GEOGRAPHIC TRENDS IN ALFALFA STAND AGE AND CROPS THAT FOLLOW ALFALFA

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Abstract

To gain perspective on alfalfa-annual crop rotations in the upper Midwest, USDA-National Agricultural Statistics Service cropland data layers and Soil Survey Geographic Database layers were combined for six states (North Dakota, South Dakota, Nebraska, Minnesota, Iowa, and Wisconsin) and seven years (2006-2012). Soil texture and geographic location both significantly affected the length of the alfalfa phase (stand age), and alfalfa stand age, soil texture, and year all significantly affected the first- and second-year crop type following alfalfa, but results varied greatly by state. Alfalfa grown in the Great Plains region was kept in production longer than alfalfa grown in the Corn Belt region of the upper midwestern United States. Corn was the most frequent first-year (61 to 92% of the first-crop) and second-year crop (51 to 76% of second-year crop) in all states except North Dakota (39% corn for first-year crop and 30% corn for second-year crop). Small grains were the first-year crop 29% of the time in the Dakotas and 1 to 11% of the time in the other four states and were the second-year crop 27% of the time in North Dakota and 2 to 9% of the second-year crop in the remaining five states. Surprisingly, soybean was the first-crop following alfalfa 12% (3-14%) of the time and was the second-year crop 28% (14 to 38%) of the time in these six states. The high proportion of alfalfa that is followed for one or two years by crops with low or no N fertilizer requirement (small grains and soybean, respectively) indicates that alfalfa N credits to following crops are often not utilized. This approach to analyzing crop rotation patterns also may prove useful for other annual and perennial crop rotations.

Introduction

The amount of N that alfalfa provides to crops that follow in rotation is largely dependent on the soil texture where alfalfa is grown and the age of the alfalfa stand at termination (Yost et al., 2013). However, no geographic and only limited survey data exist on the length of the alfalfa phase in agricultural fields in the upper Midwest. Additionally, no data are available for estimates of hectarage or patterns in crops that follow alfalfa.

The USDA-National Agricultural Statistics Service (NASS) provides the most comprehensive estimates of crop hectarage in the US, with agricultural census data collected every five years and annual grower surveys conducted in between census years. They also provide geographic annual crop hectarage estimates in cropland data layer (CDL) products by classifying satellite imagery into raster datasets with 30- or 56-m spatial resolution. With multiple CDLs (2006-2012) now available for many states, crop rotation patterns can be examined. Recent studies have used CDLs to examine and model economic scenarios of potato production in Maryland (DeFauw et al., 2012), and to monitor shifts from crop rotation of corn and soybean towards increased monoculture cropping of these two crops in the Midwestern United States (Plourde et al., 2012), but CDLs have not been used to examine rotations of perennial and annual crops.

The objectives of this research were to: 1) determine whether soil texture (coarse-, medium-, or fine-textured soils) is related to the length of the alfalfa phase, 2) describe geographic trends in alfalfa phase length; and 3) determine whether the length of the alfalfa phase, soil texture, or year affect the crops grown for two years after alfalfa termination.

Approach

Cropland data layers from USDA-NASS for six states (Iowa, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin) and seven years (2006-2012) were combined to analyze crop rotation patterns in the upper midwestern United States. The original categories in the CDLs were re-classified into six crop categories (alfalfa, corn, soybean (*Glycine max* [L] Merr.), sunflower (*Helianthus annus* L.), small grains, and other crops) and three other categories (noncropland, water, and a combination of perennial forage called “grass”). The corn category included all types of corn and the small grains category included all major and minor small grains.

In order to combine CDLs across the seven years, CDLs with spatial resolution of 56 m (2006-2009) were split to 28-m resolution and then resampled at 30-m resolution with the nearest neighbor sampling technique. The CDLs were smoothed with two passes of a majority filter in order to remove single or small clusters of pixels inside broader agricultural fields or other large areas. After smoothing, CDLs from all seven years within a state were combined into a single raster with seven digit values for each cell using the Raster Calculator tool so that the crop category was identified for the each of seven sequential years. The combined seven year raster data were converted to polygons for each state using the Conversion tool. Polygons with ≥1 yr of alfalfa and ≥0.5 ha in size were selected for alfalfa stand age and following crop analyses.

To determine the length of the alfalfa phase, we selected all polygons with ≥2 consecutive years of alfalfa that began with and were followed by a crop (corn, small grains, soybean, sunflower, or other crops) for any set of years between 2006 and 2012. The ≥6- and ≥7-yr-old alfalfa stands ended with alfalfa in 2012 and the ≥7-yr-old alfalfa began with alfalfa in 2006. The category ‘grass’ was converted to ‘alfalfa’ if the probability of alfalfa being misclassified as grass was ≥10% higher than the reverse, based on NASS analyses with ground truth data by state. First-year crops following ≥2 yr of alfalfa were selected in 2008-2012 and the same criterion was used for second-year crops in 2009-2012. In order to test the effect of alfalfa stand age on the type of following crop, the data were restricted to first-year crop in 2011 and second-year crop in 2012. Thus, only first- and second-year crops following 2- to ≥5-yr-old alfalfa could be determined for this analysis.

Soil texture class attributes from the NRCS soil survey geographic database (Soil Survey Staff, 2011) vector data layer were categorized into three soil texture groups and spatially joined to CDL polygons. The coarse-textured category included sand and loamy sand soils. The fine-textured category included clay, clay loam, and silty clay loam soils. The medium-textured category included loam, silt loam, sandy loam, fine sandy loam, and sandy clay loam soils. Soils with a complex of multiple soil series were classified using the texture of the first soil in the complex.

All raster and vector data processing, smoothing, merging, selecting attributes, mapping, and spatial analysis were conducted using ArcGIS (ArcGIS 10.1, ESRI, Redlands, CA). Two-way interactions of categorical variables were analyzed using chi-square tests at $P \leq 0.05$. Spatial clustering in alfalfa stand age across the six states was evaluated with the Getis-Ord Gi* statistic at $P \leq 0.05$ using Hot Spot Analysis. The Hot Spot Analysis was conducted with Euclidean distance as the distance method and fixed distance band as the conceptualization of spatial relationships.

Summary

Alfalfa phase length by soil texture

Alfalfa stands in North Dakota were maintained for ≥6 or ≥7 yr nearly 75% of the time for coarse- and medium-textured soils, whereas only 65% of the alfalfa phases were ≥6 or ≥7 yr on fine-textured soils (Fig. 1). In South Dakota, the alfalfa phase lengths also were shorter for fine-textured compared to coarse- and medium-textured soils. Minnesota had shorter alfalfa phases than Nebraska across soil textures, but both states had similar trends in differences among soil textures; shorter phases occurred on fine-textured soils. Iowa had the shortest alfalfa rotations (nearly 80% of the alfalfa was grown for ≤ 3 yr across soil textures). In Wisconsin, stands were kept longer on coarse-textured soils than on finer textured soils.

Alfalfa phase length by geographic location

Geographic location had a significant effect on the length of the alfalfa phase (Fig. 2). Shorter phases were typical in Iowa (except for southern edge of the state), the southeastern part of South Dakota, the eastern quarter of Nebraska, and nearly everywhere south of Interstate 94 in Minnesota. Longer alfalfa phases were typical across the entire state of North Dakota (except for a small amount in the Red River Valley) in western areas of South Dakota and Nebraska and northern areas of Minnesota. Wisconsin had the greatest spatial complexity in alfalfa stand ages, with three clusters of both young and old alfalfa stands.

First-year crop by alfalfa phase length, soil texture, and year

Alfalfa phase length (2 to ≥5 yr) was significantly related to the type of first crop following alfalfa in 2011 across states (Fig. 3), with largest differences in North Dakota and Minnesota. In North Dakota, longer alfalfa phases were more frequently followed by soybean, whereas shorter alfalfa phases were more frequently followed by other crops. In Minnesota, small grains as the first-year crop increased from 7 to 31% when following a 4-yr-long alfalfa phase compared to the other phase lengths. The remaining four states had smaller differences in first-year crop among alfalfa phase length, with small grains being slightly more typical after longer alfalfa phases in South Dakota, Nebraska, and Iowa, and soybean being more typical following a short alfalfa phase in Nebraska. The diversity of first-year crops was highest in Wisconsin when following short alfalfa phases than longer ones.

The first-year crop also varied with soil texture (Fig.3). In North Dakota, the frequency of corn as the first-year crop was highest for coarse-textured soils and small grains had the highest frequency on medium-textured soils. Corn was the dominant first-year crop on coarse- and medium-textured soils in South Dakota and the frequency of small grains increased from 8 to 27% for fine-textured soils compared to coarser textured soils. Nebraska had slightly more soybean as the first-year crop on fine-textured soils compared to the other two soil types and in Minnesota corn was replaced by small grains and soybean on coarse- and medium-textured soils, respectively. Soil texture had minimal impact on the type of first-year crop grown in Iowa, because the proportions of the two dominant crops were consistent (87% corn across textures and 12% soybean across textures). First-year crop types also were consistent across textures in Wisconsin, with the exception of slightly more corn grown as the first-year crop on medium-textured soils compared to the other categories.

Corn was the dominant first-year crop following alfalfa in all states except North Dakota. Surprisingly, soybean, which needs no N fertilizer, was the first-year crop following alfalfa 2 to 28% of the time across years and states (Fig. 3). North Dakota had the lowest amount of corn as the first-year crop and the highest amount of small grains, sunflower, and other crops among states. The frequency of corn as first-year crop decreased and other crop frequency increased in 2009 to 2011 for North Dakota. Corn frequency increased and small grains frequency decreased over time in South Dakota. In Nebraska and Wisconsin, first-year crop types were relatively consistent over time, but Nebraska had more small grains and soybean as the first-year crop than Wisconsin. Corn was grown as the first-year crop less frequently in 2009 and 2010 in Minnesota and Iowa compared to other years.

Second-year crop by alfalfa phase length, soil texture, and year

Second-year crop following alfalfa in 2012 was affected by the length of the alfalfa phase in each state (Fig. 3). Soybean frequency as the second-year crop in North Dakota was higher when following the alfalfa phases of ≥ 5 yr and the frequency of alfalfa as the second-crop increased for 4-yr phase lengths relative to the others. In South Dakota, corn frequency increased from 38 to 53% when following alfalfa phases that lasted 3, 4, and ≥ 5 yr relative to 2-yr alfalfa. The frequency of alfalfa as the second-crop was higher for shorter alfalfa phases in Nebraska and Wisconsin and there was a slightly higher frequency for other crops and small grains for the longest alfalfa phases. Soybean and small grains frequency increased for the longer alfalfa phases (4 and ≥ 5 yr) relative to shorter rotations in Minnesota. Second-year crops following 2-yr alfalfa phases in Iowa were more frequently soybean than after longer alfalfa phases, which were more typically corn.

As with the first-year crop, the second-year crop following alfalfa was affected by soil texture in each state (Fig. 3). In North Dakota, the frequencies of sunflower, other crops, and soybean increased and corn decreased in finer-textured soils. Only other crops (such as sorghum, potatoes, etc.) were grown on coarse-textured soils in South Dakota and small grains and soybean frequency increased for medium- and fine-textured soils. In Nebraska, frequency of alfalfa and other crops as the second-year crop decreased and frequency of soybean with finer soil textures. The frequency of corn as the second-year crop increased relative to other crop types for medium-textured soils in Minnesota and for coarse- or medium-textured soils in Iowa. Alfalfa frequency decreased and corn frequency increased for fine-textured soils relative to other soil texture categories in Wisconsin.

The type of second-year crop following alfalfa was affected by year in each state (Fig. 3). In North Dakota, Nebraska, and Minnesota, the frequency of corn as the second-year crop in 2010 and 2011 decreased relative to the other years. North Dakota had a large increase in frequency of alfalfa in 2011 and small grains were replaced by other crops in Nebraska from 2009 to 2011 (3 percentage point change). In South Dakota, there was a decrease in frequency of small grains with a corresponding increase in soybean and alfalfa frequency over time. The frequency of corn as the second crop increased over time in Iowa. Small grain and alfalfa increased in frequency and soybean decreased in 2010-2011 in Wisconsin.

These are the first geographically specific estimates that describe alfalfa-annual crop rotations in the US. Such spatial descriptions of the length of the alfalfa phase and the crops follow alfalfa in rotation should improve estimates of potential site-specific economic and environmental benefits of alfalfa in crop rotations, aid in planning of fertilizer need assessments for alfalfa and the crops that follow, and aid in the development of education, outreach, and future research on alfalfa production and best crop rotation practices. This approach also may prove useful for examining rotation patterns of other annual and perennial crops.

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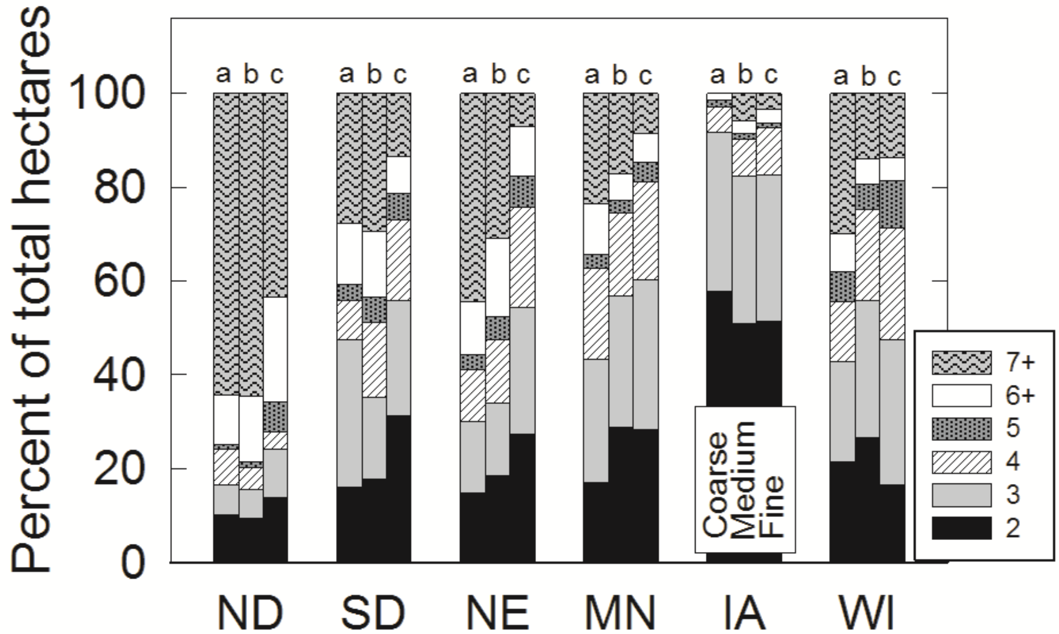

Fig.1. The percent of total hectares where the phase length of alfalfa (shading represent years) could be determined from USDA-National Agricultural Statistics Service cropland data layers (2006-2012) by state and soil texture class. Letters above bars denote differences among categories within states according to chi-squared tests at $P \leq 0.05$.

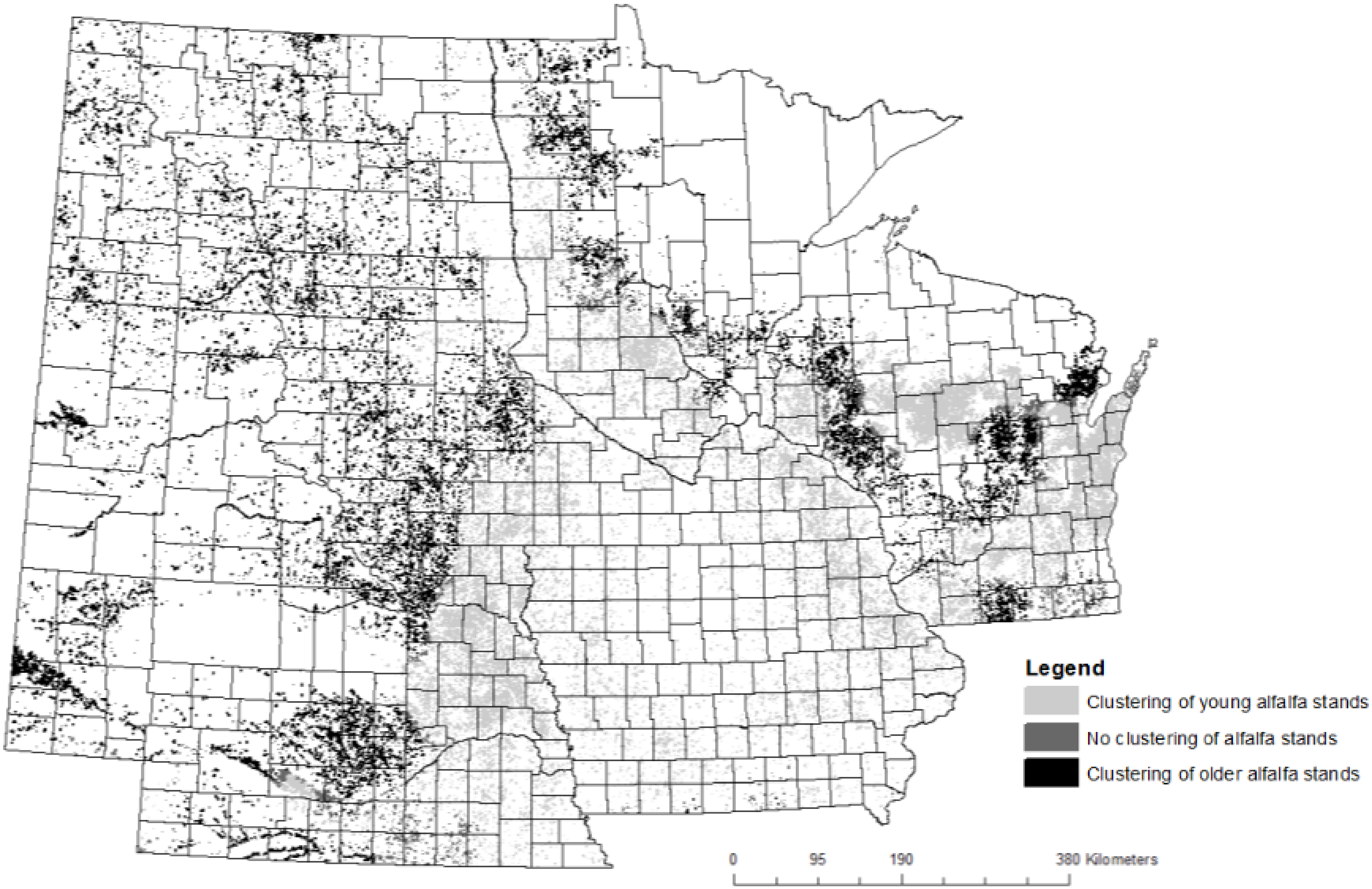

Fig.2. Spatial clustering patterns of alfalfa phase length (2 to ≥7-yr) across the upper Midwest according to Getis-Ord Gi* statistic at $P \leq 0.05$.

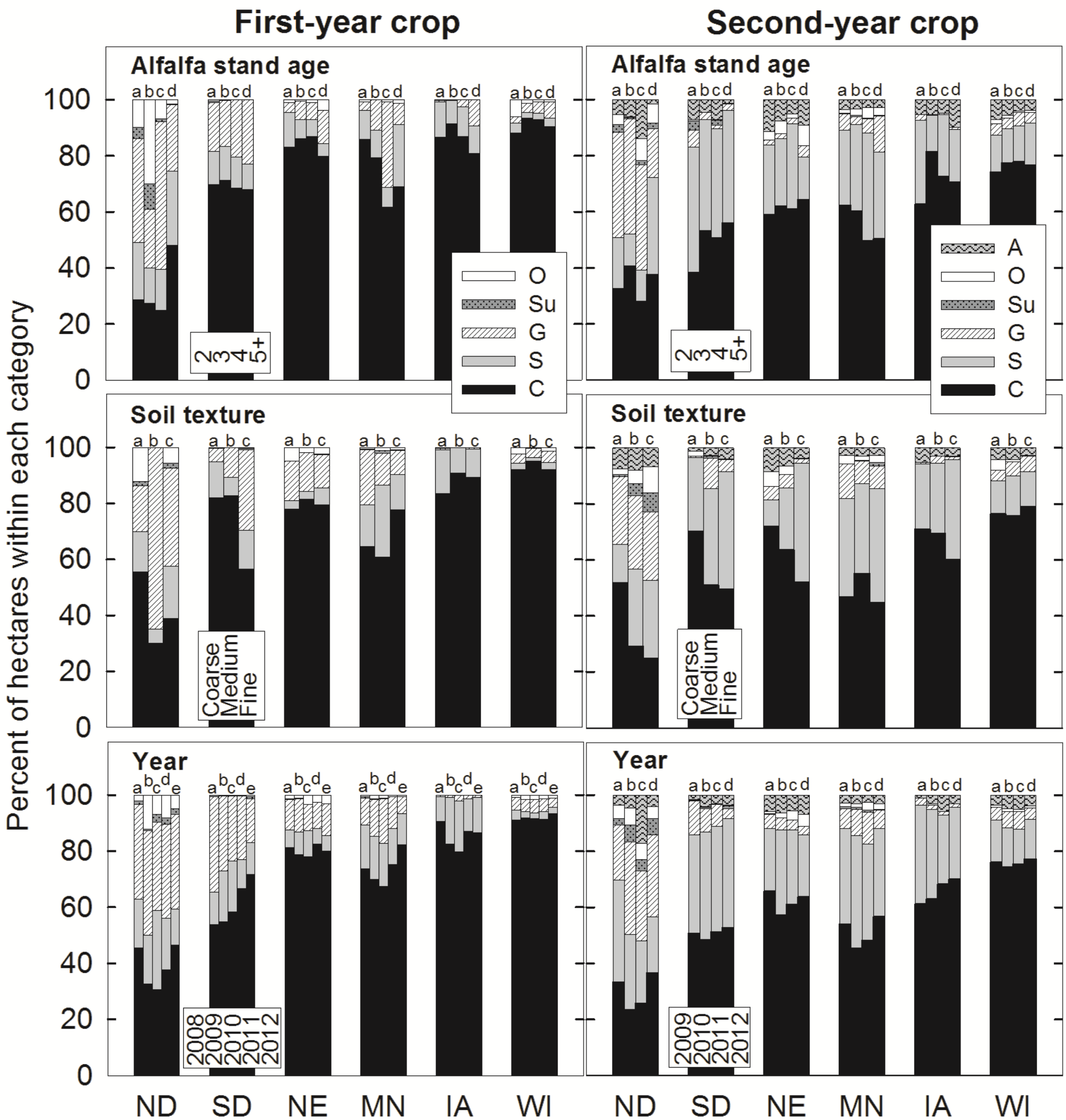

Fig.3. The percent of the total hectares where first- or second-year crop following ≥2-yr-old alfalfa could be determined from USDA-National Agricultural Statistics Service cropland data layers that were corn (C), soybean (S), small grains (G), sunflower (Su), other crops (O), or alfalfa (A) for each state by the length of the alfalfa phase (top), soil texture (middle), and year when the indicated crops were grown (bottom). Letters above bars denote differences among categories within states according to chi-squared tests at $P \leq 0.05$.

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