properties.

The goal of this project was to develop a first generation model that will provide high-resolution visual tools to delineate vineyard suitability for extension personnel and potential grape growers. The specific objectives of this study were to:

1. Generate macroclimate maps of the state that include occurrence of mid-winter critical temperatures and Growing Degree Day Summation and define optimum growing regions based on macroclimate threshold.
2. Generate mesoclimate maps for Jackson and Union counties, Illinois (study area) based on optimum growing regions identified in objective one using absolute elevation, slope, aspect, soil properties, and current land use.
3. Develop a cartographic model that will arithmetically sum the layers identified in Objectives 1 and 2 and generate maps of predicted suitable vineyard sites in study area.
4. Apply the cartographic model by comparing the predicted suitable sites on the mesoclimate maps and existing commercial peach orchards and vineyards in the study area.

MATERIALS AND METHODS

In this first generation model, as with many of its counterparts in the eastern United States (Boyer, 1998; Wolf, 2003; Wu et al., 2004) a weighted linear indexing model for potential vineyard site suitability analysis was used. There was no sensitivity analysis conducted on the macroclimate and mesoclimate point distributions as it was beyond the scope of this project. The dataset for soil characteristics has a resolution of 625 ha, which introduced a significant amount of conflation to the finished maps as reported by Boyer (1998) and Wu et al. (2004).

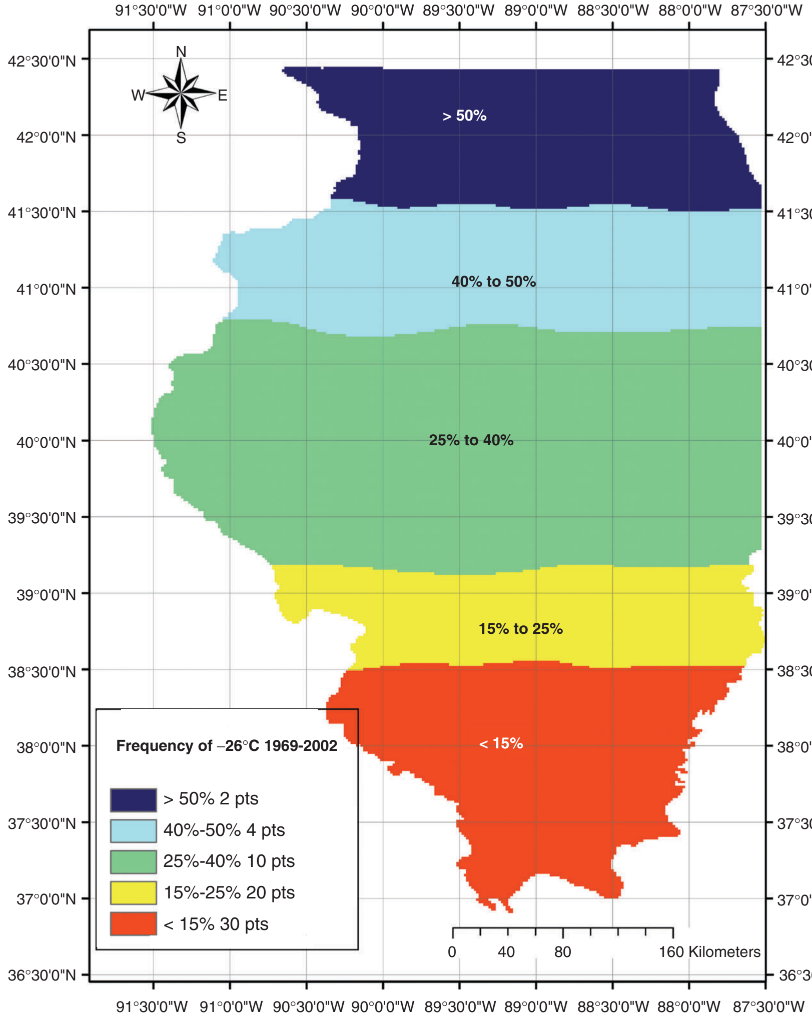
Macroclimate Layer and Surface Generation

The data used in calculations for occurrence of critical temperatures of −26°C and Growing Degree Day Summation (GDD 10°C base) between 1969 and 2002 (33 years) were measured at 83 weather stations in the state as provided by the Office of the Illinois State Climatologist (Jim Angel, personal communication, 2002). For both datasets, a relational database (RDba) was created by assigning an index number for each of the weather stations. The RDba was summarized in SAS 8.2 (SAS Institute, Cary, NC) by creating means for each of the weather stations throughout the span of the years included in the set. The RDba was then linked to the dataset containing the latitude, longitude and elevation for the 83 weather stations.

The eighty-three weather station extreme temperature minima and GDD were fitted to a trivariate smoothing spline in ArcGIS 8.2. (ESRI Inst., Redlands, CA). The data were fitted to fifteen equi-samples comprised of the three-dimensional latitude, longitude, and elevation values. The degree of data smoothing imposed by the procedure was optimized to minimize the predicted error of the fitted spline, as assessed by the generalized cross validation (GCV). The GCV was calculated by systematically calculating the residual of each data point, as it was withheld from the fitting procedure, and then adding a suitably normalized sum of the squares of these residuals. This is a reliable, intuitively direct assessment of the predictive error (Wahba, 1990; Hutchinson and Gessler, 1994).

The surfaces created by the trivariate spline fitting of temperature data were then clipped (an intersection procedure in GIS that uses the political boundaries as a template over the surfaces created) using the political county boundary projections for both temperature variables (Figures 1 and 2). Both surfaces were reclassified using the Spatial Analyst extension of ArcGIS 8.2 according to the Viticulture Site Suitability point distribution (Table 1). The resultant layers (Figures 1 and 2) were then overlaid on each other and the values in each cell were added in the Raster Calculator of ArcGIS 8.2 to calculate and derive the Macroclimate Raster Layer (Figure 3).

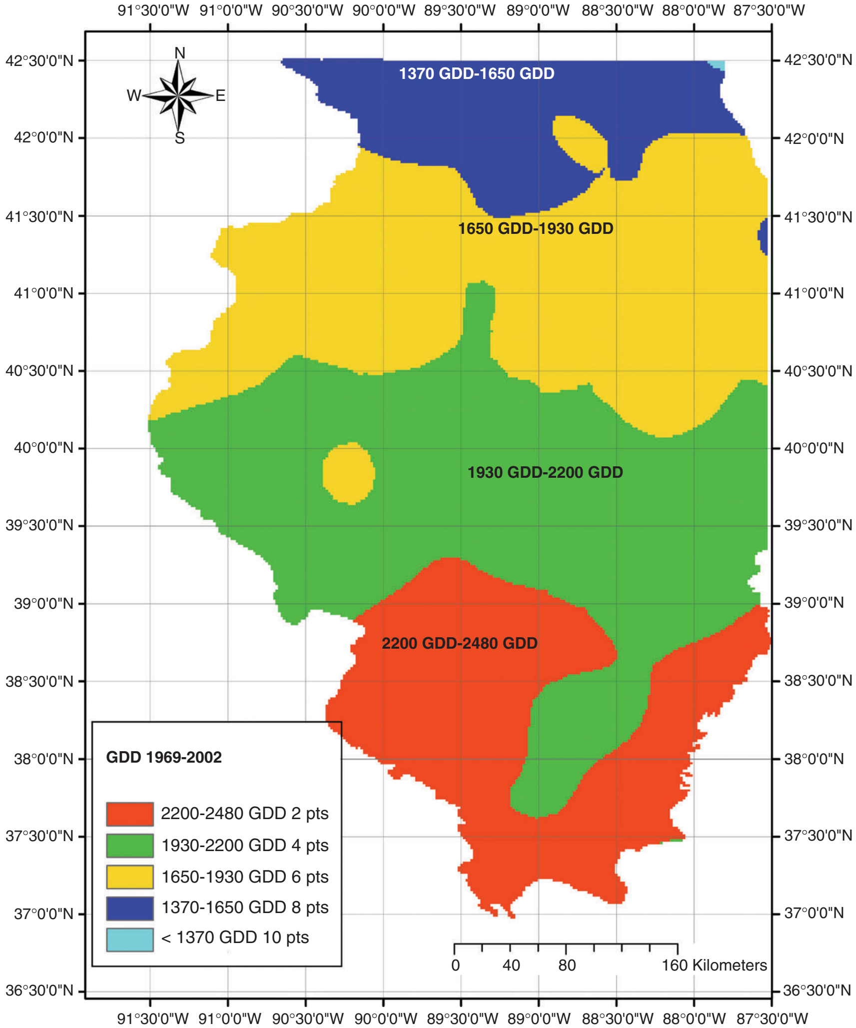
FIGURE 1. Occurrence of extreme minimum temperature (−26°C) in Illinois 1969-2002.



Mesoclimate Layer and Surface Generation

The mesoscale maps for Jackson and Union counties were generated using the Surface Analysis tool of the Spatial Analyst in ArcGIS 8.2. The raw data (Figure 4) were acquired from the United States Geological Survey (2002a). The National Elevation Data Set with a resolution

FIGURE 2. Growing degree day (GDD) summation (10°C) base in Illinois 1969-2002.



of 100 m^2 (1/3 arc second) was used to generate the slope and aspect layers. The raw data layers are as follows: Absolute elevation (Figure 4), slope, and aspect. The slope and aspect layers with the absolute elevation above sea level (asl) were classified using the Reclassify option in the Spatial Analyst in ArcGIS 8.2 with the assigned point distribution (Table 1).

TABLE 1. Macroscale climate variables, mesoscale land attribute ranking, and sub-classification schemes as used in Jackson and Union Counties, IL vineyard site suitability (Spatial Decision Support System).

Point value	Attribute	Sub-classification	Sub-class assigned value (points)
Macro scale 40 points	Frequency of $-26°C$ occurrence (1969-2002) (30 points possible)[a] (%)	< 15	30
		15-25	20
		25-40	10
		40-50	4
		> 50	2
	Growing degree day summation mean[b] (1969-2002) (10 points possible[c])	1093-1370	10
		1370-1650	8
		1650-1930	6
		1930-2200	4
		2200-2480	2
Meso scale 40 points	Absolute elevation (asl) (20 points possible)[d] (m)	> 259	20
		244-259	18
		229-244	16
		213-229	14
		198-213	12
		183-198	10
		168-183	8
		152-168	6
		137-152	4
		< 137	2
	Slope (10 points possible) (%)	5-10	10
		11-15	8
		1-4	5
		> 15	2
		0 (flat)	1
	Aspect (10 points possible)	NE	10
		N, E	9
		NW, SE	7
		Flat	4
		W	3
		S	2
		SW	1

TABLE 1 (continued)

Point value	Attribute	Sub-classification	Sub-class assigned value (points)
Land Attributes 20 points	Soil Drainage (7 points possible)[e]	Well-drained	7
		Moderately well-drained	5
		Somewhat poorly drained	2
		Poorly-very poorly drained	0
	Soil % organic matter (3 points possible) (%)	> 5	0
		3-5	1
		2-3	3
		1-2	2
		< 1	1
	Current land use[f] (10 points possible)	Herbaceous/ Agrarian	10
		Shrubs	8
		Forested/wooded	4
		Urban/water/trans-portation	0
Total = 100 points			

[a]Calculated using thin-plate smoothing splines from 83 weather stations from means between 1969-2002.
[b]Growing degree day is (10°C) based.
[c]Calculated using thin-plate smoothing splines from 83 weather stations from means between 1969-2002.
[d]Generated by surface analysis and reclassification in ArcGIS 8.2 from Digital elevation model supplied by the USGS 10 m $\times$10 m resolution.
[e]Generated by reclassification of the STATSGO dataset supplied by NRCS in ArcGIS 8.2. with a 625 ha resolution.
[f]Generated by reclassification of the Federal Land Cover Database supplied by the USGS in ArcGIS 8.2 with a resolution of 10 m $\times$ 10 m.

Land Attributes

Current Land Use. The raw data were acquired from the United States Geological Survey (2002b). The National Land Cover Data (100 m^2 resolution) were reclassified using the point distribution presented in Table 1.

Soil Properties. The raw soil characteristics data [State Soil Geographic Database (STATSGO)] were acquired from the United States Department of Agriculture, Natural Resources and Conservation Service (2002). The resolution of the STATSGO data set was 625 hectares.

FIGURE 3. Arithmetic overlay of Macroclimate Raster Layers (extreme winter temperature occurrence + growing degree day summation) 1969-2002 in Illinois.

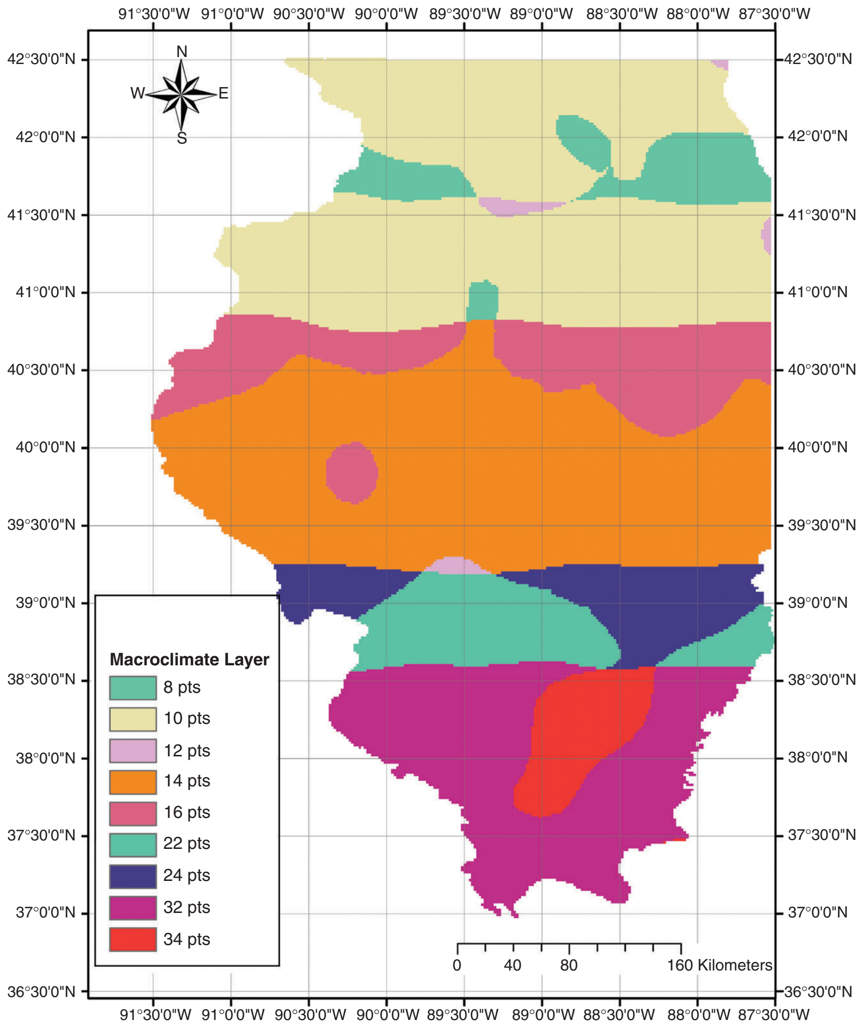
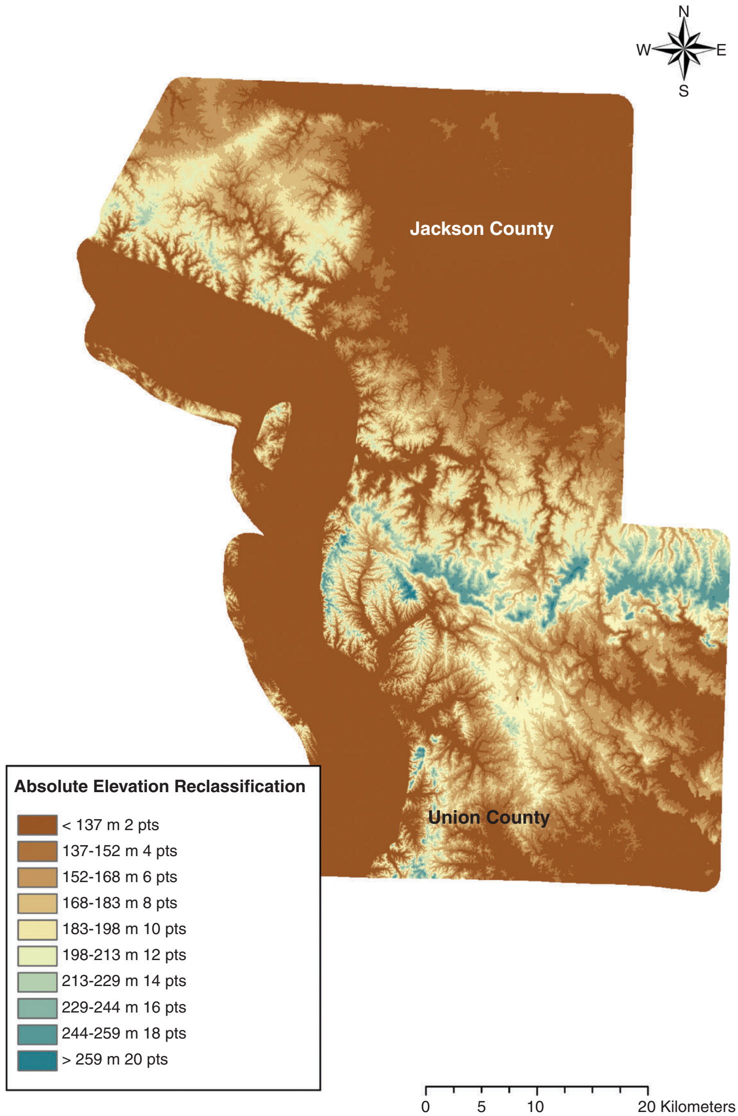


FIGURE 4. The absolute elevation above sea level of the Jackson and Union County, Illinois, and respective reclassification of point distribution.



The component and layer tables were linked to the RDba of STATSGO to generate drainage and organic matter content of the soils in the study area and reclassified.

Mesoclimate Layer Generation. Using the Raster calculator in ArcGIS 8.2, the reclassified layers, absolute elevation, slope, aspect, current land use, soil internal water drainage, and soil organic matter percentage were summed for each county (Figure 5).

Developing the Cartographic Model

The Macroclimate and Mesoclimate surfaces generated for each county were overlaid, and summed using the Raster calculator in ArcGIS 8.2. The maximum possible points a cell can attain is 100 points. The resultant composite maps were then again ranked for the Viticulture Suitability Spatial Decision Support System (Figure 6 and Table 2) in the Spatial Analyst extension of ArcGIS 8.2.

Application of Model to Existing Vineyards and Orchards

A portable Global Positioning System (GPS) (AgGPS 106, Trimble Navigation Ltd., Sunnyvale, Cal. USA) was used to plot the perimeter of representative orchard and vineyard acreage in the study area. The generated orchard and vineyard acreage perimeters were then overlaid on to the SDSS of the Study Area. The Geoprocessing Tool of ArcGIS 8.2 was used to clip the SDSS of the surveyed acreage. The area of the SDSS and the area of the surveyed orchards (5 orchards, 198.5 ha) and vineyards (5 vineyards, 24.7 ha) were calculated from the polygons generated in ArcGIS 8.2 using XTools extension (Data East, Novosibrisk, Russia).

RESULTS

Macroclimate Surface Generation

Extreme Minimum Temperature Occurrence. Absolute elevation and longitude had little effect on the occurrence of −26°C in the state. The frequency of extreme minimum temperature occurrence was dictated by the latitude (Figure 1). There was a clear division at the lat. 41°45′N where −26°C occurred in more than 50% percent of the winters over the years summarized. The frequency of reaching critical temperatures

FIGURE 5. Arithmetic overlay of Mesoclimate Raster Layers (absolute elevation + slope + aspect + soil internal water drainage + soil organic matter percentage + current land use) in Jackson and Union County, Illinois.

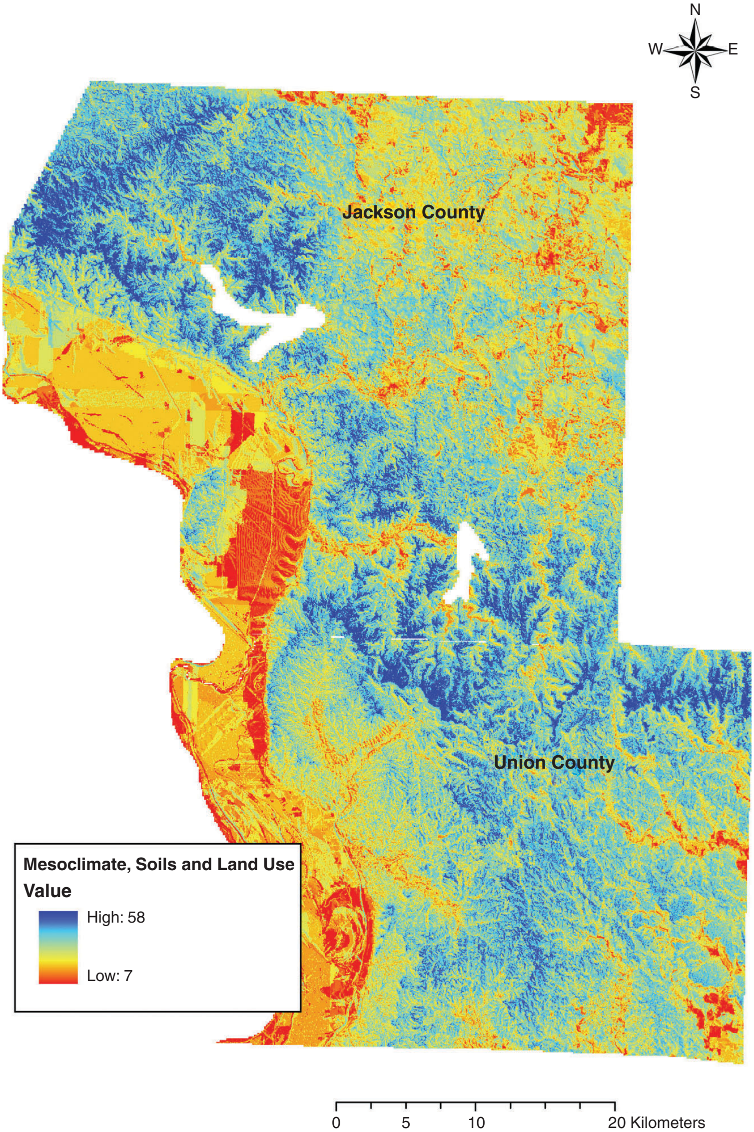


FIGURE 6. Arithmetic overlay of Macroclimate Raster Layers and Mesoclimate Raster Layers in Jackson and Union County, Illinois.

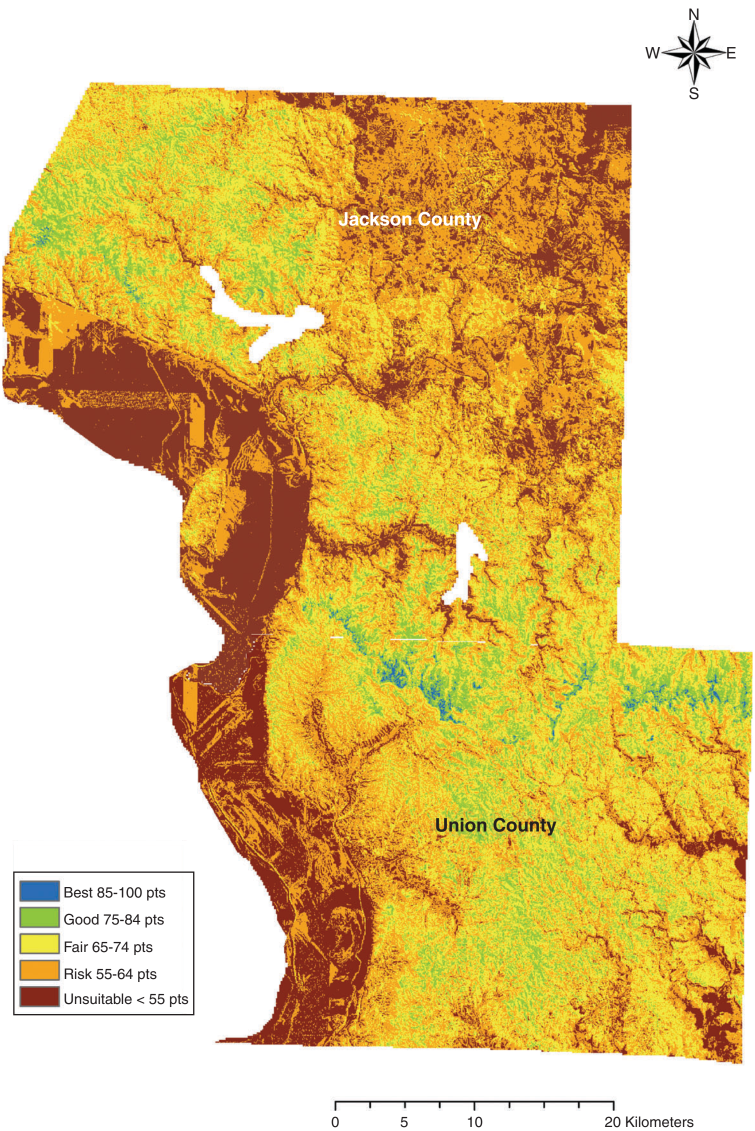


TABLE 2. Composite ranking of sites in the Jackson and Union County, Illinois according to the viticulture suitability spatial decision support system (SDSS).

Suitability ranking	Point range accumulated in SDSS
Best	85-100
Good	75-84
Fair	65-74
Risky	55-64
Unsuitable	less than 55

declined as the latitudes decreased. The central portion of the state (lat. 38°30′ N to 41°45′ N) encountered critical temperatures during 15 to 40% of winters studied (Figure 1). Southern Illinois (south of lat. 38°30′ N) experienced critical temperatures in less than 15% of the winters studied.

Growing Degree Day Summation. The latitude influenced the growing degree-day summation (GDD) in a similar pattern as the minimal temperature occurrence (Figure 2). The GDD (10°C base) accumulation was highest (2200 GDD to 2400 GDD) south of lat. 38° N, which corresponds to Region V in the GDD scale of California (> 2200 GDD) (Amerine and Winkler, 1944). North of lat. 41° N, the GDD summation (1370 GDD to 1930 GDD) corresponds to region I (< 1300 GDD) and region II (1370 GDD to 1650 GDD).

Arithmetic Overlay of Macroclimate Raster Layers

Only 8 to 14 points out of a possible 40 were accumulated above lat. 39°N in the state (Figure 3). Between the lat. 39° N and 41° N only 16 to 24 points were calculated out of a possible 40 points. Out of the possible 40 points assigned to the macroclimate variables, the most were calculated between the lat. 37° N and 38° N. The macroclimatic suitability values decreased above lat. 39° N and the least suitable portion of the state was above lat. 41° N parallel due to frequent occurrence of −26°C.

Mesoclimate Layers

Topography and Absolute Elevation. The absolute elevation in the study area was not uniform (Figure 4). The hilly areas in Jackson County were to the Northwest and South regions of the county where the maximum absolute elevation was 270 meters. The central portion of the county and its western environs presented the lowest absolute elevation.

The mean absolute elevation in Jackson County was 138 meters. The hilly areas in Union County were to the north and north-east regions of the county where the maximum absolute elevation was 314 meters. The central portion of the county, in contrast to Jackson, has a ridge with a mean absolute elevation of 270 meters. The mean absolute elevation in Union County was 150 meters.

Slope. The slope in the study area was not uniform. The areas in Jackson County where there were no hills (central and western portions) had a slope range of 0 to 3%. The desirable slope ranges for viticulture in Jackson County existed close to the Mississippi flood plain and their range was within 3.3 to 9% in the western and northwestern portions of the county. In contrast, the slope in Union County was more varied. Due to the presence of more hilly terrain, the desirable slope ranges for viticulture can be found throughout the central ridge of Union County. The mean slope in Union County was 8.7% compared with 6.0% in Jackson County.

Aspect. The aspect in Jackson County was influenced by the lack of hilly terrain (compared with Union). There were vast areas within the county, especially around the Mississippi and Big Muddy floodplains, and in the eastern portions where aspect was either flat or westerly. In the flat portion of the county (central and western sections) there were vast areas that had either west or southwestern aspects. The aspect in Union County was influenced by the presence of hilly terrain. Although there were flat areas within the floodplain in this county, their distribution was limited only to western boundaries of the county. In the northern reaches of the county, there were many ridge tops with the viticulturally favorable north, northeast or eastern aspects. Especially in the south central portion of the county, although the absolute elevation was lower compared with the northern reaches of the county, there were vast areas with northeastern aspects.

Land Attributes

Current Land Use. The study area is sparsely populated as indicated by the lack of urban development. The southern, western, and southeastern reaches of Jackson County are wooded. The central portion of Jackson County has some urban development but the areas inhabited are not densely populated. The northern reaches including some of the ridge tops in Union County area are wooded. Union County is sparsely populated and has little or no urban development. The land use in Union County is either fallow or in mixed agricultural use.

Soil Internal Water Drainage. The projection of soil internal water drainage in Jackson County varies in its distribution due to presence of the floodplain in its western reaches. The area that had the best internal drainage in Jackson County was east of the floodplain, reaching into the north-central portions of the county. In Union County, the best internal water drainage followed the same soil ridge east of the floodplain that started in Jackson County. There was limited internal water drainage in the floodplain in Union County.

Soil Percent Organic Matter. The soil percent organic matter in both counties of the study area was uniform. In both counties, including the floodplain area the soil organic matter content is characterized as moderate (2 to 3%). In Jackson County, except for the areas covered by large bodies of water and in the depression in the north-central portion of the county, soil organic matter percentage values were uniform.

The Cartographic Model and the SDSS

The SDSS as calculated by the cartographic model (Figure 6) had a resolution of 760 m^2. The presence of the floodplain, lakes, and the flat areas with lower absolute elevation affected the percentage of land suitable for viticulture in Jackson County (Table 3 and Figure 6). The "Best" and "Good" Sites as identified by the SDSS were limited mostly to the western reaches of the county and comprised, respectively, 0.15 and 13.34% of the total land. About 71% of the total acreage in Jackson County was rated "Fair" and "Risky," and about 16% to be "Unsuitable."

In Union County, due to higher mean absolute elevation and inclination of the land, the percentage of total acreage suitable for viticulture was higher than in Jackson County (Table 3 and Figure 6). The sites

TABLE 3. Proportions of total land area identified with viticulture suitability spatial decision support system (SDSS) in Jackson and Union County, Illinois.

Suitability ranking	Hectares		%	
	Jackson	Union	Jackson	Union
Best (85-100 points)	96.85	604.72	0.15	0.39
Good (75-84 points)	8504.67	9650.66	13.34	6.26
Fair (65-74 points)	25507.62	39366.63	40.01	25.53
Risky (55-64 points)	19540.75	65002.94	30.65	42.17
Unsuitable (< 55 points)	10098.35	39530.98	15.84	25.64
Total	63748.24	154155.93	100	100

ranked "Best" and "Good" were spread throughout the eastern three-fourths of the county, but the "Best" sites clustered in the eastern two-thirds and northern one-fourth of the county. Only 25% of the total area was calculated to be "Fair" in Union County.

Application of the SDSS to Existing Commercial Vineyards and Orchards

In the study area, 9 and 75% of the vineyards mapped were ranked, respectively, "Best" and "Good" (Table 4). Only 16% of these vineyards were rated as "Fair" or poorer. Based on the SDSS, and geolocated vineyards; no vineyards were planted in the "Risky" or "Unsuitable" sites. Of the commercial orchards mapped with the GPS (198.5 ha) in the study area, 6 and 45% of the acreage were rated "Best" and "Good," respectively. In contrast to vineyards that were studied, 37 and 10% of the orchard acreage were rated "Fair" and "Risky," respectively. There was even a 2% of orchard acreage located in "Unsuitable" sites.

TABLE 4. Suitability ranking by viticulture suitability spatial decision support system (SDSS) and corresponding acreage of vineyards and orchards in Jackson and Union County, Illinois.

Suitability ranking by SDSS	Surveyed acreage (ha)	Percent of total surveyed acreage (%)
	Vineyards[a]	
Best (85-100 points)	2.2	9
Good (75-84 points)	18.5	75
Fair (65-74 points)	4.0	16
Risky (55-64 points)	0.0	0
Unsuitable (< 55 points)	0.0	0
Total	24.7	~100
	Orchards[b]	
Best (85-100 points)	12.8	6
Good (75-85 points)	89.7	45
Fair (65-75 points)	72.9	37
Risky (55-64 points)	19.9	10
Unsuitable (< 55 points)	3.2	2
Total	198.5	~100

[a]Number of vineyards surveyed (1 in Jackson County; 4 in Union County, IL, 25 ha. total).
[b]Number of orchards surveyed (4 in Jackson County; 2 in Union County, IL, 199 ha. total).

DISCUSSION

Macroclimate Layers

Extreme Minimum Temperature Occurrence. Illinois exemplifies the likelihood of winter injury of grapevines increasing with increasing northern latitudes (Janick et al., 1981) (Figure 1). Northern Illinois is therefore suited to raising only hardy to very hardy French-American hybrid cultivars that will survive temperatures less than −20°F (Dami et al., 2005). The reasoning behind the increasing likelihood of critical winter temperature occurrence as the latitudes increase is that the land (continents) is not a good buffer of air temperature. This is the reason for advective freeze events occurring in continental climates (Janick et al., 1981). In Illinois, occurrence of extreme temperatures is dictated by latitudes.

Growing Degree Day Summation. The GDD distribution is similar to the critical winter temperature occurrence in Illinois. The climate, continental in nature with humid summers, is suitable for raising a variety of crops such as maize and soybeans (Janick et al., 1981), but the kind of crops that can be raised can not be explained just by GDD, as it does not take into account various growth parameters required by horticultural crops such as grapes (Kirk and Hutchinson, 1994). Therefore, GDD was only assigned 10% of the possible points despite no shortage of GDD accumulation even in the northern reaches of the state to ripen the cultivars grown in these regions. However, the length of the growing season (the number of frost-free-days) is more limiting than the GDD accumulation (Wolf, 2003), but raw data were not available for the current model. This variable should be included in future models.

Mesoclimate Layers

Assigning the most points to absolute elevation had an effect on the distribution of suitable sites. Assigning the most points to elevation at the mesoclimate level assists in avoiding lands that are prone to radiative freezes (Geiger, 1966; Boyer, 1998; Wolf, 2003; Wu et al., 2004). The best elevation range identified for the study area (229 to 259 m) is lower than the range identified for Virginia (207 to 457 m) (Boyer and Wolf, 2001). This signifies the “site specific” nature of sustainable grape production in the eastern United States. Slope point distribution also had an impact on the distribution of suitable areas, taking into account cold-air drainage in hilly terrain and flat areas. Aspect selection in the SDSS was affected by the distribution of hilly areas within the study area and is more important for delaying bud break in selected areas. For example, the SDSS avoided flat areas with south or western aspects which would have advanced: (1) Deacclimation (Westwood, 1993), (2) bud break; due to January thaw seen during mid-winter in southern, central, and northern Illinois (Johnstone et al., 1968).

The land attributes studied in the SDSS were limited to the dataset that was available, but identified two of the most important aspects of soil physical properties for vineyard establishment. However, the resolution (625 ha) of the dataset introduced conflation (mismatching of the resolution of two or more data layers in GIS (Chang, 2002)) into the SDSS. In future work, more detailed digital soil maps should measure effective soil depth, and soil pH that will aid in identifying and preparing the site with optimal soil fertility and rooting volume. This can ameliorate decision-making process for site preparation.

Application of Model to Existing Vineyards and Orchards

The areas identified as suitable for viticulture displayed good association based on experience of experts, with the areas studied that are currently in commercial production (Dami and Taylor, 2004, personal communication). For example, in a mixed orchard geolocated in Union County IL, 52% of the acreage that is in production is within the "Good" SDSS ranking according to our cartographic model (Table 4). In the vineyards studied in Union County, 82% of the acreage is within the "Good" or "Best" SDSS ranking according to the cartographic model (Table 4). In another mixed orchard that was studied that lies in between Jackson and Union Counties, 47% of the acreage is within the "Good" SDSS ranking according to the cartographic model (Table 4).

CONCLUSIONS

The digital approach used by this first generation SDSS improves the decision making process to identify suitable sites by selecting: sites that are high in elevation, sites with moderately sloping ground with north, east, or northeastern aspects, and site soils with moderate organic matter percentage and well to moderately well internal water drainage. The SDSS accomplished these objectives digitally with the aid of the high-degree precision GIS, thereby reducing the time and effort that would be spent with site visits by extension personnel and grower consultants.

However, the SDSS is specific for the two counties that were studied and is a first generation model for two counties in Illinois. The application of the SDSS to other regions of Illinois, for example, central and northern regions, would require development of different point distributions for mesoscale climate depiction and different thresholds (°C) for freeze events that matched more winter hardy grape cultivars grown there. The Virginia model (Boyer, 1998; Boyer and Wolf, 2001; Wolf, 2003) used a similar approach where the model was developed in one county then applied to other counties in the state by using point distributions specific to other regions as demanded by the differences in topography. Future work should also involve a sensitivity analysis involving the macroclimate and mesoclimate point distributions, which is lacking from this first generation SDSS. At the mesoclimate level, a detailed survey involving percent of time a damaging frost event, winter kill occurred within the existing commercial plantings is required to calculate the coefficient of determination between the SDSS and the existing commercial plantings and should also be included in future studies.

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