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Quantification of Feed Crop Supply and Demand in Idaho, 2003 – 2021

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Abstract
The expansion of the dairy industry in Idaho over the past two decades has impacted the supply and demand for feed crops in the State and Western U.S. This article presents a method for quantifying state level feed crop supply and demand on an annual basis. Results show that demand has exceeded supply for corn grain for the entire study period of 2003 to 2021, while supply and demand are largely at parity for alfalfa hay, corn silage, and barley. The extent to which feed demand is met by local or external supply has implications for risk management decisions for feed crop stakeholders in properly accounting for local production and external market risks.

Keywords: Feed crops, feed rations, quantification, supply and demand, Idaho

JEL codes: Q11; Q13

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Introduction

The absolute size and relative importance of the livestock industry in Idaho (ID) have increased since 2000. Du, Hatzenbuehler, and Taylor (2022) estimated that for 2021, cash receipts for ID livestock products, including cattle and calves, milk, and other livestock, were over $5 billion. Once cash receipts for feed crops, including alfalfa hay, barley, and corn (grain and silage) are added to those for livestock products, the percentage of livestock industry-related cash receipts as a share of the total is over 60%. The main factor that explains the overall growth in ID livestock-related cash receipts is the expansion of the dairy industry.

Figure 1 includes a plot of ID dairy cow inventories, cattle on feed inventories, and corn (grain and silage) acres harvested from 2003 to 2021. The plot shows a substantial increase in ID dairy cow numbers in the early 2000s. Corn acres harvested, which is the sum of corn grain and corn silage acres, increased in a similar fashion.[5] This suggests that the expansion of the dairy industry has substantial effects on the performance and behavior of other entities in the agricultural sector, especially farmers that grow feed crops. Results from Hatzenbuehler et al. (2021) show that the dairy industry's expansion and associated increases in dairy feed grown nearby have caused milk and hay prices to move more closely than before the early 2000s.

Based on these data and findings, a question has arisen among stakeholders in the ID livestock and feed crop industries: How much and what types of feed demand is met by local supply versus "imports" from other states or abroad? Answering this question has important implications for participants in livestock and feed crop markets, as well as Extension Educators and industry consultants who educate the public on market and price risk management. Specifically, quantifying the relative extent to which local feed demand is or is not met by local supply changes can help better characterize both the marketing and price risks that ID farm businesses face. Stakeholders in other states who have experienced substantial changes in their dairy industries may also be interested in answering this question. In this article, we describe the method we utilize to quantify feed crop supply and demand in ID for major feed crops of alfalfa hay, barley, and corn (grain and silage), and provide guidance for application to other states.

Method and Data

The strategy used to quantify the supply and demand for each crop was based on the inferred method of the U.S. Department of Agriculture (USDA) World Agricultural Outlook Board (WAOB) in compiling the World Agricultural Supply and Demand Estimates (WASDE) reports, which are released monthly. Specifically, the WASDE report includes estimates of key variables that comprise the total supply for a given crop for the U.S., including area planted, area harvested, yield, production, beginning stocks carried over from the previous crop year, and imports from abroad. Similarly, for total demand, the key variables include demand for feed, foreign exports, and stocks carried over into the next crop year[6].

Table 1 includes a summary list of the variables estimated in this study, as well as either the data source or the method used to calculate the values. Some data were obtained directly from the USDA National Agricultural Statistics Service (USDA NASS) and others are simple calculations

[5] We estimated a correlation coefficient of 0.93 for ID dairy cow inventory and corn acres in Figure 1 for 2003 – 2021.

[6] Readers familiar with the WASDE reports will observe that food is a common demand category for most crops. Since the focus of this bulletin is crops used for animal feed, we excluded food from our analysis.

based on those data.[7] The exports/imports quantity estimates for each crop were obtained from the U.S. Census Bureau USA Trade Online database (U.S. Department of Commerce, 2021). Modifications were made to align the units for barley and corn in the USDA NASS data (in bushels) with those in the USA Trade Online data (in metric tons). Since other estimates for alfalfa hay and corn silage were in tons, no further conversion was needed. For corn grain and barley, conversion factors used to convert tons to bushels were obtained from the U.S. Grains Council "Converting Grain Units" webpage (U.S. Grains Council, 2022). Regarding the observation period, the USA Trade Online database begins in 2002. Thus, the analysis begins in 2003 since that is the first year for which there is data on exports, imports, and stocks. Stocks data or estimates from 2002 are carried into 2003 for each crop. We further describe our quantification strategy for stocks and feed demand below.

Stocks Demand Estimates

Stock estimates for barley and alfalfa are directly available from USDA NASS. Since our first observation year is 2003, the value of stocks carried in for 2003 is simply the stock estimate for December 2002. Similarly, the value of stocks carried out for 2003 is the stock estimate for December 2003. Stock values for subsequent years are determined similarly.

For corn, stock estimates were dependent on several assumptions because neither on-farm stocks nor total use data are available for ID's corn grain or silage. First, we assumed that the level of stocks for corn silage were like those for corn grain. Hines and Stokes (2020) describe that storing corn silage in ID is typically done via a method called "bagged silage". To implement this method, silage corn is harvested and chopped, formed into a pile, packed down by tractors, covered with plastic, and then stored for fermentation for at least 3-4 months before feeding. Additionally, the best management practice is to remove six inches of corn silage from the front of the pile when needed for feeding, and then re-covering the pile (Hines and Stokes, 2020). These practices imply that corn silage can be stored for a substantial number of months. Second, we assume that the level of corn grain stocks in ID are close to those held in ratio terms at the national level. A commonly used ratio as a measure of "market tightness" or the amount of available supply is the stocks-to-use ratio. This ratio is calculated by dividing the stocks level by total demand or "use." To obtain a stocks-to-use ratio for the U.S., we divided the ending stocks value by the total use value in the October WASDE report for each year. For 2002, ending stocks were 1,599 million bushels and total demand was 9,817 million bushels, which implies a ratio of 1,599/9,817 = 0.16. This ratio was then multiplied by total demand in 2002 to obtain an estimate of stocks carried into 2003. The values for subsequent years were done using this same procedure.

The assumption that the stocks-to-use ratios for corn in the U.S. are equal to those in ID is difficult to fully justify due to the lack of state level data on both stocks and total use. However, we contend that this assumption is a useful starting point for the quantification analysis implemented in this study for two reasons. First, the availability of stocks data for both alfalfa hay and barley implies that stocks are held for these crops, and so it is reasonable to infer that at least some corn stocks are held by farmers and other entities in ID. Second, for barley, the other crop for which WASDE report data are available of the crops included in this study, we compared the stocks-to-use ratios for the

[7] The data, formulas, estimates, and methodological notes used in the analysis are available as an Excel file from the corresponding author upon request.

U.S. to inferred stocks-to-use ratios in ID[8]. The average estimated difference for the observation period of 2003 – 2021 for the U.S. and ID barley stocks-to-use ratios was 4%. The presence of relatively lower barley stocks levels relative to use in ID compared to the U.S. average could be explained by the presence of a substantial number of prominent barley malt processing plants in ID (Lewin et al., 2013). Specifically, while barley malt processors in ID may hold larger quantities of barley stocks than the national average, they also use more than the national average during the malting process. Overall, we are confident regarding the choice to include stocks as a use category for corn, but we note that there is likely a confidence band around the state level stocks estimates that are based on national stocks-to-use ratios. We encourage those who implement a similar analysis in other states to use national stocks-to-use ratios as a base, and then rely on secondary sources and/or expert opinion to adjust the national ratios to better reflect local conditions.

Animal Feed Demand Estimates

Estimates of demand for animal feed are based on USDA NASS animal inventories and expert opinion for guidance on feed rations for both dairy and beef cattle, as well as estimates for the number of replacement animals held by dairies and feedlots. The experts consulted were primarily University of Idaho Extension Dairy and Beef Specialists, who rely on their experiences and stakeholder advice from entities in private industry.

The basic approach was to multiply the number of animals by a conversion factor that was comprised of daily feed rations and then convert these daily values of total animal feed consumed to annual values. Dairy cow inventories are from the first of January each year (USDA NASS). Similar statewide values were used for all crops except barley. Dairy cows utilizing barley were determined as only counties in Eastern ID, since dairy industry experts stated that barley is not typically included in dairy feed rations in other regions of the state. The second category of animals was "cattle on feed," for which data were also obtained from USDA NASS inventories as of January 1 for each year.

The final category of animals was "replacements and feeder cattle," which includes heifers, steers, and cows that are being fed in the dairy or feedlot prior to being counted as dairy cows or "cattle on feed" within USDA's datasets. Heifers represented 69% of the "replacements and feeder cattle" category. Expert opinion was relied upon for estimates of the number of replacements and the number of days each year each animal segment is fed. Specifically, for dairy cows, experts specified that there is typically a 1:1 ratio of the number of dairy cows to "replacements and feeder cattle." Experts indicated a 2:1 ratio for the number of beef cattle on feed relative to "replacements and feeder cattle" was more common, so the number of beef cattle "replacements and feeder cattle" was obtained by dividing the beef cattle on feed inventory by two. It is important to note that the beef cattle "replacement and feeder cattle" are inclusive of backgrounded animals. Finally, dairy "replacements and feeder cattle" were grouped to consume food for the full year, while beef "replacements and feeder cattle" were determined to only be backgrounded and fed with rations for two months of the year. Thus, the daily rations for dairy "replacements and feeder cattle" were multiplied by 365 to obtain annual values for dairy "replacements and feeder cattle" feed consumed, while those for beef "replacements and feeder cattle" were multiplied by 60 to obtain their analogous quantity.

[8] For the estimation of stocks-to-use for barley in ID, we used total production as equal to total use, since, as discussed below, we are unable to fully account for all use of barley in Idaho due to a lack of data on processing demand for malting barley. This is discussed in further detail in the "Observed Trends in Supply and Demand Balances" subsection.

The next part of determining the quantity of each type of crop consumed as animal feed was recognizing how feed rations have evolved over our observation period. As noted above, these estimated average daily rations are based on expert opinion. These daily rations are also estimated on an "as fed" basis and are inclusive of feed lost to waste/spoilage. Table 2 is a summary of the average daily feed rations as estimated by dairy and beef experts. The estimated values for dairy cows show that the amount of alfalfa hay fed in their ration has continually declined to about one-third for 2021 compared to 2003. The opposite, but not quite to the same extent applies for corn silage, for which the average daily ration has about doubled over the past two decades. Corn grain and barley shares of dairy rations have remained relatively stable. Fed rations for beef cattle have also remained stable. However, replacements have followed a similar trajectory to dairy cows, but with a less pronounced decline in alfalfa fed and a more evident increase in corn silage.

Application in Other States

The method we use can be applied in other states, since it relies in large part on secondary data from USDA NASS and the U.S. Census Bureau. Several adjustments will be needed for such application. First, while ID is a prominent barley producing state, many other states in the West and rest of the U.S. are not. Thus, the portfolio of analyzed feed crops will vary by state. The most challenging part of our method was determining the daily feed rations, and our strategy was to obtain estimates via interviews with University of Idaho Dairy and Beef Specialists. If these types of experts are not available from within Extension, then other industry experts will be needed. We interviewed several Specialists of each type to verify the robustness of initially obtained estimates.

Observed Trends in Supply and Demand Balances

The final part of the analysis determines total supply, total demand, and the supply-demand (S-D) balance. Total supply is the sum of total production, imports, and beginning stocks. Total demand is the sum of total feed consumption, exports, and ending stocks. The S-D balance is equal to total supply minus total demand. Figure 2 shows a plot of the ratio of the S-D balance divided by total supply for each crop for 2003 to 2021. In this figure, ratio values above zero imply that local (Idaho) supply is greater than local demand, while negative ratios imply a state's supply is less than its demand.

Figure 2 illustrates that feed barley supply has consistently exceeded its demand over the last two decades. The reasoning for this is clear for barley, since, as estimated by the National Barley Improvement Committee (2019), the national percentages of barley used for malting and animal feed are 62% and 29% respectively. State level references for ID declare that, as of 2003, malting varieties accounted for about 60% of barley acres planted (Robertson and Wesenberg, 2003). Additionally, as of 2013, barley malting processing capacity was over 25 million bushels per year (Lewin et al., 2013). Since actual processing uses and current processing capacity are unknown, we acknowledge that we cannot account for all the substantial malting processing demand for barley. However, values of planted varieties and processing capacity as of 2013 imply that most of the barley grown in ID is either used locally for malting or animal feed. Thus, we expect that if we were able to fully quantify the barley demand for malting, then the overall S-D balance would be near zero in most years.

For alfalfa hay, our estimates also imply that supply has consistently exceeded feed demand over the past several decades. However, we acknowledge that we are not able to fully account for all the demand for alfalfa hay (or other feed) by animals that are not on dairies or feedlots. Specifically,

USDA NASS data show that there were a total of 2.5 million cattle and calves in ID as of 2021 (USDA NASS, 2021). Our estimates show that there were about 1.7 million animals on dairies or feedlots as of 2021, which implies that about 800,000 cattle and calves were being reared on rangelands. These cattle and calves on rangelands commonly need supplemental feed, including hay and silage, beyond range grasses for some periods, especially during winter and in summer during drought (Hill and Kilpack, 2022). Thus, their demand for feed would increase our overall estimates. However, due to the heterogeneity of rangeland grasses and associated nutrient composition, as well as climates in different rangeland regions in ID, we did not include this portion of feed demand in our analysis. Thus, much of the alfalfa hay supply quantity that exceeds demand in Figure 2 is most likely accounted for by non-dairy or feedlot cattle and calves and equine.

For corn silage, the quantity supplied is estimated to have exceeded demand in the early part of the observation period, but they have moved towards parity in recent years. Similar to alfalfa hay, part of corn silage demand remains unaccounted for with winter or summer drought feeding of rangeland-based cattle and calves. Additionally, corn silage amounts included in animal rations are typically lower in Eastern ID than in other regions in some periods of the year. Due to the substantial amount of water and weight in silage, it is not economically feasible to ship silage extremely far within ID or across neighboring state lines. Thus, we expect that fully accounting for all corn silage demand would result in corn silage S-D balances near zero.

Corn grain is a bit of an outlier in that the S-D balances for much of the observation period are well below zero, and there is not a major source of unaccounted demand. However, there is one ethanol plant in Southern Idaho (Renewable Fuels Association, n.d.), which may use corn grain in ethanol production. Although the capacity for that ethanol plant is known, it is uncertain how much actual corn grain is utilized on an annual basis. Corn grain S-D balances are not only different than other crops in their levels of imbalance over time, but also display substantially greater year-to-year volatility. This volatility is largely explained by changes in corn grain acreage across crop years. Corn grain is primarily a rotation crop in ID, and so is generally included in standard multi-year crop rotations that include cash crops such as potatoes or sugar beets (Spangler et al., 2022). Thus, some of the variation in S-D balances reflects traditional crop rotation cycles, while some also likely reflects relative profitability of corn compared to other rotation crops. The main points are that the variation in the corn grain S-D balances over time are largely driven by supply rather than demand fluctuations and that they remain below zero as of 2021. Thus, some users of corn grain are likely sourcing some of their corn grain from other states.

Conclusions and Implications

This article presents a method for quantifying the supply and demand of feed crops at the state level. For the 2003 to 2021 years, substantial changes occurred in ID's livestock industry with the dairy industry's continued steady expansion and feed rations changing dramatically. The primary goal of this article was to determine, using our quantified supply and demand (S-D) balances, the extent to which ID's dairy and cattle producers and/or feed sellers are relying on local supplies from within ID compared to supplies from outside ID. Results from the quantification analysis show that ID S-D balances for corn grain have been negative for the entire study period of 2003 to 2021, while ID is largely self-sufficient in alfalfa hay, corn silage, and barley. The self-sufficiency status for corn silage has mainly been maintained through increased acreage and production over time, as corn silage quantities in dairy and feedlot beef have also increased substantially over the observation period.

These determinations are important for industry stakeholders and Extension Educators because the production and price risk exposure profiles have adjusted along with changes in surplus-deficit status. Specifically, ID dairy and feed producers still have significant exposure to growing conditions and prices in the U.S. Corn Belt and international corn markets. This implies that risk management strategies for dairy and cattle producers and feed sellers must account for conditions in corn producing regions and corn markets. Looking forward, dairy and beef cattle industry stakeholders will need to continue to monitor and plan for actions that will come with a continual expansion of dairy cow inventories, along with possible ongoing increases in corn silage included in dairy rations. Specifically, Extension Educators and other agricultural industry professionals will need to expand research and development pertaining to best practices for ensuring that corn silage production levels can be maintained and/or increased in the years ahead. Such efforts would include expanding grower education regarding management of weeds and insect pests that can impact corn growth under irrigated systems, as well as developing corn silage storage protocols that help maintain nutritional quality throughout the crop year.

This study has several qualifications that deserve acknowledgment. First, this is an annual analysis, and so does not capture the cross flows of feed crops that are traded across state lines continually throughout the year, but rather represent net traded values. Second, while actual data were relied upon to as much of a degree as possible, the key segment of the analysis, quantifying daily feed rations for dairy cows and beef cattle, and how they have evolved over time, was dependent on expert opinion. Thus, the quantified values would best be interpreted as having an error band associated with them. However, we believe that the general quantities of the crops analyzed which are consumed by dairy and feedlot cattle are consistent with conditions observed in ID.

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Figures and Tables

Table 1. List of Variables, Data Sources, and Calculations for Determining the Supply and Demand for Feed Crops in Idaho, 2003 to 2021

Variable	Data source and/or calculation method
Supply	
Area planted	USDA NASS
Area harvested	USDA NASS
Yield	USDA NASS
Production	Multiply area harvested • yield
Stocks - carried in	USDA NASS and assumptions (for corn silage and grain)[a]
Imports	U.S. Census Bureau and U.S. Grains Council for conversion (for corn grain and barley)
Total supply	Sum of production, stocks – carried in, imports
Demand	
Exports	U.S. Census Bureau and U.S. Grains Council for conversion (for corn grain and barley)
Feed	Estimates based on expert opinion[b] and USDA NASS
Stocks – carried out	USDA NASS and assumptions (for corn silage and grain)[a]
Total demand	Sum of exports, feed, and stocks – carried out
Supply and demand equilibrium	
Marketing Year Average (MYA) price	USDA NASS

[a] *Corn silage stock estimates are not available at the national and state level, so we assumed that silage stocks were similar in level to those for corn grain. Additionally, since corn grain stocks are unavailable at the state level, we assumed that the state stocks-to-use ratio was equal to that of the national stocks-to-use ratio which was calculated by dividing ending stocks by total use for each crop year as reported in the associated October WASDE report.*

[b] *Expert opinions were those of University of Idaho Extension Dairy and Beef Specialists and their industry contacts.*

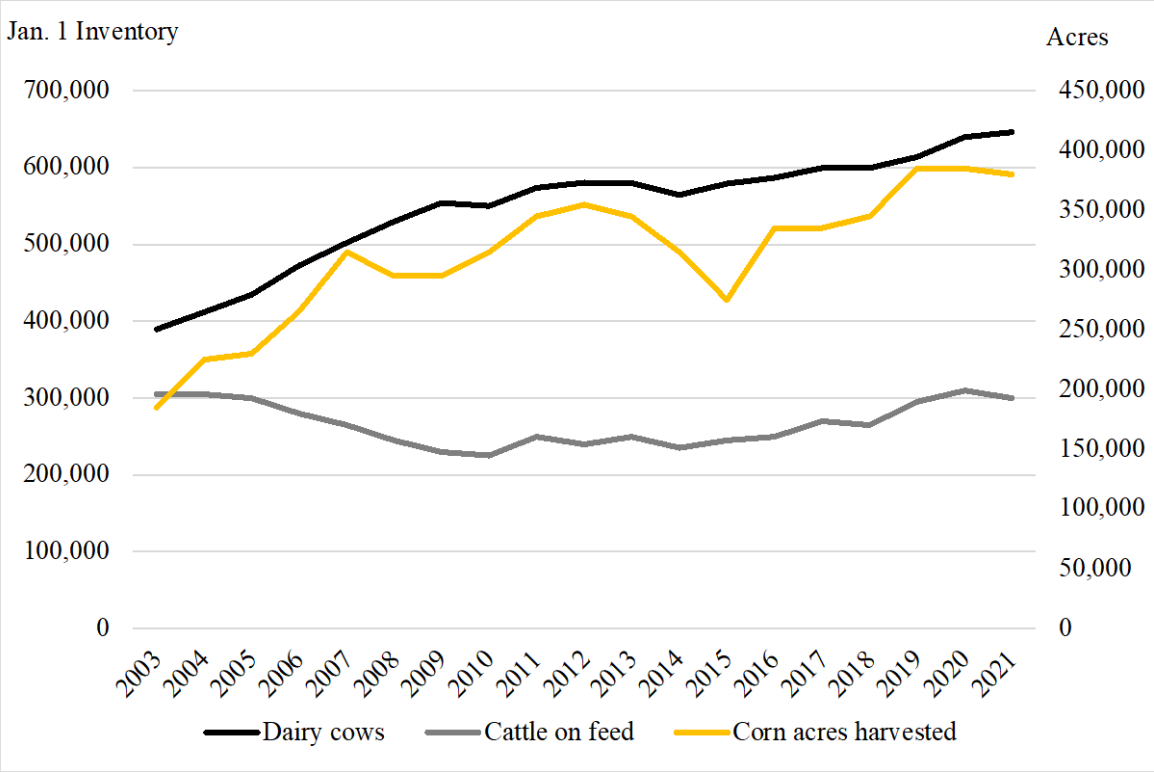
Table 2. Average Daily Rations (in lbs.) Over Five-Year Intervals for Idaho Dairy Cows, Beef Cattle, and Replacements and Feeder Cattle, 2003 - 2021

	2003 - 2006	2007 - 2011	2012 - 2016	2017 - 2021
	Dairy cows (lbs./day)			
Alfalfa hay	18.2	14.6	10.6	6.6
Corn silage	27.3	35.4	44.4	53.4
Corn grain	6.7	6.2	5.7	5.2
Barley	3	3	3	3
	Beef cattle (lbs./day)			
Alfalfa hay	5	5	5	5
Corn silage	5	5	5	5
Corn grain	10	10	10	10
Barley	5	5	5	5
	Replacements and feeder cattle (lbs./day)			
Alfalfa hay	13.3	11	8.5	6
Corn silage	5.5	10	15	20
Corn grain	4	4	4	4
Barley	4	4	4	4

Source: Authors compiled via expert opinion.

Note: "Replacements and feeder cattle" includes heifers, steers, and cows that are being fed in the dairy or feedlot prior to being counted as dairy cows or cattle on feed.

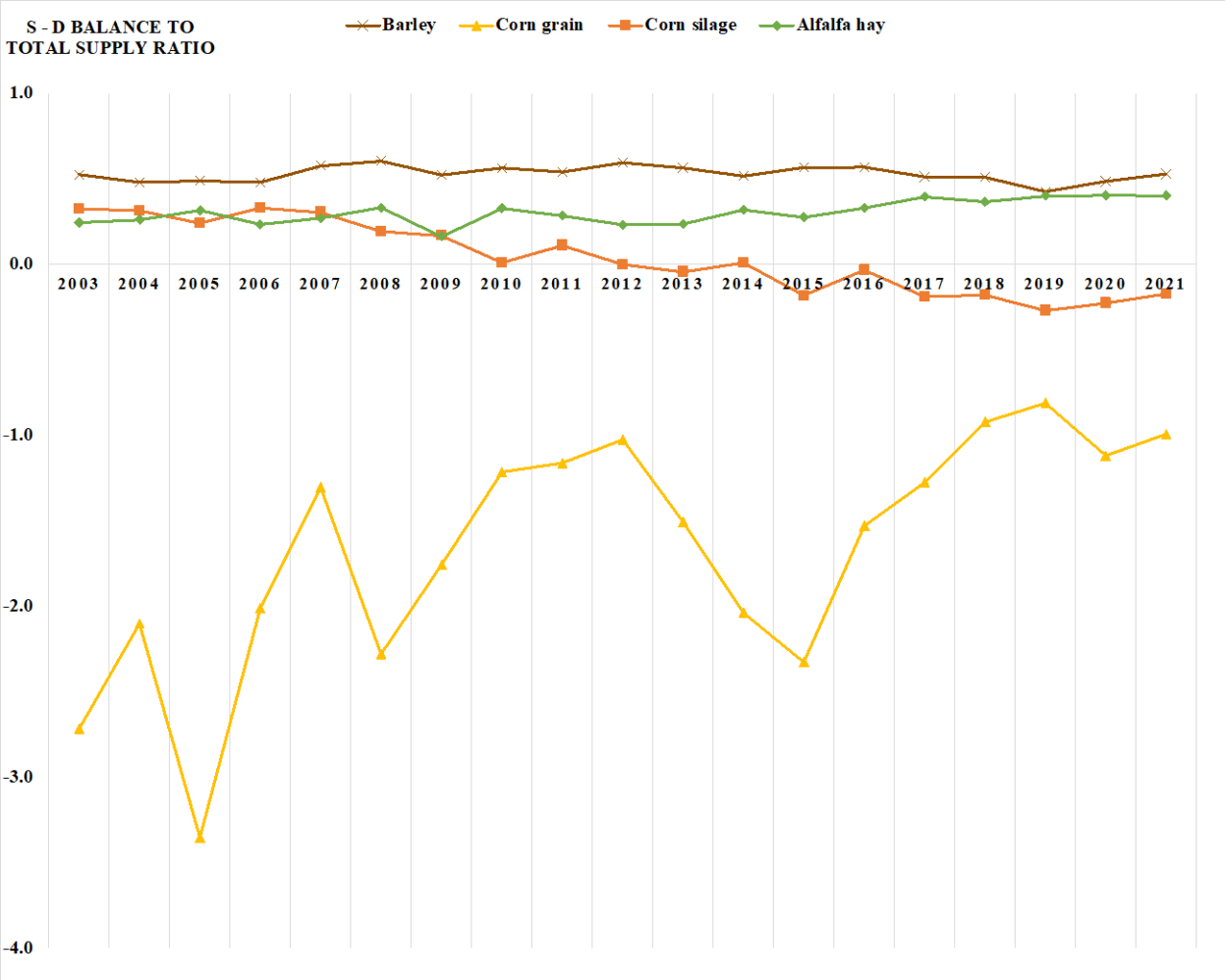
Figure 1. Plot of the Idaho Dairy Cow Inventory, Cattle on Feed Inventory, and Corn Acres Harvested, 2003 to 2021



Source: USDA NASS.

Note: Corn acres harvested is the sum of corn silage and corn grain acres harvested.

Figure 2. Supply and Demand Balance Divided by Total Supply in Idaho for Barley, Corn Grain, Corn Silage and Alfalfa Hay, 2003 to 2021



Source: Authors calculations based on data from USDA NASS and U.S. Department of Commerce.
Note: S-D balance is equal to total supply minus total demand.