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Forage harvested for silage: Methods to measure yield and nitrogen composition

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California dairy farmers typically manage cropland in addition to their animals. Most farmers grow forage crops, which are fertilized with manure and harvested for animal feed. In this way, the cropland recycles manure nutrients and helps control forage costs.

Farmers measure the dry-matter and nutrient yields from their fields to manage feed inventories, buy and sell forage, and demonstrate compliance with environmental regulations. Accurately measuring the forage yield is the first critical control point to improve calculations associated with forage yield quantity and nutrient removal calculations. When forage is purchased or sold, the pricing is often based on forage weight—typically adjusted to 70 percent moisture. Therefore, accurate dry-matter yield measurements help ensure fair pricing. Often forage is used for feed within the facility where it is grown. In this case, accurate yield measurements support cost-effective feed inventories management and purchases. Additionally, California water quality regulations limit nitrogen applications, with limits based on the estimated nitrogen yield of harvested crops. Consequently, nitrogen yield measurements are reported to regulatory agencies to document compliance (CVRWQCB 2007, 2013).

In this study, we investigated the accuracy of common practices for measuring nitrogen forage yields and investigated the most efficient ways to improve measurement accuracy. Typically, farmers measure the total weight of harvested forage and collect a representative sample to analyze for dry-matter and nutrient concentration. We compared different practices for weighing and sampling the harvested forage.

Methods

In our study, we weighed and sampled every truckload of forage for three harvests each of corn, sorghum, and winter forage (predominantly wheat) on Central Valley dairies. Within each forage type, each harvest was managed by a different dairy producer. Corn and sorghum fields were harvested in late summer or early fall, and winter forage was harvested in the spring. We used the data we gathered to compare several yield-measuring protocols that represent a range of current industry practices. We quantified the accuracy of each method by calculating the yield error, defined as the amount that each measurement is likely to under- or overestimate the actual yield (Miller et al. 2018).

Most California dairy farmers (more than 60%) measure the total weight of harvested forage by summing the weight of all truckloads (Heguy et al. 2016). Accordingly, our most intensive protocol was summing the weight of every truckload. We compared this protocol to multiplying the average weight of one random load from each truck working the harvest by the total number of loads harvested (Miller et al. 2018).

To make a representative forage sample, most farmers collect a few grab samples and mix them to form a composite (De Zorzi et al. 2005; Heguy et al. 2016). Farmers send a subsample of the composite sample to a commercial laboratory for dry-matter and nutrient analysis (Heguy et al. 2016). We quantified the accuracy of collecting one to twenty grab samples randomly from the forage delivery area during pile formation. Additionally, we tested two practical protocols for the timing of sample collection: interval and consecutive. In the interval protocol, grab samples were collected at evenly spaced times throughout the duration of the harvest. In the consecutive protocol, grab samples were collected from multiple truckloads arriving one after another (Miller et al. 2018).

Forage weighing protocols

Our research shows that weighing all truckloads of forage is key to improving the accuracy of yield measurements. On some fields, using the average weight of one load from each truck under- or overestimated the moisture-adjusted yield by up to 35 percent of the yield, even when 20 or more grab samples of forage were collected (fig. 1). To ensure accurate yield calculations for all fields, our data suggest that all truckloads of harvested forage should be weighed.

To put the possible yield error into context, consider a corn silage harvest with a 70 percent moisture-adjusted yield of 27 tons per acre, and a nitrogen yield of 220 pounds of nitrogen per acre. To compare the protocols for forage weight measurement, assume that ten grab samples are collected to quantify the dry-matter and nitrogen concentration of the forage. Multiple trucks are often used during harvest. If only one load per truck is weighed, the measured moisture-adjusted yield could be anywhere between 16 and 38 tons per acre and the nitrogen yield could be between 130 and 310 pounds per acre. In comparison, if all truckloads are weighed, the measured forage yield is between 25.5 and 28 tons per acre (adjusted to 70% moisture content) and the nitrogen yield is between 200 and 240 pounds per acre (see fig. 1).

Errors in forage weight measurements can have substantial consequences. If less accurate methods for measuring total forage weight are used, buyers can be substantially overcharged for forage (for example, they might pay for 38 tons when only 27 tons are actually delivered). On the other end of the error range, the farmer might underestimate both the dry-matter yield and the nitrogen yield (believing, for example, that 16 tons were harvested when in fact 27 were harvested). When inaccurate estimates of nitrogen yields run on the low side, they overestimate the Nitrogen Ratio (nitrogen applied divided by nitrogen yield) reported to the Central Valley Regional Water Quality Control Board (CVRWQCB 2007, 2013). For example, assuming that 308 pounds of nitrogen per acre are applied to a field and the yield is 220 pounds of nitrogen per acre, the Nitrogen Ratio is 1.4 (308 divided by 220). However, if the nitrogen yield is

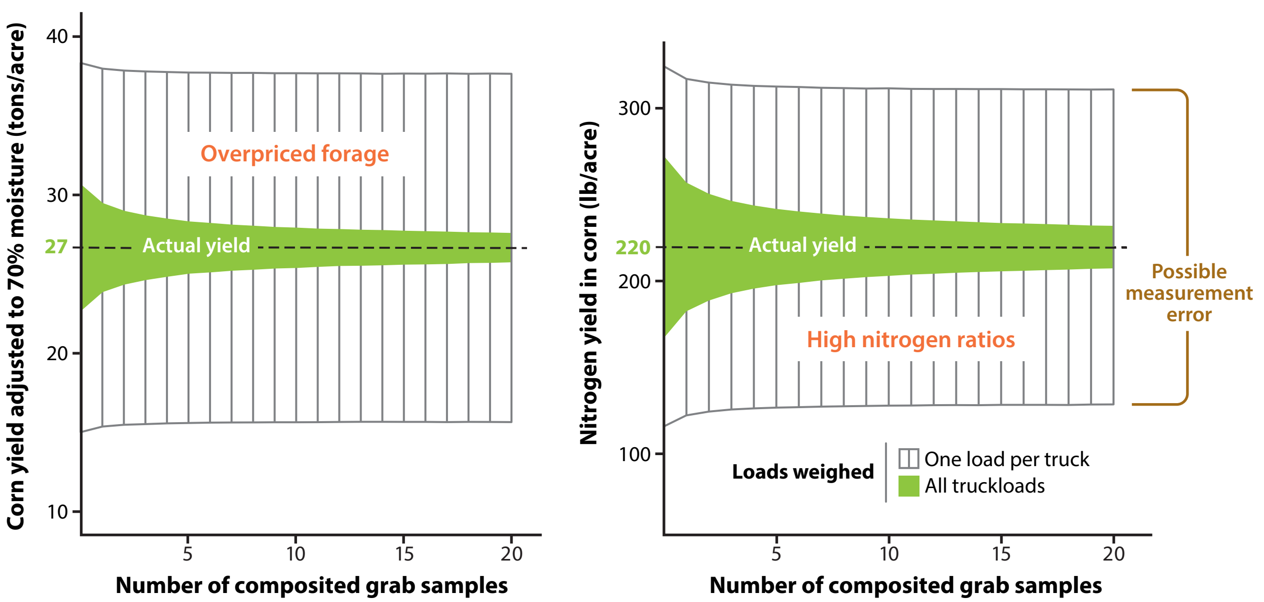

Figure 1. Accuracy of protocols for measuring total forage weight. Graphs compare the error range of 70% moisture–adjusted yield and nitrogen (N) yield of a corn forage harvest when one load per truck, versus all loads, was weighed. Error ranges were calculated assuming a moisture-adjusted yield of 27 tons per acre and an N yield of 220 pounds per acre.

underestimated at 130 pounds of nitrogen per acre, the reported ratio would be about 2.4 (308 divided by 130), well above the actual Nitrogen Ratio and a potential compliance concern.

Truckload weights often vary because of differences in forage moisture and truck fill amount. Forage moisture content varies with field conditions, and load fill varies with chop rate and truck speed. In our research, fields with the least accurate total forage weight measurements had large variations in load weights both within a single truck and between different trucks working the harvest. Because of the variation between loads carried by a single truck, weighing each truck only once during a harvest can lead to errors in measuring total forage weight. Variation in truck weight is often unavoidable, given field conditions and the availability of harvesting equipment. To overcome this possible variability, all truckloads should be weighed to guarantee an accurate measurement of total weight for the harvested forage.

Collecting a representative sample

To make representative samples, farmers collect and composite grab samples, then submit a subsample for nutrient and moisture analyses. The analytical results are used in conjunction with gross forage weight to calculate dry-matter and nutrient yields. Both the timing and frequency of sampling affect how well the composite sample represents the composition of the field.

Sample timing

In our research, a composite of grab samples spaced evenly throughout the duration of the harvest (interval sampling method) was more representative than the same number of grab samples collected from consecutive truckloads (consecutive sampling method) (fig. 2). Grab samples taken from consecutive truckloads are more likely to be from adjacent sections of the field and harvested at similar times. Collecting grab samples throughout the duration of harvest ensures that the composite sample will better represent the composition of the entire field.

We compared the possible measurement error in the context of a corn silage harvest with a 70 percent moisture-adjusted yield of 27 tons per acre. If five grab samples were collected from consecutive loads, the measured yield was between 24.6 and 29.3 tons per acre (see fig. 2). In comparison, if the five grab samples were spread evenly throughout the harvest,

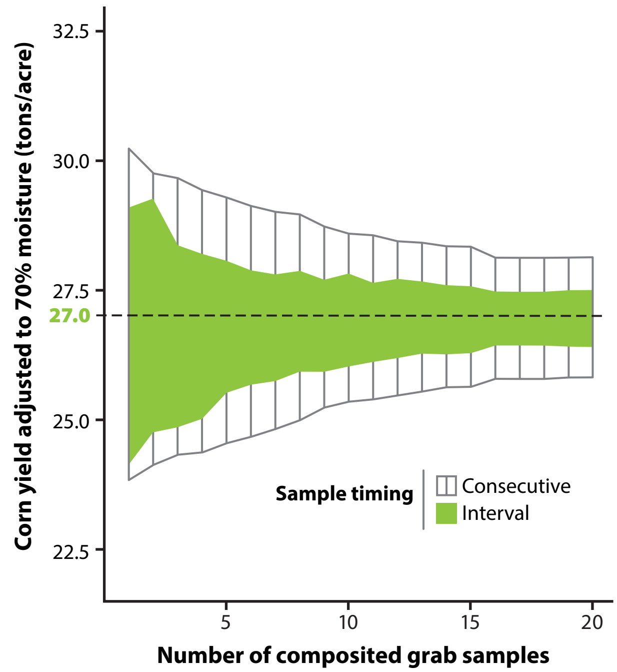

Figure 2. Timing of grab samples affects accuracy of forage yield measurements. The graph shows the error range of the 70% moisture-adjusted yield measurements for a corn silage harvest when grab samples were collected from consecutive truckloads compared to truckloads spread through the duration of the harvest (labeled as "interval"). Error ranges were calculated assuming an actual yield of 27 tons per acre.

the measured value was between 25.5 and 28 tons per acre (see fig. 2). The accuracy of yield calculation was significantly improved when samples were collected using the interval sampling method.

Sample frequency

Collecting 10 grab samples from the harvested forage offers a good balance between accuracy and practicality. Our results indicate that collecting a single sample of forage can lead to large errors in moisture-adjusted yield calculations. The moisture-adjusted yield for winter forages was off by up to 18 percent of the actual yield when it was calculated based on a single grab sample (table 1). With a composite of 10 grab samples collected throughout the duration of the harvest, errors in moisture-adjusted yield calculations were less than 5 percent of the actual yield for corn and sorghum harvests and less than 10 percent for winter forages (see table 1). Fields of winter forage generally required more grab samples to reach the same level of measurement accuracy because they were more variable. More than ten samples may be required to meet some accuracy goals; when this is the case, compositing methods may need to be adjusted to accommodate the greater volume. Ultimately, the number of grab samples required will be determined by the accuracy needs of the individual farmer and the type of forage.

Table 1. Effect of forage type on number of grab samples required for accurate yield measurements. The table shows the error range of 70% moisture-adjusted yields measured when different numbers of grab samples are collected through the duration of harvest. The errors of the yellow and green cells are within 10% and 5% of the actual yield, respectively.

	Corn	Winter forage	Sorghum
Actual yield *(tons/acre)*	**27**	**18**	**22**
Number of grab samples	**Error range of measured yield**		
1	23.6–30.8	14.8–21.4	18.7–25.5
3	25.0–29.1	16.0–19.9	20.1–24.0
5	25.5–28.7	16.5–19.5	20.5–23.6
10	25.9–28.1	16.9–19.0	20.9–23.1
15	26.1–27.9	17.1–18.8	21.1–22.9
20	26.2–27.8	17.2–18.7	21.2–22.8

The bottom line

Accurate measurements of forage yield rely on weighing all truckloads to determine total forage weight. The majority of dairy farmers in the San Joaquin Valley already follow this practice (Heguy et al. 2016). For famers with an on-farm truck scale, the cost of implementing this practice is relatively low. Purchasing an on-farm scale can save additional money because it allows commodities entering or leaving the dairy to be accurately weighed. Use of portable scales or trucks with on-board scales is an alternative way to obtain accurate total forage weights.

Obtaining a representative sample of harvested forage is important. Collecting ten grab samples throughout the duration of the harvest results in a representative composite sample for all forage types (fig. 3). Implementation of this protocol requires training farm employees in proper sampling and compositing techniques. Keep in mind that representative sampling is only the first step toward accurate forage-yield calculations. Handling, preservation, and storage of forage samples are also important. Individuals should consult their farm-specific sampling and analysis plan for record keeping and analytical compliance procedures,

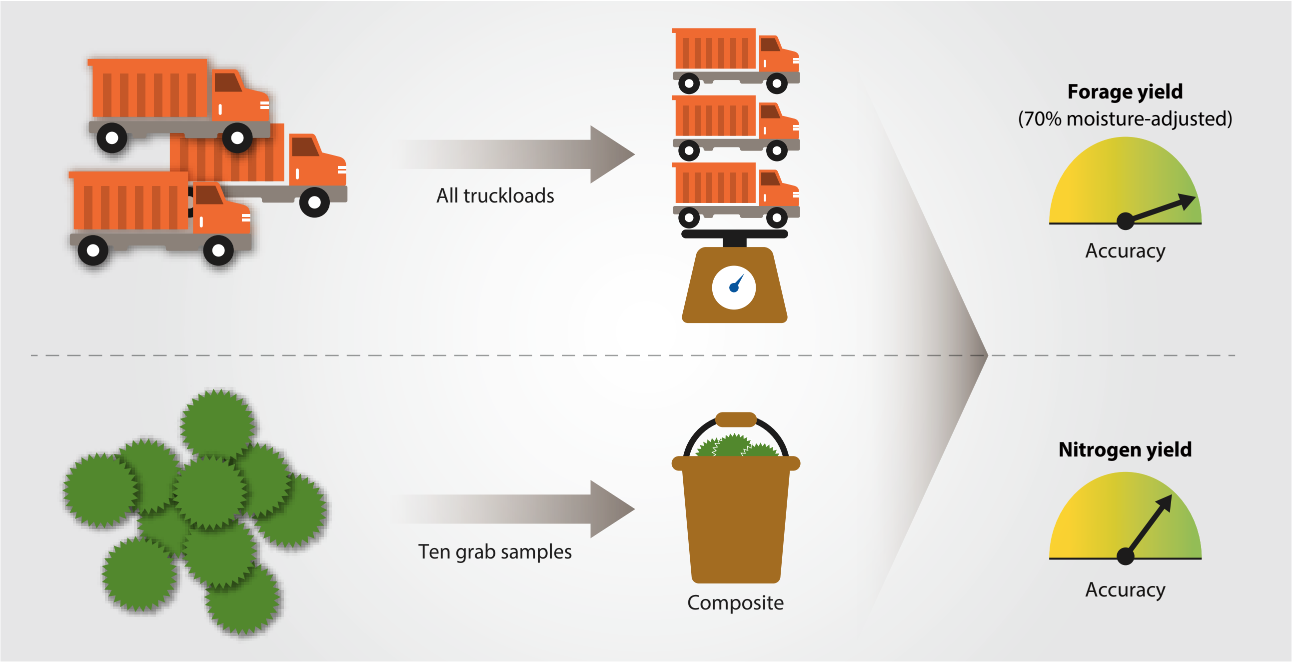

Figure 3. Recommended protocols for measuring forage yields. We recommend weighing all truckloads and collecting 10 grab samples, using an interval sampling method. Following this protocol, the error of 70% moisture-adjusted yield measurements was consistently less than 5% of the actual yield. The error of nitrogen yield measurements was consistently less than 10% of the actual nitrogen yield.

cdqap.org/wp-content/uploads/2021/06/11-03-Sampling-and-Analysis-Plan-Example.pdf. Investments in accurate measurements of forage yield will pay off in accurate feed pricing, efficient feed inventories, and defensible regulatory reporting.

For more information

More information on regulatory requirements for sampling and reporting in the Central Valley can be found in the revised Waste Discharge Requirements General Order for Existing Milk Cow Dairies, issued by the Central Valley Regional Water Quality Control Board, www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2013-0122.pdf.

Information on many aspects of dairy manure nutrient management and water quality compliance is available in the Central Valley Dairy Quality Assurance Program's Central Valley RB5 Water Quality Reference Binder, cdqap.org/binders/central-valley-water-quality/.

For more information on this study's methods and results, see Miller et al. (2018).

Acknowledgements

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