ALFALFA YIELD GAP –
HOW BIG IS IT AND WHAT IS ITS ECONOMIC SIGNIFICANCE?

Michael Russelle[1]

ABSTRACT

Yield, quality, and persistence – all are critically important for alfalfa growers. We have suspected for a long time that the average yield of alfalfa reported for US farms is far less than what growers could produce. What are reasonable alfalfa yield goals? What can we use to gauge them? Data from the 2012 Census of Agriculture were used to estimate yields on the median farm and the minimum yields on the top 10% of farms in each state. The yields reported by the top producers appear reasonable, based on cultivar trials. Across the 11 Western states, the top 10% of growers harvest 1.5 *to 2.7 times* as much irrigated alfalfa dry hay per acre as producers in the middle of the pack, equivalent to a net profit of $285 to $690/acre.

Key Words: alfalfa, yield gap, variety trial, NASS, Agricultural Census

INTRODUCTION

Alfalfa is the fourth most widely grown crop in the US, following corn, soybean, and wheat and is particularly important in the West as a feed for domestic livestock and as an export crop. Alfalfa acreage has declined 40% over the past 50 years, despite its many benefits to livestock rations, cropping systems, soil and water quality, and carbon sequestration. Numerous reasons have been suggested for this decline, including stable and relatively low alfalfa yields compared to large increases in corn yield due to private and public plant breeding efforts, improved and more predictable quality of corn silage, the need for only one harvest for corn, rather than several for alfalfa, and the reliability of hay marketing and transportation, which allows producers to eliminate the machinery and reduce their management tasks that are required for alfalfa production.

My hypothesis, although I have no supporting data, is that low yield expectations play a major role in the declining acreage. This is due both the relatively low average alfalfa yields reported by state and federal agricultural statistics services, and to the subpar yields that many producers apparently achieve in their operations. Lower yield expectations mean fewer producers continue to raise alfalfa as they expand crop acreage or decide to focus only on livestock operations, and fewer add alfalfa to an established cropping system. Many producers estimate yield by the load, how full the silos or sheds are, by the appearance of the crop in the field, or other means, especially if they use the crop directly. In contrast, commercial forage producers are very likely to know the moisture content and weight of the forage produced. It would be a great improvement to our knowledge base to have their reports of whole-field yields.

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[1] M. Russelle (russelle@umn.edu) Adjunct Professor, Dept. of Soil, Water, & Climate, Univ. of Minnesota, 1991 Upper Buford Circle, Saint Paul, MN 55108 **In:** Proceedings, 2017 Western Alfalfa and Forage Symposium, Reno, NV, Nov 28-30, 2017. UC Cooperative Extension, Plant Sciences Department, University of California, Davis, CA 95616. (See http://alfalfa.ucdavis.edu for this and other alfalfa conference Proceedings.)

So, is there an alfalfa yield gap – a measureable difference between "average" yields and what good management on reasonable soils with economically sufficient inputs can produce? I found that there is a yield gap in both nonirrigated and irrigated alfalfa across the US (Russelle, 2013). In this paper, I focus particularly on the 11 Western states.

CULTIVAR TRIAL EVIDENCE

Cultivar (variety) testing has become more difficult in recent years, but many states still conduct these independent trials of small plot yields in primary alfalfa production areas. They typically are conducted over 2 or more production years to limit the effects of poor weather, and receive all required inputs to minimize the effects of subpar management.

The data in Figure 1 are the geometric means for each trial location, excluding experimental lines and check cultivars (typically old cultivars with significant yield-limiting characteristics). The geometric mean is a better indicator of central tendency than the average for data that include one or a few high values, which often is true for cultivar trials. Otherwise, the geometric mean is similar to the average.

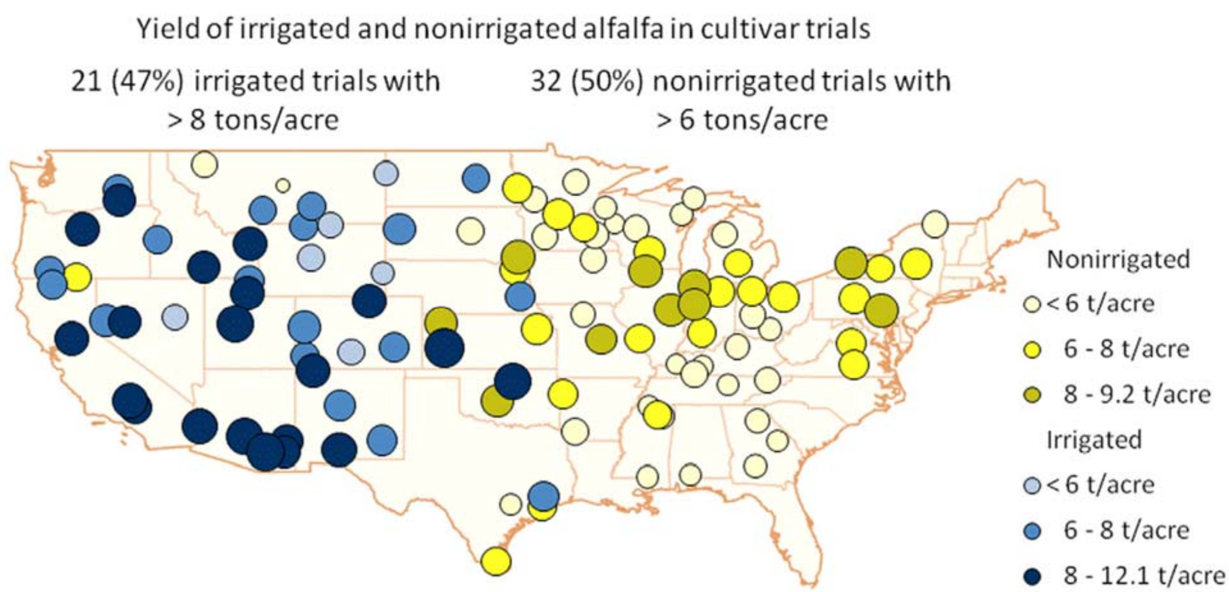

Figure 1. *Alfalfa dry hay yield (13% moisture) from cultivar (variety) trials across the continental US (Russelle, 2013). Tests were conducted over 2 or 3 production seasons, and the reported yields were reduced by 11.5% to account for typical harvest losses.*

Under irrigated conditions, which in these trials were designed to minimize yield limitations due to drought, nearly one-half of the trials produced yields exceeding 8 tons/acre. In every Western state except Montana and Wyoming, at least one location produced alfalfa dry hay yields higher than 8 tons/acre. At other sites, yields were lower due to growing season length, soil conditions, and so on.

Small plots are not like whole fields. Cultivar trials are meant to do head-to-head comparisons under conditions that are as uniform and well managed as possible. They provide an estimate of maximum yield based on the crop genetic potential. They often are conducted on good soils with excellent control of pests and pathogens. Irrigation is expected to be much more uniform than under farm field conditions. Thus, the yields in Figure 2 may exceed what is possible for whole fields or whole farms.

LONG-TERM WHOLE FIELD MEASUREMENTS

We know that some producers have considerably higher yields than others. The best evidence of this is the multi-year, whole field Wisconsin Alfalfa Yield and Persistence Program to determine actual yields of nonirrigated alfalfa over the age of the stand (Bertram, 2017). Over a decade, the project followed 80 fields for 1 to 4 years, determining yield, moisture content, and forage quality at every cutting. Field sizes have averaged 66 acres, ranging from 5 to 225 acres. Figure 2 summarizes their findings on yield.

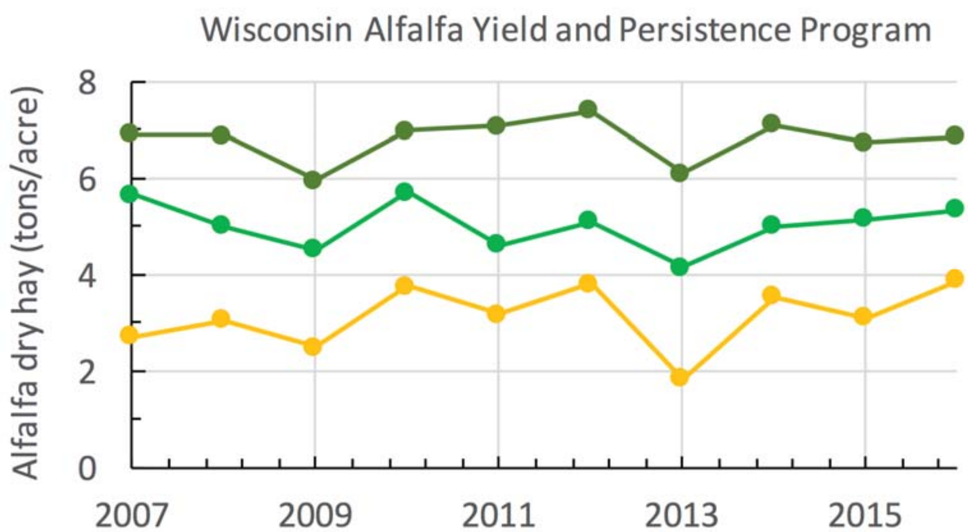

Figure 2. *Alfalfa dry hay equivalent yield for the lowest (yellow and highest (dark green) yielding fields, and the average of all fields measured in Wisconsin in each of 10 years. Data from Bertram (2017).*

The top fields yielded 1.2 to 2.5 tons more alfalfa day hay than the average of all fields. Ten fields in the study have been among the top four in two to three years, indicating that soil, location, and other site-specific conditions matter, but that year-to-year variations in rainfall, for example, can reduce or support yield. These top-yielding fields generally declined only in the 4th year of production to average or 7 to 15% below the average yield across fields that season. The lowest yielding fields were consistently below or within 4% of the average yield in other years. These results support the idea that *some fields are persistently yield-limited*, whereas other fields support high yields unless weather, for example, intervenes.

I am not aware of similar data from other states, although the usefulness of these whole-field trials seems apparent. The next step would be to determine what is likely limiting yields on some fields through evaluating whether modern cultivars were seeded, measuring harvest losses and soil pH and fertility, etc.

WHOLE FARM ESTIMATES

What is missing from the normal agricultural statistics is the distribution of yield. The average yield for a state does not help us understand the range that producers report. For the purposes of this paper, we need more information, especially about the higher end of the range.

I requested a special tabulation of the 2012 Census of Agriculture to provide the number of farm operations, acres, and total production of alfalfa dry hay by state. The results are given for 1.5-tons/acre increments of yield up to 9 tons/acre, and 3 tons/acre increments thereafter. The large increment at the upper end was required to reduce the number of data points withheld. The National Agricultural Statistics Service (NASS) does not release data that might compromise privacy of individual farm operations, and therefore withholds some data points when the number of farm operations within a category is small.

Because there are questions about producers' estimates of yield from alfalfa fields harvested as haylage alone or haylage and dry hay (Russelle, 2013), I restricted this analysis to the NASS category of "Alfalfa dry hay" and excluded farms that reported haylage or greenchop production, farms that reported alfalfa seed production, and farms that reported having more than 20 cattle. These restrictions clearly limited the kinds of farm operations that are included in the results, but should adequately and more accurately represent the distribution of dry hay yield. Furthermore, estimates are for the entire production of the farm, and therefore may include establishment year harvests.

Cumulative frequency graphs were generated with the NASS data, from which I could determine the likely yield of farms along the curve. In this type of graph, higher yielding situations are plotted further to the right, not higher on the graph.

In Figure 3, the three colored curves are for the indicated irrigation scenarios in Idaho. Median alfalfa dry hay yields were about 1.5 tons/acre for farms that did not irrigate alfalfa in 2012, 2.1 tons/acre for "Partial irrigation" (where all alfalfa was partially irrigated or where some fields were irrigated and others on the farm were not), and 4.2 tons/acre for farms where all alfalfa fields were irrigated. In each case, one-half of the farms reported yields below these levels, and one-half reported higher yields.

Similarly, the minimum yield reported by the highest 10% of the farms was 2.7, 4.6, and 6.2 tons/acre for none, partially, and entirely irrigated alfalfa, respectively. On the median farm, irrigating the entire alfalfa crop improved yield by 2.7 tons/acre, whereas there was a yield advantage of 3.5-tons/acre for irrigation with the top performers.

It is possible that the producers who reported the highest yields were harvesting alfalfa that was only fit for dry cows and ewes. But that seems unlikely. It also is possible that high yields were exaggerated guesses. That is possible, but the number of producers in the top 10% makes that unlikely.

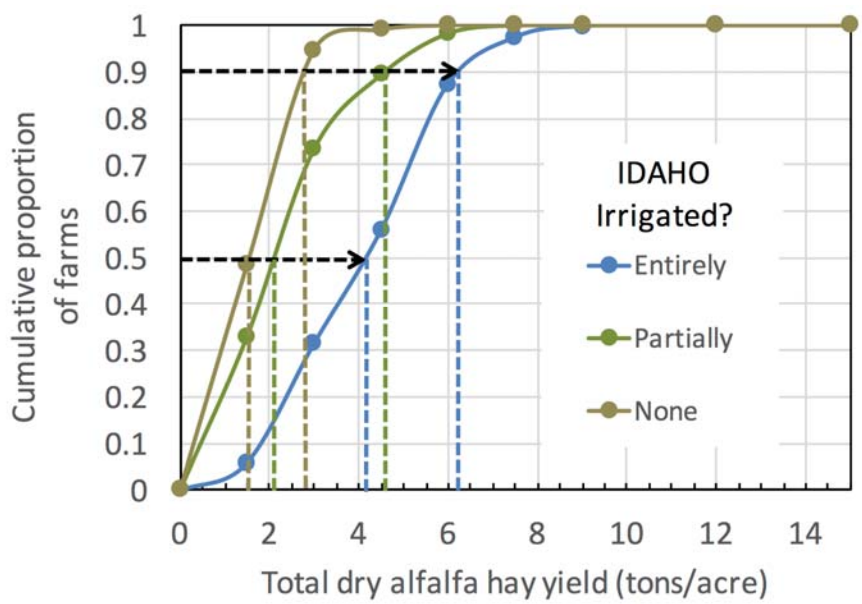

Figure 3. *Cumulative fraction of Idaho farms that reported dry alfalfa hay production in the 2012 Census of Agriculture, plotted at the upper range of each yield increment. Each curve represents farms with no irrigated alfalfa, with partial irrigation (either of all fields or of the entire crop), or with all the fields irrigated. The arrow at 0.5 (50%) indicates the median farm yield under each irrigation scenario; the arrow at 0.9 (90%) indicates the lowest yield of the highest 10% of farms in each irrigation scenario.*

Table 1. *Average, median, and top 10% whole-farm yields of entirely irrigated alfalfa dry hay producers, based on a special tabulation of the 2012 Census of Agriculture. These are a subset of operations that harvested alfalfa only as dry hay.*

State	Number of farms	Average yield	Median yield (50th percentile)	Minimum yield of top 10%
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Arizona	124	6.8	5.1	9.0
California	611	6.0	5.6	9.2
Colorado	1834	3.0	2.4	5.3
Idaho	2248	4.4	4.2	6.4
Montana	1785	3.0	2.6	4.8
Nevada	429	4.1	3.8	5.8
New Mexico	660	4.8	2.8	7.5
Oregon	904	4.0	3.7	5.9
Utah	2010	4.0	3.4	5.8
Washington	445	5.8	4.7	7.5
Wyoming	1263	3.1	2.6	5.0

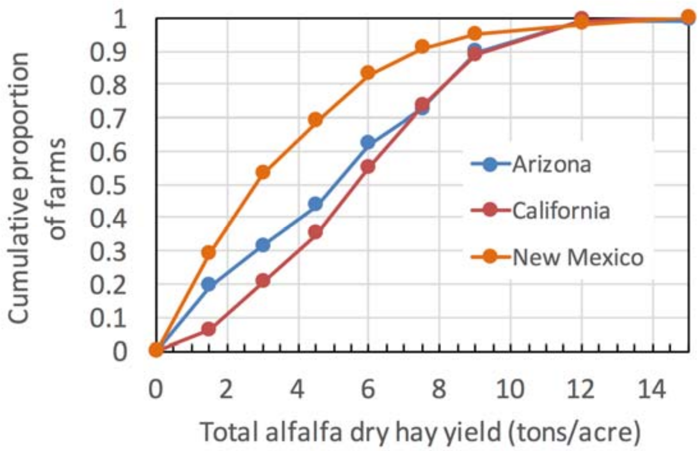

Figure 3. Cumulative fraction of farms in the three Southwestern states that reported dry alfalfa hay production in the 2012 Census of Agriculture.

In Figures 3, 4, and 5, all data are for entirely irrigated alfalfa. It is evident that alfalfa dry hay yields at the lower end of the range differ greatly among the three Southwest states (Fig. 3). Very few farms reported yields of only 1.5 tons/acre in California, whereas in New Mexico, 30% of farms reported whole farm yields of 1.5 tons/acre or less. Of course, the environmental conditions are generally much less extreme across the irrigated area of California and if it were possible to have data from specific areas, we could compare "apples to apples," as the saying goes. At the other end of the range, 10% of the reporting farms in New Mexico achieved yields of at least 7.5 tons/acres, whereas the top 10% in California and Arizona had yields of at least 9 tons/acre.

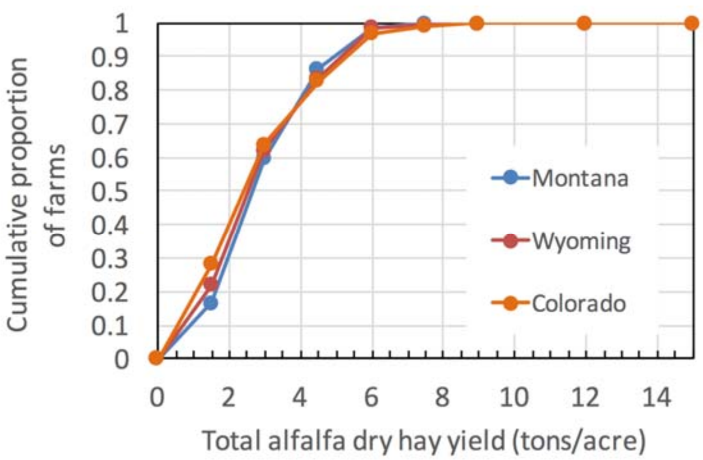

Figure 4. Cumulative fraction of farms in the three Mountain states that reported dry alfalfa hay production in the 2012 Census of Agriculture.

Yields of irrigated alfalfa in the three mountain states shown in Figure 4 were similar, except for the lowest yield increment. In Colorado, whole farm yields were 1.5 tons/acre or less on 28% of the operations, but on only 17% of Montana operations. All were similar with respect to yields at the high end of the range.

In the remaining Western states shown in Figure 5, 10% or less of the farms reported alfalfa yields lower than 1.5 tons/acre. Otherwise, a greater percentage of farms produced higher alfalfa yields in Washington than the other states.

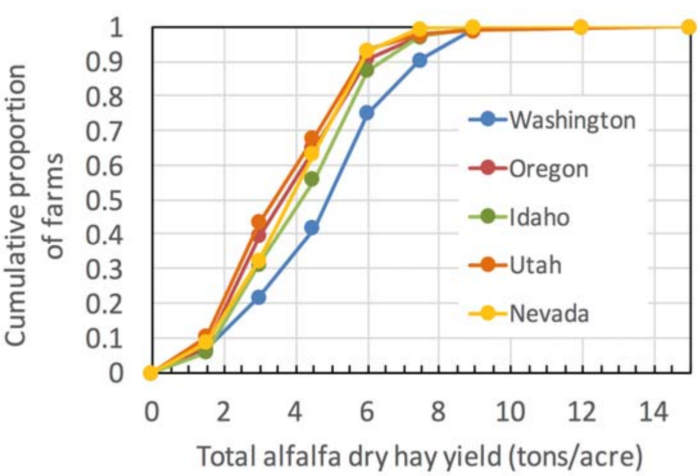

Figure 5. Cumulative fraction of farms in the five Pacific Northwest and Mountain states that reported dry alfalfa hay production in the 2012 Census of Agriculture.

The key take-home message from Table 1 is that the top 10% of farms in the 11 Western states apparently are achieving at least 30% to nearly 80% higher yields than the average state yield, and 50 to 170% higher than yields on the "median" farm. The yield gap between the top 10% and the state average is *at least* 1.7 to 3.2 tons/acre under conditions where the crop is entirely irrigated. The yields shown for the Top 10% are the *lower limit* for that group.

From this specific dataset we can conclude that more than 1100 farms (between 12 (Arizona) and 224 (Idaho) operations, that is, 10% of each total number of farms) are achieving considerably higher yields of alfalfa dry hay than most other operations.

ECONOMICS

Putnam et al. (2010) estimated the value of improved alfalfa cultivars based on yields in cultivar trials. I use the same method here, recognizing the relatively minor increase in costs for seed ($60 amortized over a 4-year stand life), acknowledging that pest control expenses may be reduced with improved cultivars, but are highly site- and situation-specific, and assuming no significant increase in marginal costs for greater yields. I, too, assume a hay price of $150/ton.

The difference between the state average yield and the lowest yields for the top 10% of farms shown in Table 1 translates to an annual net return of $240 to $465/acre. Compared to the median farms in each state, annual net returns are at least $285 to $690/acre. Looked an another way, these are the net losses currently experienced because of inadequate management.

We do not know how many acres of alfalfa could be managed to produce at alfalfa's genetic potential, but the story here is that the gap is large between what some producers achieve and what most do. The increased gross return would easily cover increased input costs.

Alfalfa production requires a broader range of management skills and knowledge than other feed crops. Alfalfa attracts insect pests and can host multiple disease organisms that impair above- and below-ground growth and function. It requires excellent harvest management to achieve the desired yield and quality, and harvests are multi-pass operations that often must be done under less than optimum conditions and require a labor force during the growing season when it may not otherwise be needed. If both hay and haylage are produced, more equipment is needed. Alfalfa requires significant potassium (potash) availability, does best in neutral to alkaline pH soils, persists longer and is more resilient to drought when subsoils allow root proliferation, and suffers from topsoil compaction by traffic.

But in the West particularly, water is the issue – availability, quality, and cost. Even as irrigation practices have to change, which very likely will reduce the amount of yield that is achievable on a given field in a given season, the benefit of applying excellent management of all aspects of alfalfa production will show up on the scales and in income.

Acknowledgment
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