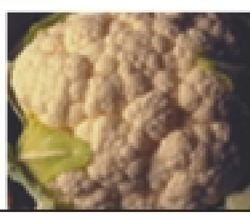
Alternative Crops *for the* Big Horn Basin, Wyoming

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Introduction

The Big Horn Basin (Big Horn, Park, and Washakie Counties) accounts for 27 percent of the crop production value in Wyoming (Wyoming Agricultural Statistics Service, 1998). Sugar beet, alfalfa seed, and barley are three high value crops in the region that are produced commercially, while the remaining products, such as spring wheat, silage corn, and dry beans (primarily grown as staple crops) result in lower economic returns. The viability of some of these cash crops (e.g., sugar beet) is threatened periodically (e.g., short rotations) as pest cycles interrupt productivity (Koch et al., 1995). Breaking these cycles and still maintaining high profit margins merits investigation. Not only is economic diversification important to Wyoming, but with approximately 20 crops supplying our world's food supply, the probability for catastrophic events to impact agricultural production of one or more staple crops is high.

The production of alternative crops in the basin is one possible solution for enhancing the commercial agriculture base of this important agronomic region. Crops that might be cultivated in the area must be identified in order for growers to consider new agricultural production potentials. Alternative crops, such as amaranth, buckwheat, canola, and faba bean, could provide an opportunity for agriculturalists to increase income while breaking weed and pest cycles; additional factors that must be considered include specialized equipment, specific management practices involving soil fertility, irrigation, availability of herbicides, and rotation effects, as well as market availability. Identification of alternative crops based on crop growth modeling is an initial step in diversifying the agricultural commodities in the Big Horn Basin. Techniques demonstrated in this project may be used to support diversification of food production capabilities in other regions.

The goal of this project was to develop maps of areas within the Big Horn Basin that could potentially support new or alternative crops. The study was designed to use GIS, specifically ARC/INFO and ArcView (ESRI, Redlands, CA), to investigate alternative crops for the region. Environmental traits (e.g., soils, temperature, and length of growing season) will dictate where various crops can be produced. Maps developed in this study will provide Big Horn Basin producers with potential alternatives to current crop production practices. Objectives of this study were to develop a soils layer for the Big Horn Basin study area, create continuous data layers of 31 climatic variables, determine crop growth parameters for 28 agricultural crops, and combine growth parameters with environmental data to display and describe areas of possible alternative crop production.

Materials and methods

Site description

The Big Horn Basin is located in the northwestern corner of Wyoming (Figure 1). It consists of three counties and is a major agricultural region within the state. The study area consists of approximately 1,900,000 acres or about 3,000 square miles. The relatively low elevation of the area, in comparison to the rest of the state, results in the region having less than 90 to more than 120 frost-free days (Western Regional Climate Center, 1998).

The 1:24,000 USGS topographic quadrangle maps and the Wyoming State Land Cover Classification (Spatial Data and Visualization Center, 1998) were utilized to prepare land coverage and characteristics of the study area. As this study focuses on the possible production of alternative crops, and because crop production in the area requires irrigation, areas with slopes exceeding five percent were eliminated by examination of topographic maps. Those lands already in agricultural production would be prime candidates for alternative crop production; therefore, only quadrangles with greater than 25 percent agricultural land were selected. However, ground-truthing efforts in May 1998 indicated certain areas should be excluded because they possessed little agricultural production potential due to topography or lack of irrigation water. The final study area consisted of a total of 59 7.5-minute USGS quadrangle maps.

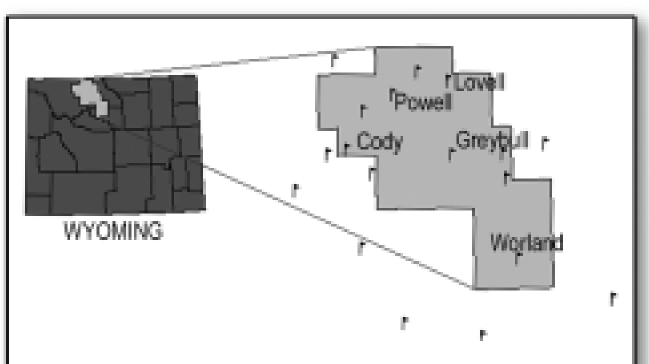

Figure 1. Location of the study area and weather stations within the Big Horn Basin, Wyoming. Weather stations are noted as flags.

Soils description

Published soil survey data was not available for a majority of the study area; only soils in Washakie County have been surveyed in detail (Iiams, 1983). To utilize soils information, a GIS-derived soils map was generated using Big Horn Basin bedrock geology, surficial geology, and elevation properties (Spatial Data and Visualization Center, 1998). Soil series mapped in Washakie County (Iiams, 1983) were examined to determine the bedrock and surficial geology combinations upon which they occurred. These combinations were used to predict soils for the rest of the study area. As these soil series did not account for the entire Big Horn Basin study area, other geologic combinations were applied to the model, utilizing decision rules that were developed using Arc Macro Language (Munn and Arneson, 1998). Based on this method, every bedrock or surficial geology combination in the study area was assigned a soil family classification. A representative soils series was assigned to each family from series currently mapped in Wyoming. The predicted soils map was field checked and updated to correct variations between the model-generated map and field results.

Climate data

Eighteen weather stations exist in and around the study area (Figure 1). These stations have been collecting weather data for 30 years or longer (Western Regional Climate Center, 1998). The weather station locations and attributes were used to create continuous weather patterns for the basin; contour lines were generated from the point data utilizing geostatistics. Geostatistics has proven to be advantageous when compared to other methods of extrapolation (Kravchenko et al., 1996). Semi-variograms of each environmental attribute were plotted, and cross validation and kriging techniques were applied. The result produced a grid layer for each climatic attribute with values assigned to the different points within the grid layer. This information was entered into ArcView and continuous grid data layers were created for each climatic variable. Six classes were used in the climatic layers to best illustrate the general characteristics that would affect crop growth, rather than the subtle differences. For a detailed description of the creation of the climatic data, refer to Agricultural Experiment Station Bulletin B-1089 (Young et al., 2000b).

Crop growth parameters

The crop growth parameters for the 28 crops modeled were derived through documented sources. Many of the parameters used to compile a list of growth requirements for each crop were taken from Purdue University's Web site ("Center for New Crops and Plant Products," 1998). Other sources of information were the Cooperative Extension publications from various university Web sites (Young et al., 2000a).

Model formation

The software used in collecting and analyzing the data was ARC/INFO version 7.1.2 and ArcView 3.1 (ESRI, Redlands, CA). Once the data were compiled into the GIS, analysis was performed using map algebra. The parameters queried included items such as length of frost-free season, soil type, maximum July temperature, and minimum September temperature. Areas with the desired crop growth parameter combinations for each crop were identified and mapped.

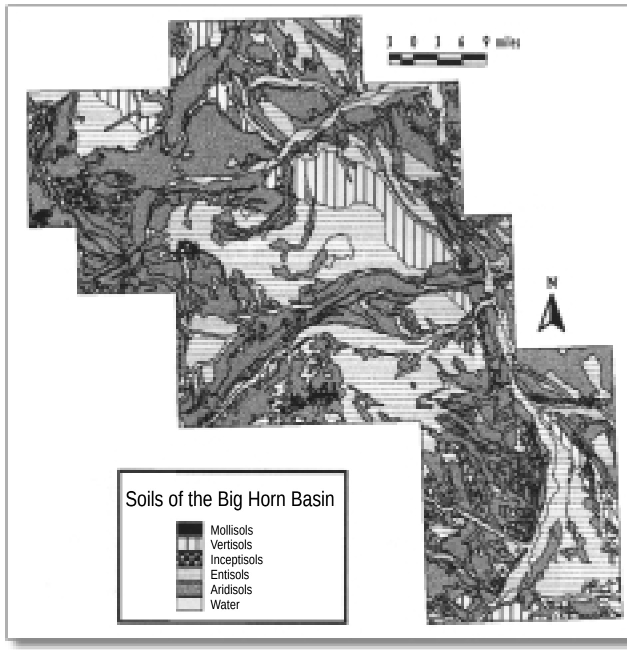

Figure 2. Soils map of the Big Horn Basin study area derived from surficial geology, bedrock geology, and elevation.

Results and discussion

Soil model

The GIS-based soil map included 19 different soil associations and water (Figure 2). The lowland areas where agriculture currently occurs are mostly comprised of Torrifluvents and Haplargids. The higher elevation soils, where agricultural practices are primarily livestock grazing and forestry, consist of Argicryolls and Cryepts. Ground-truthing conducted in May 1998 confirmed that the GIS-based soils map created with a landscape/geology model was accurate after minor revision to accommodate field variations. Creation of the soils data layer allowed for the use of textural classes in the alternative crop analysis.

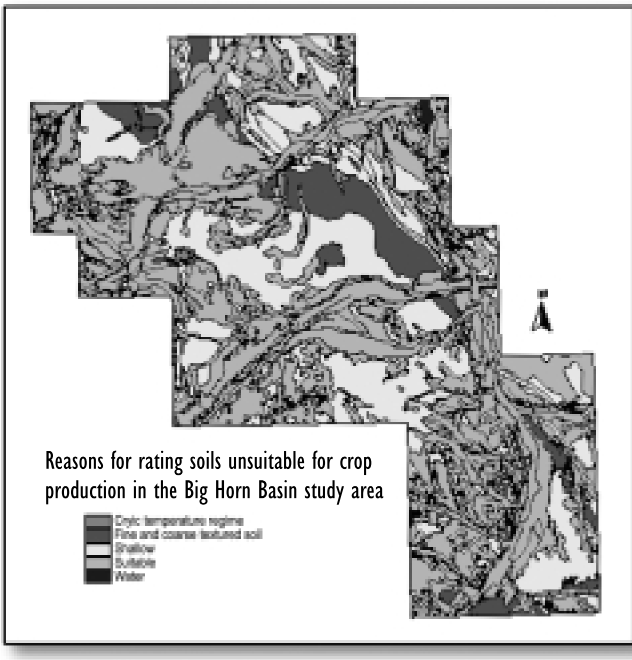

Figure 3. Reasons for rating soils unsuitable for crop production in the Big Horn Basin study area based upon soil temperature regime, soil texture, depth to bedrock, and open water.

From the soils map, researchers have determined that a large proportion of the land is classified as Torrifluvents—soils on which a significant amount of irrigated agriculture currently occurs in the Big Horn Basin. In an arid region, crop development commonly occurs in flood-plain soils. Other soils in the study area are not conducive to crop growth, even with irrigation. These are soils that are cold, have a high shrink-swell tendency, possess too low of a water-holding capacity, or are shallow to bedrock and, therefore, were eliminated from analysis, as they are not capable of profitable crop growth (Figure 3). The remaining soils will be referred to as suitable soils for crop production because they do not possess any major limitations to crop growth. They are deep (greater than 3 feet) and have a texture conducive (not fine- or coarse-textured) to plant growth. Soils suitable for crop growth account for 62 percent of the study area. Water availability (irrigation capabilities) was not investigated in this study.

Environmental data

The continuous layers representing the climatic variables were prepared using geostatistics. Thirty-one continuous layers (Table 1) were developed for climatic variables representing the Big Horn Basin, of which 20 were used in the crop modeling simulations. Summer precipitation, June maximum temperature, and 90 percent chance of frost-free period are shown in Figure 4 to illustrate the various climatic attributes used in determining the areas where new or alternative crops could possibly grow. These contour maps are related to the topography of the surrounding study area; i.e., with an increase in elevation, there is a decrease in frost-free period, a decrease in growing degree-days, an increase in precipitation, and a decrease in temperature. The final products of the geostatistical analysis are spatially referenced climatic maps that enable potential areas of alternative crop growth to be determined when suitable soil and environmental parameters are identified.

Crop growth parameters

Information provided in Table 2 was used to predict areas in the Big Horn Basin that are potentially suited for the production of a particular alternative crop. Information pertaining to suitable soils was used for each crop, and all modeling efforts assumed that irrigation water would be available. Climatic variables listed in Table 1 were used to narrow the areas where the individual crops may be grown. The approach developed in this study is versatile. As additional crop growth parameters are obtained, they can be included in the table

Table 1. Climatic variables in the Big Horn Basin, Wyoming, evaluated using statistical and geostatistical methods. Climatic variables used as crop growth parameters in the modeling of areas potentially capable of alternative crop production are shown in bold.

Annual precipitation	Number of days in August exceeding 90°F
Summer precipitation	**September minimum temperature**
May minimum temperature	**September mean temperature**
May mean temperature	September maximum temperature
May maximum temperature	**Summer mean temperature**
June minimum temperature	Shortest frost-free period (32°F)
June mean temperature	**90% chance of frost-free period (32°F)**
June maximum temperature	**80% chance of frost-free period (32°F)**
Number of days in June exceeding 90°F	Shortest frost-free period (28°F)
July minimum temperature	**90% chance of frost-free period (28°F)**
July mean temperature	80% chance of frost-free period (28°F)
July maximum temperature	**Growing degree-days (Base 40°F)**
Number of days in July exceeding 90°F	Growing degree-days (Base 45°F)
August minimum temperature	Growing degree-days (Base 50°F)
August mean temperature	Growing degree-days (Base 55°F)
August maximum temperature	

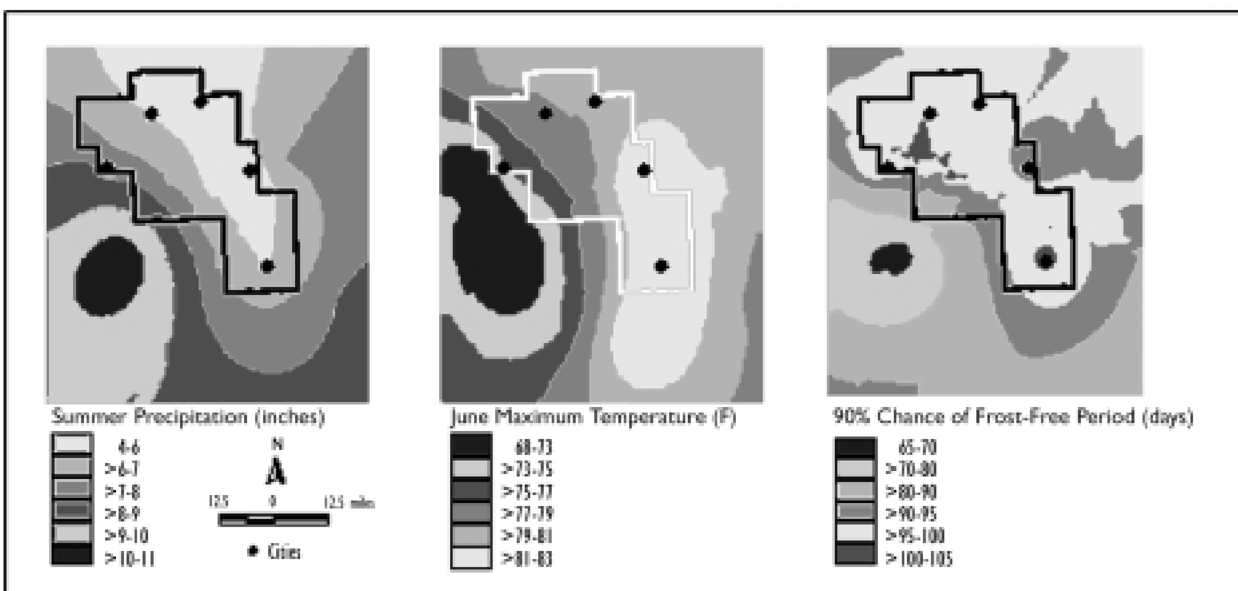

Figure 4. Selected climatic data layers derived from geostatistical analysis of Big Horn Basin weather station data. See Figure 1 for city identification.

Table 2. Crop growth parameters used for predicting areas with soil and temperature conditions appropriate for production of alternative crops in the Big Horn Basin, Wyoming. Parameters used to determine the potential areas for alternative crop production are shown in bold. See Table 3 for scientific names.

Crop	Soil *characteristics*[1]	Temperature (T) *considerations*[2]	Precipitation/irrigation requirements	Comments[3]	References
Amaranth	**Suitable soils**, pH ~ 6	**≥95 d 90% FFP (32F), JJA min T ≥ 50F w/max T ≥70F**, optimum germination at 65–70F	Drought tolerant, reduced **irrigation** requirements	**>95 d GS**, frost required after maturity	6, 26, 30,36
Asparagus	**Suitable soils**, pH > 6, loams but not clays	**MJJA max T ≤ 90F, mean summer T 65–75F**,	Requires **irrigation**	**> 60 d GS**, need 3 GS to harvest, best where soils freeze ~ 3 inches	7, 13, 23, 24, 25
Beet	**Suitable soils**, pH 6–7.6, well-drained	**≥75 d 90% FFP (32F), optimum mean summer T 55–72F**	Requires **irrigation**	**50–90 d GS**, tolerates frost & light freeze	23
Broccoli	**Suitable soils**, pH 6–8	**MJJ Max T ≤ 85F, optimum mean summer T 40–70C**	Requires **irrigation**	**>105 d GS**, frost tolerant	6, 18, 23
Buckwheat	**Suitable soils**, prefers medium-textured soils	**≥75 d 90% FFP (32FC), < 9 d in July over 90F**, T > 77F reduces seed set & yield	Requires **irrigation**, sensitive to drought stress	**75–90 d GS, GDD 1,200 d (base T 40F)**, easily killed by frost	6, 22, 28
Cabbage	**Suitable soils**, pH 6–8	**≥75 d 90% FFP (28F), JJA mean T 69–73F**	Requires **irrigation**	**75–110 d GS**, tolerates moderate frost	23, 32
Canola	**Suitable soils**, prefers medium-textured soils	**≥90 d 90% FFP (32F), < 11 d in July over 90F, September min T ≥ 41F**, prefers < 77F during flowering	>12 inch precipitation for dryland, requires **irrigation**	**72–104 d GS, 860–920 GDD (base T 40F)**	4, 20
Carrot	**Suitable soils**, pH 6.5–7.8 mineral & 5.5–6.8 organic soils	**JJA mean T > 60F but < 70F, July & August min T > 50F**	minimum 12 inch precipitation, requires **irrigation**	**> 60 d GS**	6, 21
Cauliflower	**Suitable soils**, pH 6–8	**≥55 d 90% FFP (32F), JJA mean T ≤ 68F**, prefers cooler T	Requires **irrigation**	**50–70 d GS**, tolerates light frost	6
Chickpea	**Suitable soils**, pH 5.5–8.6, well-drained	**MJJ Min T ≥ 40F**, optimum mean T 65–75F	Needs 25-40 inch precipitation, requires **irrigation**	**> 90 d GS**, some tolerance to early frosts	6, 7
Cowpea	**Suitable soils**, pH 4.3–7.9, salt intolerant	**≥90 d 90% FFP (32F), MJJ max T ≥ 55F**, optimum T 55–82F	Drought resistant, requires **irrigation**	**>90 d GS**, sensitive to frost	33
Crambe	**Suitable soils**, pH 5–7.8, wet soils unsuitable	**MJJA max T ≤ 86F with mean T 43–70F**	Somewhat drought tolerant, requires **irrigation**	**100 d GS**, seedlings tolerant to < 24F	6, 21
Faba bean	**Suitable soils**, pH 4.5–8.3, acid tolerant	**MJJA max T ≥ 65F, JJA mean T 60–80F**	Needs 25–40 inch precipitation, requires **irrigation**	May wilt at T > 95F	6, 29, 33

Crop	Soil *characteristics*[1]	Temperature (T) *considerations*[2]	Precipitation/irrigation requirements	Comments[3]	References
Field pea	**Suitable soils**, pH 5.5–7.5, salt intolerant	**≥90 d 90% FFP (28F), MJJ max T < 90F, June mean T 55–66F**	20 inch **irrigation** requirement	**52–90 d GS**, withstands heavy frosts	5, 33
Kentucky bluegrass turf seed	**Suitable soils**, pH 4.5–8.5, adapted to most soils	**May & June max T ≤ 77F, mean summer T < 75F**	Drought tolerant, requires **irrigation**	**65–85 d GS**, good cold tolerance	1, 7, 11
Leek	**Suitable soils**, pH ~ 6.5, does best in organic rich, nonacid soils	**≥105 d 90% FFP (28F), May & June max T ≤ 77F**	Requires **irrigation**	**105 d GS**, can tolerate cold conditions	15
Lentil	**Suitable soils**, pH 4.5–8.2, prefers medium-textured soils	**≥80 d 90% FFP (32F), May & June max T ≤ 80F, August mean T ≤ 70F**	Needs 12–18 inches precipitation, requires **irrigation**	**>80 d GS**, tolerant to early frosts	5, 7, 27
Lettuce	**Suitable soils**, pH 6–6.8 mineral & 4–6 organic soils	**May & June mean T 45–65F, August & September mean T ≤ 70F**	Needs 10-12 inch precipitation, requires **irrigation**	**65–80 d GS**, tolerates moderate freeze	6
Medic	**Suitable soils**, pH 6.8–9	**≥120 d 90% FFP (26F)**	Need 15–20 inch precipitation, requires **irrigation**	**>120 d GS**, tolerates cold conditions	33, 35
Mint	**Suitable soils**, pH > 6, prefers well-drained, deep soils	**≥110 d 90% FFP (28F), MJJA max T ≥ 68F & ≤ 86F**	Requires **irrigation**	Can tolerate cold T as low as 10F	9, 12
Onion	**Suitable soils**, pH ~ 6.6, prefers fertile soils	**≥110 d 90% FFP (28F), MJJA mean T ≥ 55F**	Requires **irrigation**	**>90 d GS**, can tolerate cold T as low as 20F	13, 32
Quinoa	**Suitable soils**, pH 4.5–9.5	**≥100 d 90% FFP (32F)**	Needs 12–40 inches precipitation, requires **irrigation**	**100 d GS**, can tolerate cold T as low as 23F	6
Radish	**Suitable soils**, pH 6–8, well-drained soils	**May min T > 4C, June mean T ≥ 60 to 65F**	Requires **irrigation**	**21–42 d GS**	6, 34
Safflower	**Suitable soils**, pH 5.4–8.2, adapted to many soils	**≥110 d 80% FFP (32FC), mean summer T 43–80F**	Needs 8–50 inch precipitation, requires **irrigation**	**110 d GS**, requires above-freezing T	6
Sesame	**Suitable soils**, pH 4.3–8.7, prefers fertile soils, intolerant to salt & wet conditions	**JJA max T ≤ 90F, summer mean T 70–80F**	Needs 50-65 cm precipitation, requires **irrigation**	**>90 d GS**, needs warm growing season	6
Sorghum	**Suitable soils**, pH 5.5–7.5	**MJJA max T ≥ 70F**	Somewhat drought & salt tolerant, requires **irrigation**	**>95 d GS**, frost sensitive	3, 7, 8
Sunflower	**Suitable soils**, pH 4.5–8.7, adapted to most soils	**≥90 d 90% FFP (32F), June min T ≥ 50F**	Drought tolerant, 8-160 inch precipitation, requires **irrigation**	**90 d GS**, sensitive to cold (32F)	6, 10, 23
Tall fescue	**Suitable soils**, pH 5.5–8.5, prefers heavy, medium-textured soils	**≥95 d 90% FFP (32F)**	Needs ≥ 18 inches precipitation, requires **irrigation**	**>95 d GS**	2, 7

[1] See Figure 3 for areas classified as having suitable soils.
[2] FFP = frost-free period using 32°F or 28°F base temperatures; MJJAS = May, June, July, August, and September.
[3] GS = length of growing season; GDD = growing degree-days.

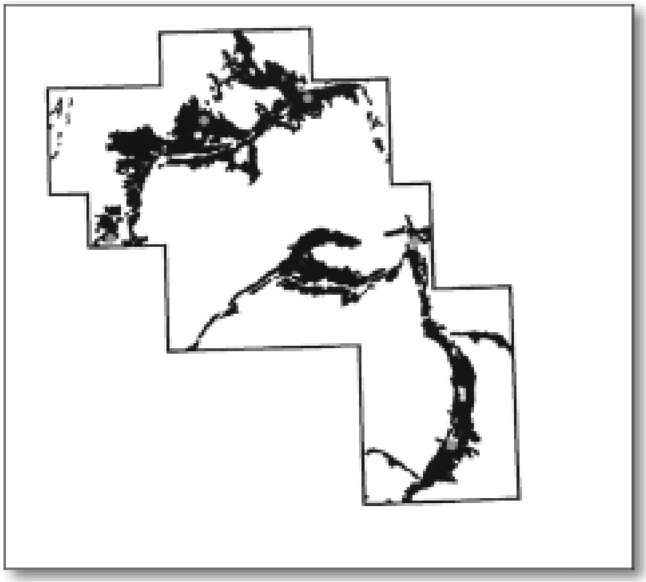

Figure 5. Lands currently under irrigated agricultural production shown in black (adapted from the Spatial Data and Visualization Center, University of Wyoming, 1998). See Figure 1 for identification of cities.

of soil and climatic conditions required by the alternative crop. A new simulation can be completed rapidly, resulting in a refinement of the suitable areas in the Big Horn Basin that could be used for the alternative crop production.

Although the search for alternative crop growth requirements resulted in a vast amount of information, much of the acquired data was considerably general. While common growth requirements were identified for different crops, particular conditions pertaining to specific crop varieties were not available for use. The growth parameters for each crop are a broad categorization of what each crop would require for proper growth and development. More detailed parameters relating to the exact crop variety being considered should be investigated thoroughly before attempting actual production.

Production potential in the Big Horn Basin

Land currently under irrigated agricultural production (Figure 5) was identified through aerial photo interpretation (Spatial Data and Visualization Center, 1998). To test the validity of the crop growth model, the four major crops grown in the region were researched. The crop growth requirements for alfalfa, barley, dry beans, and sugar beets were evaluated using the crop growth model. Figure 6 illustrates the areas suitable for production of the four major crops currently grown in the Big Horn Basin. The area outlined, overlaying the predicted growth areas, is the land currently in agricultural production (Spatial Data and Visualization Center, 1998). The difference between the actual production and predicted areas of crop growth can be attributed to irrigation capabilities. The low amount of annual precipitation in the study area dictates that dryland agriculture is generally not feasible. Therefore, all agriculture potential in the area assumes that adequate irrigation water is present for crop production.

Altogether, 28 crops were modeled for possible production in the Big Horn Basin (Tables 2 and 3). The areas potentially capable of alternative crop production are displayed in Figures 7 to 13. Figures 7 and 8 display those crops that have potential for production on suitable soils in the eastern part of the study area, while Figures 9, 10, and 11 illustrate plants that prefer suitable soils in the western area. The crops that could possibly be grown on suitable soils throughout the study area are shown in Figures 12 and 13. In addition to the 28 alternative crops listed in Tables 2 and 3, guayule, jojoba, and meadowfoam were

Table 3. Predicted area for alternative crop production in the Big Horn Basin.

Crop	Scientific name	Predicted area (ac)
Warm area crops		
Amaranth	*Amaranthus cruentus* L.	167,000
Chickpea	*Cicer arietinum* L.	465,000
Onion	*Allium cepa* L.	644,000
Quinoa	*Chenopodium quinoa* Willd.	67,000
Safflower	*Carthamus tinctorius* L.	586,000
Sesame	*Sesamum indicum* L.	143,000
Sorghum	*Sorghum bicolor* (L.) Moench	513,000
Sunflower	*Helianthus annuus* L.	207,000
Cool area crops		
Broccoli	*Brassica oleracea* L. var. *indica* Plenck	462,000
Buckwheat	*Fagopyrum esculentum* Moench	297,000
Canola	*Brassica napus*	281,000
Carrot	*Daucus carota* L.	460,000
Cauliflower	*Brassica oleracea* L. var. *botrytis* L.	84,000
Crambe	*Crambe abyssinica* Hochst. Ex R.E.Fr.	462,000
Kentucky bluegrass turf seed	*Poa pratensis* L.	43,000
Leek	*Allium porrum* L.	220,000
Lentil	*Lens culinaris* Medik.	750,000
Lettuce	*Lactuca sativa* L.	738,000
Mint	*Mentha piperita* L.	87,000
Radish	*Raphanus sativus* L.	720,000
Crops adapted to entire area		
Asparagus	*Asparagus officinalis* L.	957,000
Beet	*Beta vulgaris* L. subsp. *vulgaris*	1,173,000
Cabbage	*Brassica oleracea* L. var. *capitata* L.	1,157,000
Cowpea	*Vigna unguiculata* (L.) Walp. subsp. *unguiculata*	1,143,000
Faba bean	*Vicia faba* L. var. *faba*	1,155,000
Field pea	*Pisum sativum* L.	1,093,000
Medic seed	*Medicago truncatula* Gaertn.	907,000
Tall fescue turf seed	*Festuca arundinacea* Schreb.	973,000

initially considered in this study, but due to soil and, in particular, climatic condition requirements, their adaptability in the Big Horn Basin was concluded to be unfeasible.

Four of the 28 crops will be illustrated in greater detail for the purpose of defining how specific crop growth parameters were used to identify areas conducive to their production. The four crops considered were amaranth, buckwheat, canola, and faba bean, with their potential production areas shown in Figures 7, 9, and 13. Amaranth was selected to determine if warm season crops have the potential to be introduced into the region; buckwheat was modeled because it is a popular alternative crop; canola was chosen because it has successfully been introduced into Montana agriculture; and faba bean was studied because other beans are currently grown throughout the Big Horn Basin.

Amaranth requires a frost-free period (base 32 degrees Fahrenheit) of 95 days or more; no June, July, or August monthly minimum temperatures below 50 degrees Fahrenheit or maximum temperatures greater than 70 degrees Fahrenheit; a growing season of 95 or more days; and suitable soils (see Figure 7). Table 3 indicates amaranth may be produced on about 167,000 acres in the Big Horn Basin. Buckwheat production requires a frost-free period (base 32 degrees Fahrenheit) of 75

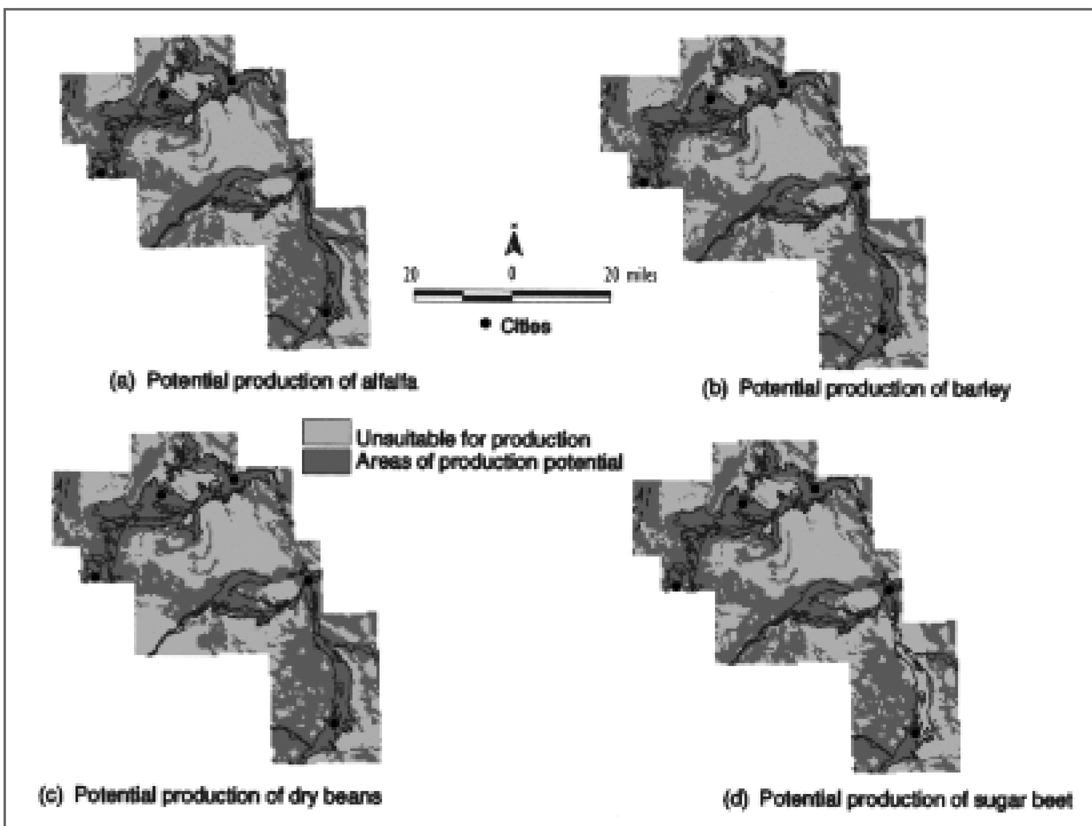

Figure 6. Predicted area of crop growth for the four main crops currently under production in the Big Horn Basin. See Figure 1 for city identification and Figure 5 for areas currently used for irrigated agricultural production.

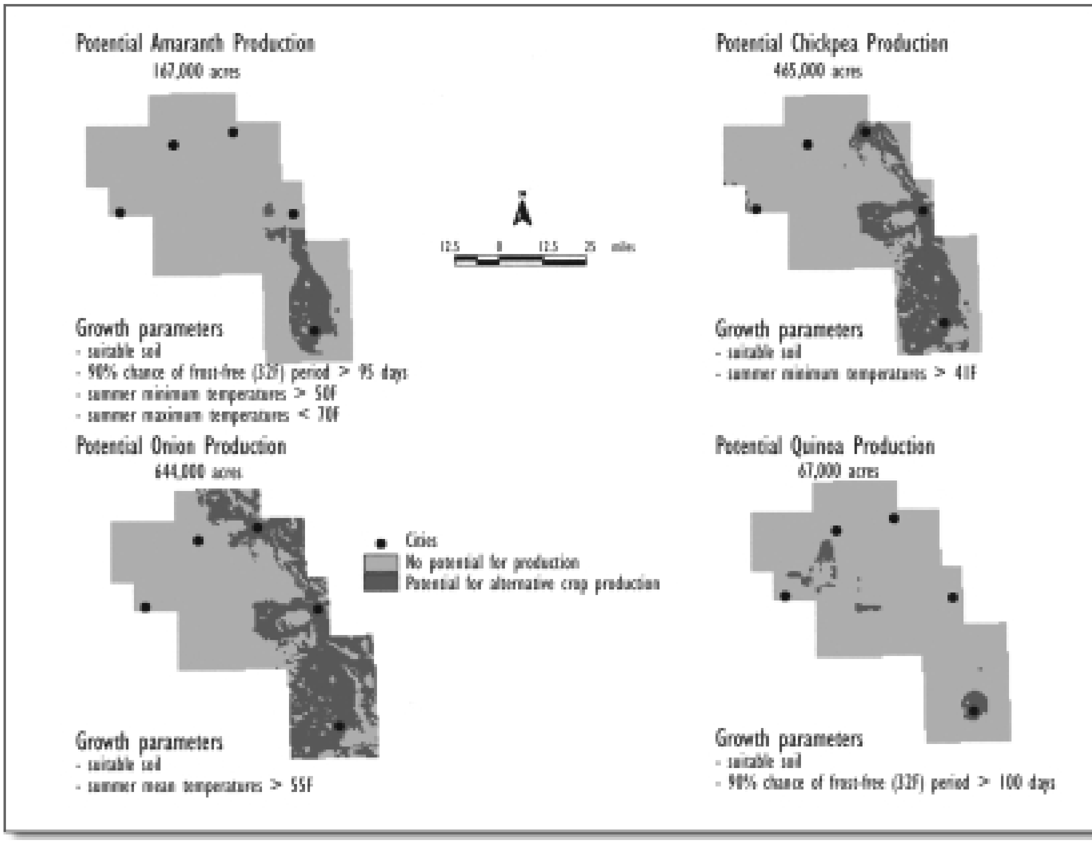

Figure 7. Potential production area for amaranth, chickpea, onion, and quinoa in the Big Horn Basin. See Figure 1 for city identification.

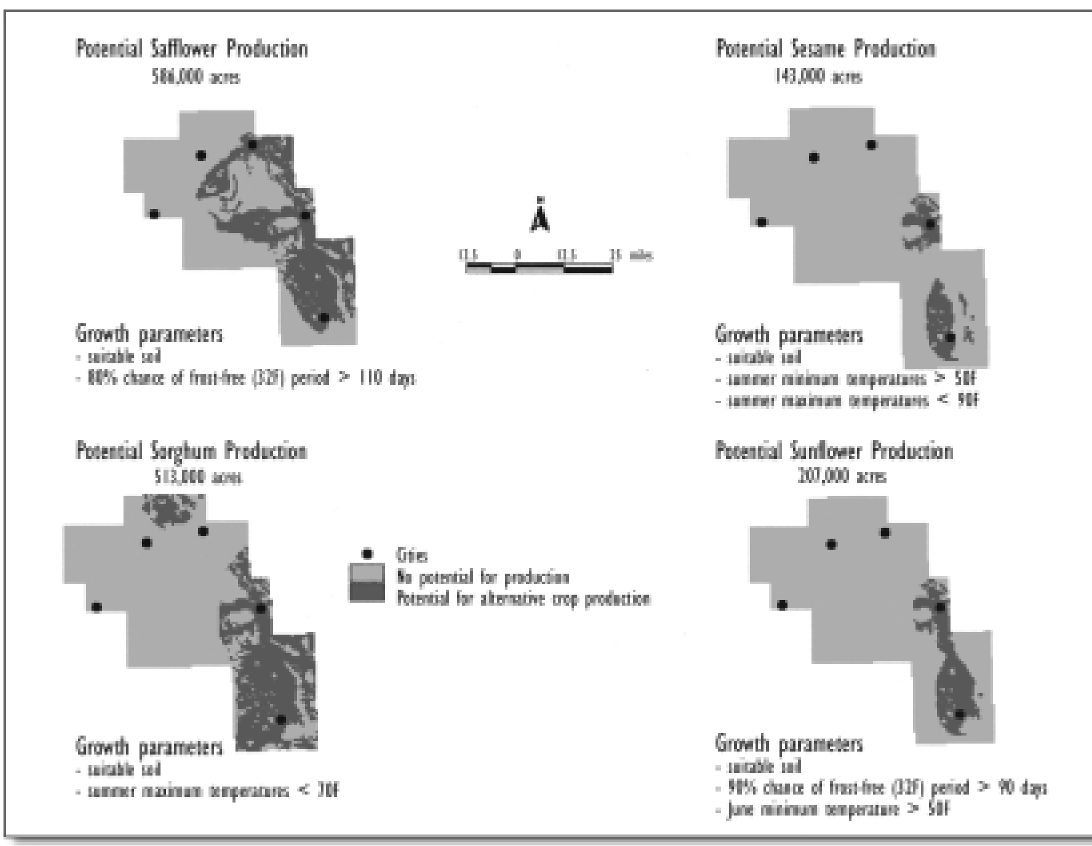

Figure 8. Potential production area for safflower, sesame, sorghum, and sunflower in the Big Horn Basin. See Figure 1 for city identification.

days or more; no more than 9 days over 90 degrees Fahrenheit in July; a 75 to 90 day growing season; 1,200 growing degree days using a base temperature of 40 degrees Fahrenheit; and suitable soils, including no soils with a clay-texture family classification (Figure 9). The potential area for buckwheat production is approximately 297,000 acres in the Big Horn Basin (Table 3). Canola production requires a frost-free period (32 degrees Fahrenheit or greater) of 90 days or more, no more than 11 days over 90 degrees Fahrenheit in July, no September minimum temperatures below 40 degrees Fahrenheit, a 72 to 104 day growing season, growing degree days of 860 to 920 days using a base temperature of 40 degrees Fahrenheit, and suitable soils with no fine-textured family classification (Figure 9). With these requirements, nearly 281,000 acres are potentially suited for canola production in the Big Horn Basin (Table 3). Faba bean production requires May, June, July, and August maximum temperatures greater than or equal to 65 degrees Fahrenheit; June, July, and August mean temperatures between 60 and 80 degrees Fahrenheit; and suitable soils (Figure 13). Potential production area consists of more than 1,100,000 acres in the Big Horn Basin (Table 3).

Predictions of areas suited to the 28 crops studied suggested that the eight alternative crops modeled (amaranth, chickpea, onion, quinoa, safflower, sesame, sorghum, and sunflower) are adapted to the soil and climate conditions of the eastern part of the Big Horn Basin (see Figures 7 and 8). This is the warmest area and has the longest frost-free period. These crops require more heat to develop than the cool season crops. Several of these warm season crops cannot tolerate cold temperatures in the months of May, June, and July, or they need the warmer mean monthly temperatures that are found in the eastern region of the study area. Table 3 lists the extent of the area that may be used for the warm area crops.

Several of the crops modeled in this study prefer cooler climatic condition and include broccoli, buckwheat, canola, carrot, cauliflower, crambe, Kentucky bluegrass turf seed, leek, lentil, lettuce, mint, and radish (Figures 9, 10, and 11). These are cool season crops that prefer less heat during the growing period. Because of this preference for cooler temperatures, potential production of these crops may be possible in the western portion of the Big Horn Basin. Monthly maximum temperatures often limit the regions where these crops may be grown; maximum May, June, July, and August temperatures generally need to be below 85 degrees Fahrenheit with cooler mean summer temperatures. Many of these crops also have short growing seasons that range from as little as 21 days for radish to 90 days for buckwheat, unless the crop is tolerant to frost conditions, which can extend the growing season to more than 100 days.

In the modeling efforts, researchers also identified eight crops (asparagus, *Asparagus officinalis*; beet, *Beta vulgaris*; cabbage, *Brassica oleracea* L.; cowpea, *Vigna unguiculata*; faba bean, field pea, *Pisum sativum*; medic seed, *Medicago truncatula*; and tall fescue turf seed, *Festuca arundinacea*) that may potentially be cultivated throughout the study area on suitable soils if irrigation water is available (Figures 12 and 13). These crops tend to have broad temperature ranges, allowing them to be adapted to a large portion of the Big Horn Basin. Fewer climate restrictions, such as monthly minimum, mean, or

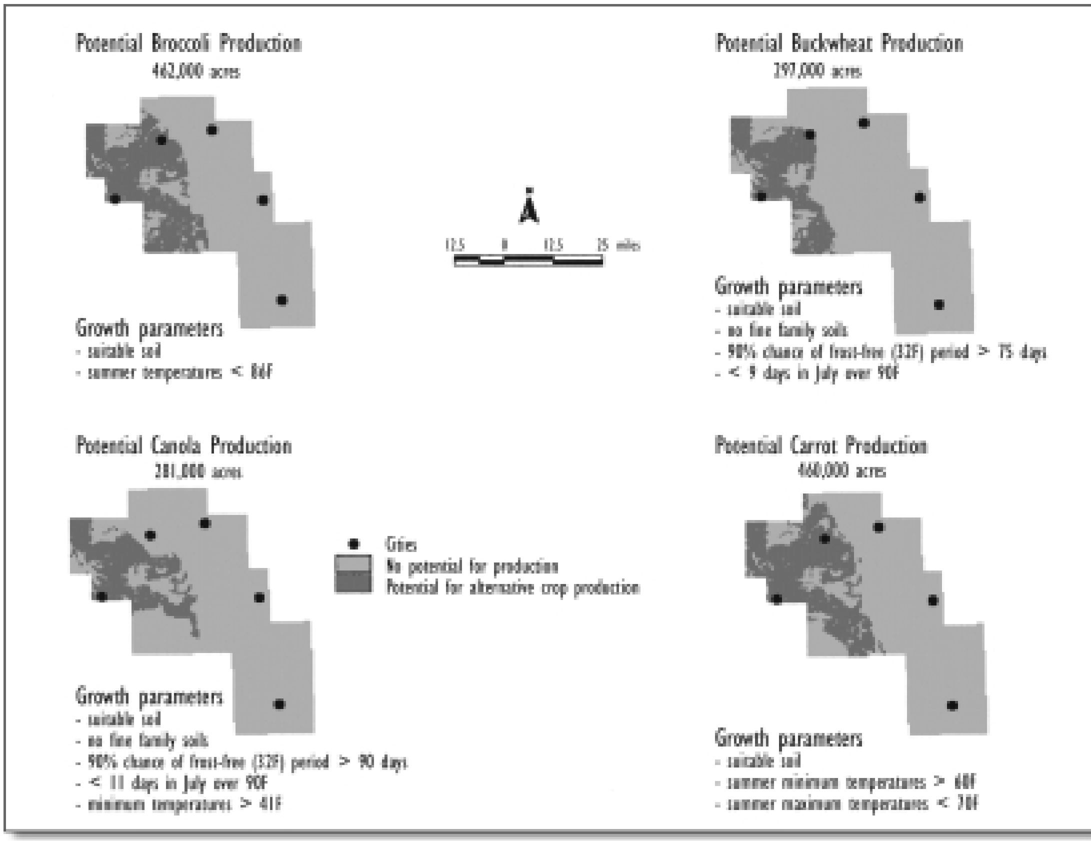

Figure 9. Potential production area for broccoli, buckwheat, canola, and carrot in the Big Horn Basin. See Figure 1 for city identification.

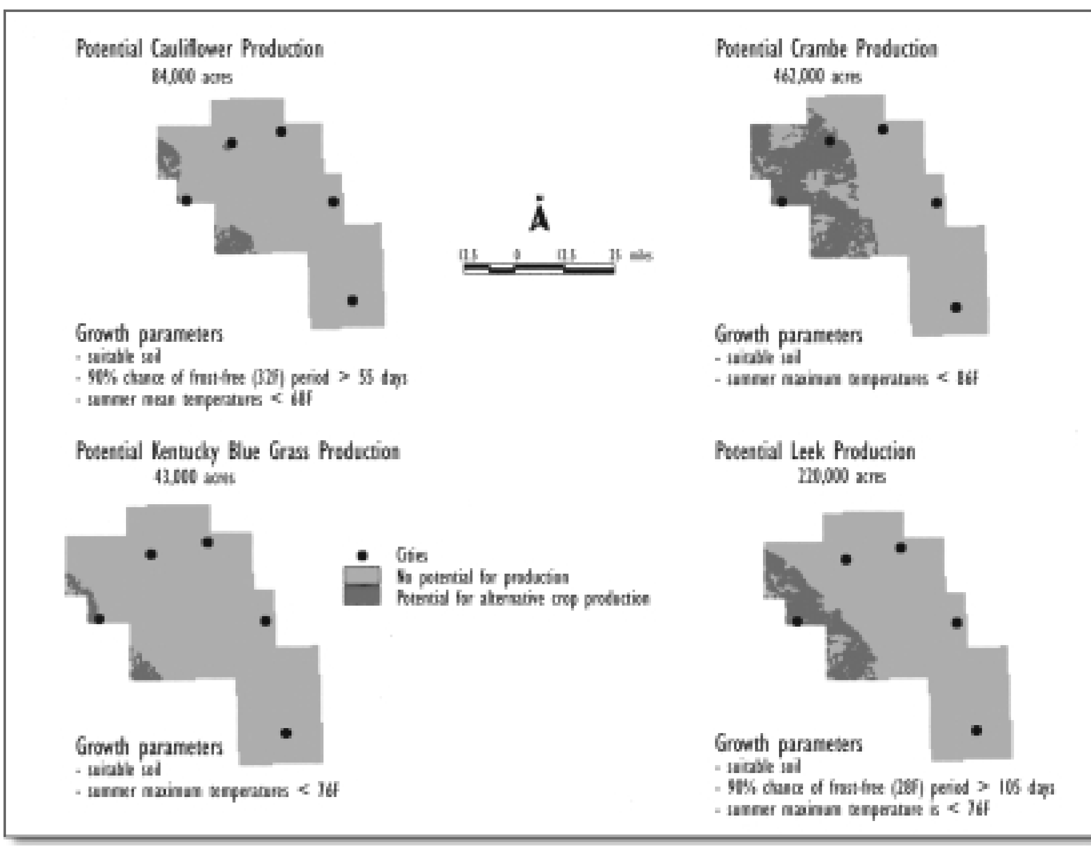

Figure 10. Potential production area for cauliflower, crambe, Kentucky blue grass, and leek in the Big Horn Basin. See Figure 1 for city identification.

maximum temperatures, allow these crops to be adapted to regions within the Big Horn Basin study area that could enhance the regions agronomical diversity.

According to a former Park County Cooperative Extension Educator (J. Jenkins, 1998), the Big Horn Basin has soil, water, and climatic conditions that will allow the production of a variety of new and alternative crops that are currently not cultivated in the area. Many of the crops investigated could possibly be grown in parts of the study area; however, not all of these crops will prove economically successful. For example, some crops may grow in the area but may not produce profitable yields. For others, marketing capabilities may be extremely limited. Economic analysis of the feasibility of producing the alternative crops evaluated in this study is essential before field trials. A crop yield model should be employed to predict whether an alternative crop could compete in the marketplace. In addition, some crops may cause unplanned problems for the farmer. For example, if canola, which is an alternative host for the sugar beet nematode (Koch et al., 1995), is grown in rotations with sugar beet the nematode could overwinter in the roots of canola, resulting in a potential problem to the following year's sugar beet crop. Concerns related to alternative hosts, susceptibility to diseases currently in the Big Horn Basin, cultural practices, and production capabilities are some of the issues requiring further research before attempting to introduce an alternative crop into the region.

Conclusion

A Geographic Information System (GIS) was used to combine spatial data to identify areas with unique combinations of environmental characteristics (e.g., soils, temperature, length of growing season) for possible introduction of new crops. A soils data layer was developed using a predictive model based on the region's surficial geology, bedrock geology, and elevation.

Monthly minimum, mean, and maximum summer temperatures; precipitation; growing degree-days; and frost-free season were obtained from National Climate Data Center weather stations located in the Big Horn Basin. Climatic data from the weather stations was extrapolated using geostatistics to develop continuous data layers of 31 climatic variables for the study area, of which 20 were used in the crop growth model simulations.

The Big Horn Basin of Wyoming has soil and climatic conditions conducive to producing a variety of agricultural crops because of its longer growing season (in comparison to the rest of the state) and availability of irrigation water. The opportunity exists for crop diversification to break pest cycles, limit pesticide use, and increase agricultural profits. Soils suitable for irrigated crop production comprise 62 percent of the Big Horn Basin study area. Growth parameters identified for 28 new crops included combinations of soil and climate conditions. Maps of alternative crop production areas suggested that 8 crops (amaranth, chickpea, onion, quinoa, safflower, sesame, sorghum, and sunflower) could potentially be cultivated in eastern Big Horn Basin where temperatures are warmest, another 12 crops (broccoli, buckwheat, canola, carrot, cauliflower, crambe, Kentucky bluegrass turf seed, leek, lentil, lettuce, mint, and radish) could be produced in the western Big Horn Basin where temperatures tend to be cooler, and 8 additional crops (asparagus, beet, cabbage, cowpea, faba bean, field

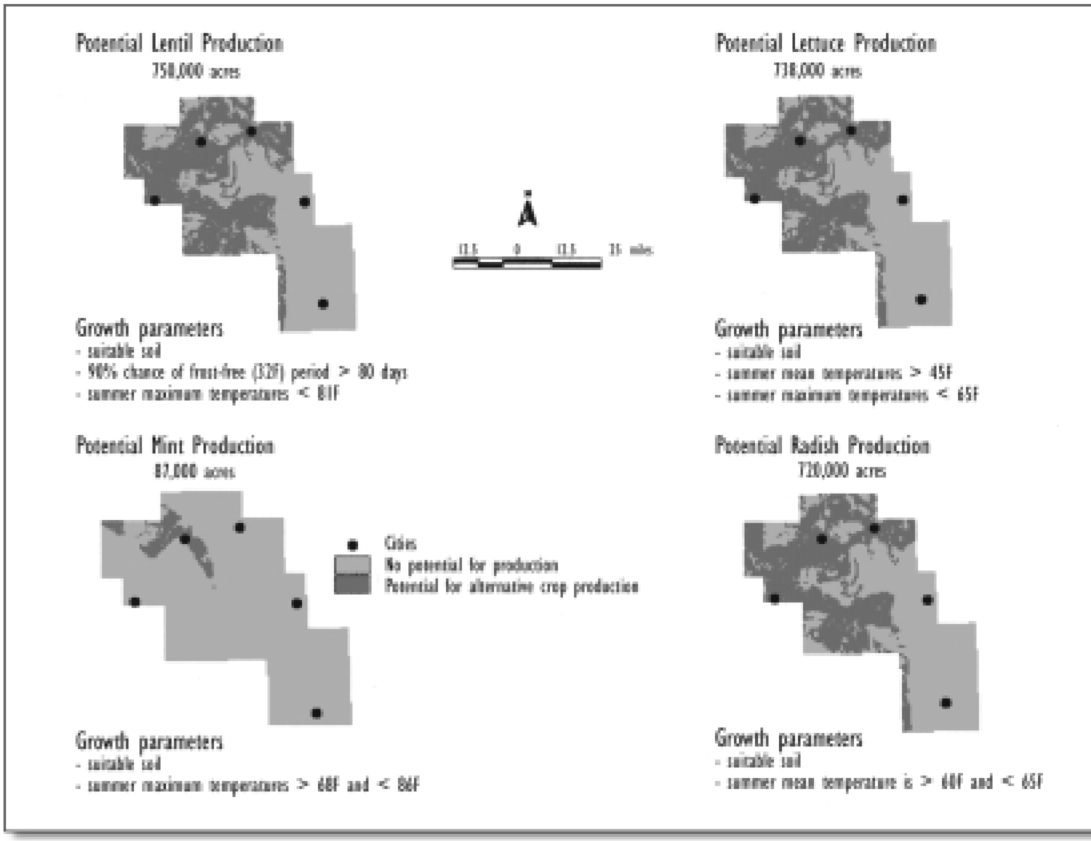

Figure 11. Potential production area for lentil, lettuce, mint, and radish in the Big Horn Basin. See Figure 1 for city identification.

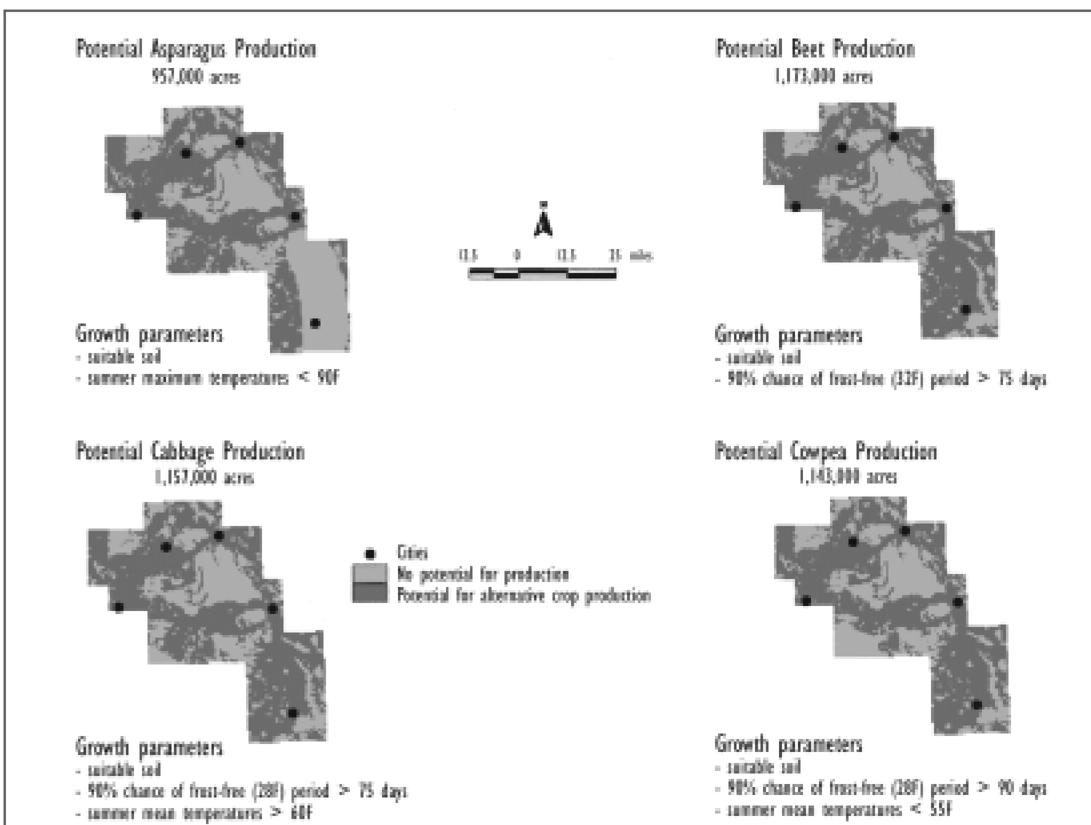

Figure 12. Potential production area for asparagus, beet, cabbage, and cowpea in the Big Horn Basin. See Figure 1 for city identification.

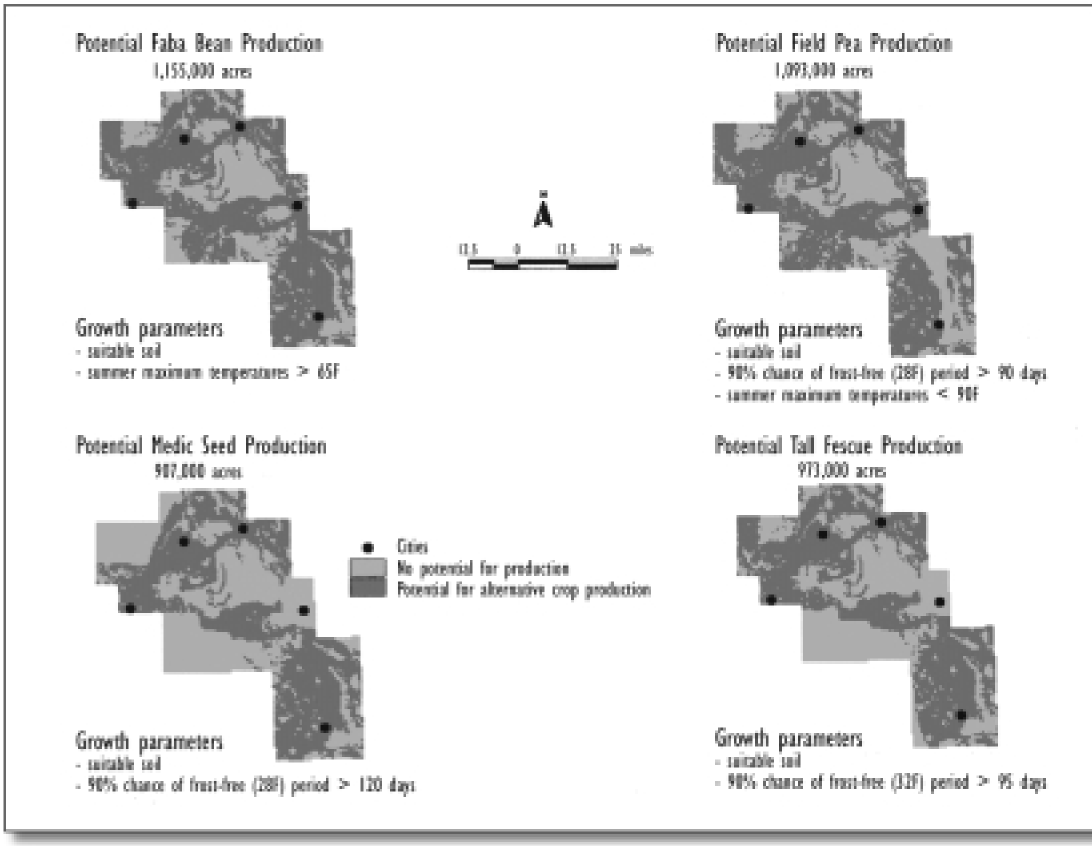

Figure 13. Potential production area for faba bean, field pea, medic seed, and tall fescue in the Big Horn Basin. See Figure 1 for city identification.

pea, medic seed, and tall fescue turf seed) that may possibly be cultivated throughout the Big Horn Basin study area in suitable soils. The alternative crop production area maps derived from this project will be useful to growers, land-use planners, and county and state agencies in the Big Horn Basin seeking information on different agricultural practices and new production systems.

This study has shown that GIS is an excellent tool for exploring the possibilities of cultivating new or alternative crops. The process of locating areas potentially suitable for production is rapid once the necessary information is entered into the database. Caution should be taken, however, in the choice of alternative crops as alternate hosts may increase pest problems in some agricultural fields. Additional studies are needed to determine if introduction of new or alternative crops is economically feasible.

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