W 840

Dairy Manure Land Application Management

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TENNESSEE DAIRY MANURE LAND APPLICATION RATE WORKSHEET

(Complete this form each time you land apply manure; retain for recording keeping.)

FARM: _____ **FIELD:** _____

1. SOIL TEST

Year: _____ **P:** ☐Low ☐Medium ☐High ☐Very High **K:** ☐Low ☐Medium ☐High ☐Very High

2. MANURE TEST (report "as is" per unit: ☐ ton, solid manure ☐ 1,000 gallon, liquid manure)

Source: _____ **Sample Year(s):** _____

Phosphorus (MP): _____ lb-P_2O_5/unit **Potassium (MK):** _____ lb-K_2O/unit

Ammonia Nitrogen (AN): _____ lb-N/unit **Organic Nitrogen (ON):** _____ lb-N/unit

Volatilization Factor (**VF,** Appendix **Table 4**): _____ Availability Factor (**AF**, Appendix **Table 5**): _____

Available Nitrogen (AvN) = (**AN** × **VF**) + (**ON** × **AF**) = _____ lb-N/unit

3. CROP INFORMATION

Crop: _____ **Yield Goal (YG):** _____ per acre

Application Time: ☐ Establish ☐ Maintain ☐ Renovate ☐ Topdress ☐ Corn-Split ☐ Double Crop

Harvest Form: ☐ Grain/Seed ☐Silage ☐ Green Chop ☐ Pasture ☐ Hay ☐ Biofuel

Crop Nutrient Application Recommendations – see Appendix **Table 6**:

N = _____ lb-N/ac **P** = _____ lb-P_2O_5/ac **K** = _____ lb-K_2O/ac

Phosphorus Removal (PR) – see Crop Phosphorus Removal Rate (**CPRR**) in Appendix **Table 9**:

PR = **YG** × **CPRR** = _____ × _____ = _____ lb-P_2O_5/ac

4. FIELD NITROGEN CREDIT (FNC) (choose one option)

☐ Manure has not been applied to this field within the prior 24 months: **FNC** = 0 lb-N/ac

☐ Use Appendix **Table 10** to calculate your credit and list the value here: **FNC** = _____ lb-N/ac

5. AGRONOMIC MANURE APPLICATION PLANNING

Step 1. **N-Rate**: (**N** - **FNC**) ÷ **AvN** = (_____ - _____) ÷ _____ = _____ ☐ton/ac ☐ 1,000-gallon/ac

Step 2. **PR-Rate**: **PR** ÷ **MP** = _____ ÷ _____ = _____ ☐ton/ac ☐ 1,000-gallon/ac

Step 3. Max Rate: ☐ Soil **P** < Very High = **N-Rate**

☐ Soil **P** is Very High = **N-Rate** or **PR-Rate**, whichever is lower

Step 4. Decide what Manure Application Rate (**MAR**) you will use: _____ units/ac

6. SUPPLEMENTARY NUTRIENTS *(Maximum additional chemical or other fertilizer N-P-K needed)*

☐ Nitrogen: (**N** - **FNC**) - (**MAR** × **AvN**) = (_____ - _____) - (_____× _____) = _____ lb-N/ac

☐ Phosphorus: **P** - (**MAR** × **MP**) = _____ - (_____× _____) = _____ lb-P_2O_5/ac

☐ Potassium: **P** - (**MAR** × **MK**) = _____ - (_____× _____) = _____ lb-K_2O/ac

Other N & P fertilizers used (type & lb/ac used): _____

7. SITE SPECIFIC CONSERVATION PRACTICES

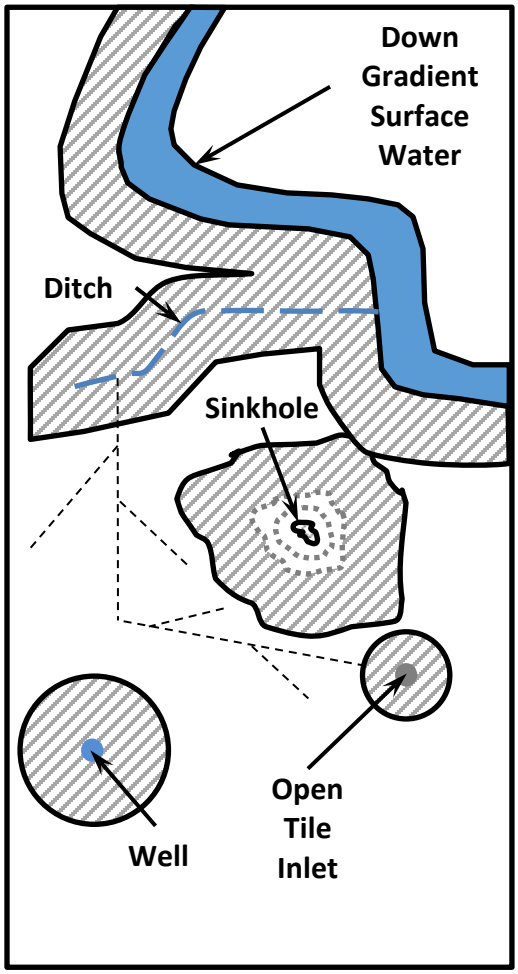
☐ **Application Rate:** Follow spreading equipment directions to target your manure application rate.

☐ **Application Timing:** Apply manure to agronomic crops within four weeks of planting or the target application dates listed in the Appendix **Table 6** footnotes. Apply manure to forages with the onset of favorable growth conditions or immediately after harvest when an additional harvest is expected.

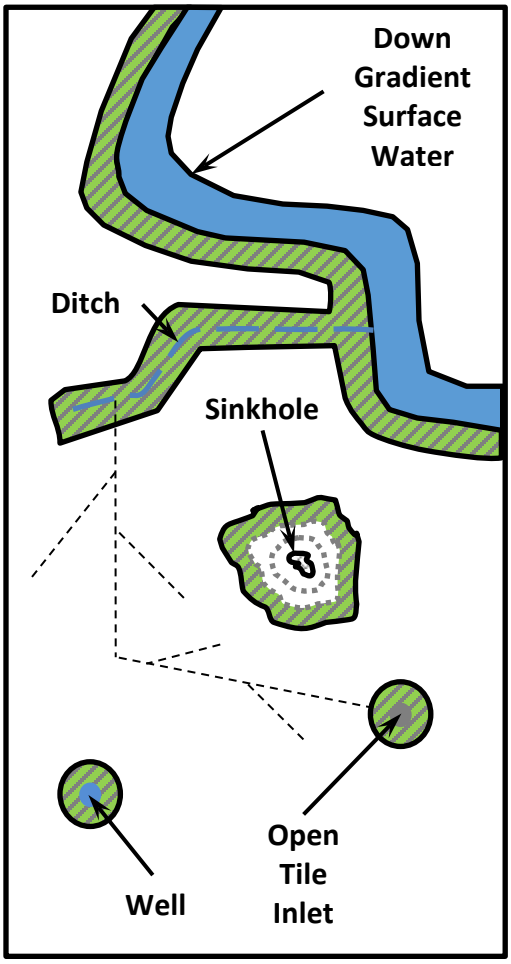
☐ **Field Conditions:** Don't apply manure to frozen, snow covered, or wet soil or steep (≥ 20%) slopes.

☐ **Weather Forecast:** Don't apply manure if precipitation capable of producing runoff (1/4" + rainfall) is likely (≥ 50% local forecast) within 24 hours of the planned application time.

☐ **Setbacks/Buffers:** Don't apply manure within 100 ft of the sensitive areas below or any conduit or drainage to surface or groundwater. You can reduce the setback to 35 feet if the sensitive area/conduit is protected by a 35 ft wide vegetated buffer.



Don't apply manure within 100 ft of un-buffered sensitive areas



Don't apply manure within 35 ft of sensitive areas with 35 ft buffers

☐ **Spreadable Acres (SAc) = _____ :** Use an overhead image/map to estimate the area in acres where manure can be applied outside of the field setbacks/buffers. The maximum amount of manure you can apply to the field is: **MAR** x **SAc** = _____ x _____ = _____ ☐ ton/ac ☐ 1,000-gallon/ac

SIGNATURE: _____ Date(s) Manure Applied: _____

Your signature attests to your good faith effort to use this Worksheet to apply manure nutrients agronomically and verifies that you have implemented the site specific conservations practices in Step 7.

DAIRY MANURE LAND APPLICATION MANAGEMENT

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INTRODUCTION

This publication provides Tennessee dairy producers that do not have a Concentrated Animal Feeding Operation (CAFO) permit with a Worksheet to set agronomic manure application rates. The entire document should be read prior to using the Worksheet for the first time. After you are familiar with the Worksheet, use this publication as a reference resource.

All Tennessee dairies with more than 700 mature animals confined and that manage liquid manure require a state operating permit (SOP) and a professionally prepared Nutrient Management Plan (NMP). Dairies with a CAFO permit **MUST** follow the land application guidelines contained in their NMP and should **NOT** use this Worksheet.

Maximize Manure Value. This Worksheet helps dairy producers control production cost by maximizing the value of manure nutrients and minimizing costs for fertilizers without sacrificing economic crop returns.

Environmental Regulations. Stormwater runoff that contains land-applied dairy manure, or excess nutrients from land applied-dairy manure, can be considered an illegal discharge by the Environmental Protection Agency (EPA). For unpermitted dairy farms, this Worksheet allows producers to manage manure so it is "***land applied in accordance with site-specific nutrient management practices that ensure appropriate agricultural utilization of the nutrients***" (**40 C.F.R. § 122.23(e)(1)**). This regulatory requirement strictly applies to dairy farms that confine 700-plus mature dairy cows (**40 C.F.R. §122.23(b)(4)**), and can apply to smaller farms that discharge without a CAFO permit. This Worksheet provides dairy producers with a field-specific nutrient management system for agricultural utilization of manure nutrients and a recordkeeping form (**40 C.F.R. §122.23(e)(2)**).

Minimize the Negative Environmental Impact of Land Applied Manure. Applying more nutrients than your crop demands can enrich surface waters with nutrients that degrade both local and distant receiving waters. The Worksheet sets manure application rates that minimize the possible negative environmental impacts of manure nutrients.

INFORMATION REQUIRED TO USE WORKSHEET

Assemble the following information prior to using this Worksheet:

- Field soil test(s).
- Manure test(s).
- Field crop history and yield data (five years).
- Field manure application records for the prior two years.
- Field images/maps that show the field area in acres—obtain from your local USDA Natural Resources Conservation Service or Farm Service Agency office.

PART 1. SOIL TEST

Why soil sample? Soil tests enable dairy producers to manage manure nutrients efficiently. **University of Tennessee Extension Publication PB 1061** describes how to properly collect soil samples [1]. Follow the area frequency recommendation in PB 1061, collecting a composite soil sample for every 10 acres, which is required to effectively manage soil pH (e.g., with variable rate lime applications). However, you can use an average composite soil test result per field or 100 acres, whichever is smaller, when calculating your manure application rate with this Worksheet. Collect soil samples every one to five years, depending on which crop you are growing, as recommended in Appendix **Table 1**. Identify the year you collected your soils samples in **Part 1** of the Worksheet.

Which lab should I use to analyze my soil samples? Send your soil samples to a lab that participates in the **North American Proficiency Testing Program** for the **Mehlich-1** extraction procedure. Both the **University of Tennessee Extension Soil, Plant and Pest Lab** in Nashville, Tennessee, and **Waypoint Analytical** in Memphis, Tennessee, participate in this program that validates soil testing procedures.

Which soil test method should I use? Different soil test procedures have been developed for different regions of the United States. Generally, these procedures mix soil samples with a dilute acid and then measure the **P** and **K** in the acid solution [2]. The intent is to create an index of your crop's ability to use **P** and **K** from your field soils. Specify that your lab uses the **Mehlich-1** analysis procedure to test your soils.

Crop P & K application rates are based on your soil test results. UT Extension recommends crop application rates of phosphorus and potassium fertilizer based on **Mehlich-1** soil **P** and **K** concentration categories: Low-L, Medium-M, High-H and Very High-VH [2]. The **Soil, Plant and Pest Lab** specifies the **P** and **K** concentration categories on your soil test report. You can use Appendix **Table 2** to identify the **P** and **K** concentration categories using your soil test report(s) [3]. Identify the average **P** and **K** concentration category for your field soils in **Part 1** of the Worksheet.

Crop N application rates are not based on a soil test. Soil tests for nitrogen are not used in Tennessee because total N in soil is not well correlated with crop yield. Instead, it is widely accepted that N rate studies for each non-legume crop is the proper way to estimate nitrogen need. Thus, recommended nitrogen application rates in Tennessee are based on replicated yield studies that use a range of nitrogen application rates to soils that have **P** and **K** concentrations that will not limit yield.

PART 2. MANURE TEST

Collect manure samples. Dairy manure nutrient concentrations vary among farms because different rations and manure management strategies are used. Do not use "book" values for manure nutrient concentrations. Collect representative samples from each unique manure source yearly following the instructions in Appendix **Table 3**. Use the most recent analysis or the average of the previous two to three analyses in the Worksheet. Collect samples from stockpiled solid manure three weeks prior to land application so you'll have enough time to use the results to set your current application rate. For good recordkeeping, identify the manure source and sample analysis year(s) in Worksheet **Part 2**.

Which lab should I use to analyze my manure samples? Send your manure samples to a lab certified by the **Minnesota Department of Agriculture Manure Testing Laboratory Certification Program**. **Waypoint Analytical** in Memphis, TN and **Waters Agricultural Laboratory** in Owensboro, KY are currently certified manure analysis laboratories. In Worksheet **Part 2**, list the results for the manure **total phosphorus** (**MP**) and **total potassium** (**MK**) on an "as is" basis per "ton" for solid manure or "1,000-gallon" for liquid manure.

Manure Ammonia Nitrogen. Analyze your manure for **ammonia nitrogen** (**AN**) (**Figure 1**). List the **AN** concentration in Worksheet **Part 2**. Ammonia volatilizes at different rates depending on how you land apply manure [4-6]. List your application method **Volatilization Factor** (**VF**) using Appendix **Table 4**. Manure ammonia does not provide "residual" nitrogen to future crops.

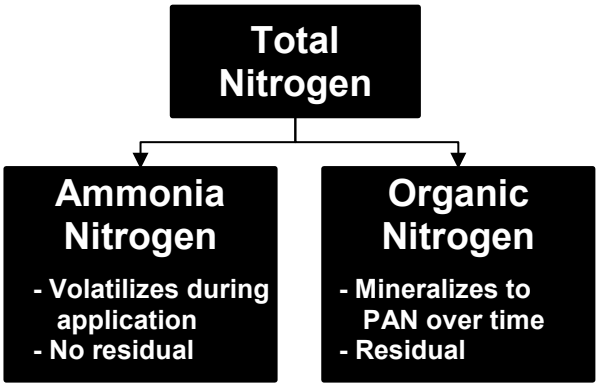

Figure 1. Nitrogen in manure.

Manure Organic Nitrogen. The other form of manure nitrogen is Organic Nitrogen (**ON**), which can be calculated by subtracting **AN** from Total Nitrogen (**Figure 1**). List your manure **ON** in Worksheet **Part 2**. Manure organic matter is "mineralized" by soil bacteria to release plant available nitrogen. List the **Availability Factor** (**AF**) for your manure type in Worksheet **Part 2** using Appendix **Table 5**. Some portion of the current manure application **ON** will likely become plant available for future crops as "residual" nitrogen (see **Part 4**), so retain the Worksheet to track **ON** applications over time.

Manure Available Nitrogen. The manure application rate calculated with this Worksheet uses recommended chemical fertilizer rates as a reference standard for crop production. Chemical fertilizers are "100% plant available," meaning that all the applied N, P and K can be used to grow crops [4]. Dairy manure phosphorus and potassium are approximately "100% plant available" [7]. However, the nitrogen in dairy manure is never "100% plant available." In Worksheet **Part 2** estimate your manure crop available nitrogen (**AvN**) by multiplying **AN** by your **Volatilization Factor** (**VF**) and adding that to the manure **ON** multiplied by your appropriate **Availability Factor** (**AF).**

PART 3. CROP INFORMATION

Crop-Yield Goal. You must consider the nutrient needs for the specific crop you will be producing along with a realistic **Yield Goal** (**YG**) for that crop. Set your **YG** as the average yield obtained in the last five cropping cycles after dropping the lowest and highest yields. If you don't have yield data, use yields for nearby fields, **UT Extension variety trial data** or your **USDA-NASS** county yield average increased by 10 percent.

Application Time and Harvest Form. Time your manure applications for when your crop needs nutrients as recommended in Appendix **Table 6**. For agronomic crops, apply nutrients at establishment, as a split application for corn grain (at planting and then again when the corn is about 16 inches tall), as a fall and/or spring topdress for small grains, and to establish a double crop. For forages, apply manure to establish new forage stands, maintain an established stand, renovate a declining stand, and as a split application for corn silage. You can also apply manure to topdress small grain forages in spring and/or fall or to forages immediately after harvest when an additional cutting is expected. Identify your manure application time and the crop harvest form in **Part 3** of the Worksheet.

Nitrogen (**N**). In **Part 3**, list the crop recommended **N** application rate (lbs-N/ac) using the condensed UT Extension fertilizer application rate recommendations in Appendix **Table 6** [8, 9]; the recommended rates generally don't depend on your **YG** or a soil test. However, for corn the **YG** does affect the recommended **N** application rate. Also, be aware that you can use a Pre-Sidedress Nitrate soil test to refine the **N** application rate during a split application of **N** to corn [10].

Legumes. Legumes are plants that supply their own nitrogen by hosting special bacteria in root nodules. The **N** application rate you enter in Step 1 should reflect a Legume Nitrogen Credit (**LNC**) if your preceding crop was a soybean or a single species legume cover crop or if you are interseeding legumes into your current crop. See Appendix **Table 7** and **Table 8** to determine what **LNC** you should be use.

Phosphorus (**P**) and **Potassium** (**K**)**.** In **Part 3**, list the recommended application rates for phosphorus (**P** - lbs P_2O_5/ac) and potassium (**K** – lbs K_2O)/ac) using Appendix **Table 6**. The recommended rates depend on your soil test results in Worksheet **Part 1**. The recommended **P** and **K** application rates ensure these elements will not limit crop yield.

Phosphorus Removal (PR). An estimate of your crop phosphorus removal (**PR**) is one basis to set your manure application rate in **Part 5** of the Worksheet. Look up your Crop Phosphorus Removal Rate (**CPRR**) in Appendix **Table 9**, making sure to match the harvest form you will use. In **Part 3**, multiply your **YG** by the **CPRR** to estimate your **PR**.

PART 4. FIELD NITROGEN CREDIT

What is a Field Nitrogen Credit? Anytime dairy manure or other organic fertilizers are applied to fields, some part of the organic nitrogen (**ON**) present in the manure/organic fertilizer will likely become available to help produce future crops. This occurs as the organic material is decomposed slowly by soil bacteria in a process called mineralization that releases plant available nitrogen. This "residual" or "carryover" nitrogen from previous dairy manure applications is estimated in Appendix Worksheet **Part 4** as a Field Nitrogen Credit (**FNC**). The **FNC** reduces the amount of nitrogen (**N**) required to produce your current crop. However, the **FNC** is difficult to predict accurately, partly because mineralization rates are affected by soil moisture (rainfall) and temperature that vary from year to year and within crop growing seasons [7, 11]. Research has shown that a **FNC** is quantifiable within one to two years following manure applications and that the residual credit is more reliable and may increase with repeated manure applications [6, 11, 12].

Analyze Dairy Manure for Organic Nitrogen. Dairy manure ammonia nitrogen (**AN**) and organic nitrogen (**ON**) concentrations vary significantly from farm to farm. Test your dairy manure for **AN**, which will then allow you to calculate your manure **ON** as the difference between the Total Nitrogen and **AN** (**Figure 1**). This **ON** will likely provide crop available nitrogen for two years after manure application and is the basis for predicting the **FNC**.

Field Nitrogen Credit from Dairy Manure Organic Nitrogen. Dairy manure will provide "residual" plant available nitrogen equal to approximately 10 percent of the **ON** when applied within the prior 12 months. Dairy manure will provide "residual" or "carryover" nitrogen equal to approximately 5 percent of the **ON** when applied between 12 to 24 months ago. Thus, to estimate the **FNC** you need historical records of your manure **ON** applications to the current field for the prior two years. Use Appendix **Table 10** to list and calculate the **FNC** for your prior dairy manure applications. Attach the completed **Table 10** calculations to the Worksheet for recordkeeping. These records will assist you in making more accurate estimates of your **FNC** for future crops.

Estimating the Field Nitrogen Credit for Organic Fertilizers Other Than Manure. If you have applied other organic fertilizers (e.g., poultry litter or biosolids) to your field over the past two years, the **FNC** for those materials should also listed in **Table 10**. Ideally, you will have measurements of the **ON** concentrations for these other organic fertilizers. If you don't, you can estimate the **ON** as 50 percent of the Total Nitrogen.

PART 5. AGRONOMIC MANURE APPLICATION RATE PLANNING

There must be a dividing line between what can be justified as an agronomic manure application rate, which naturally has a maximum value, and higher rates that are inefficient and prone to be interpreted as land disposal and potentially polluting. In **Part 5** of the Worksheet you will calculate two possible maximum agronomic rates as you consider which manure application rate you'd like to use to produce your crop.

Step 1. Calculate Nitrogen Manure Application Rate. Your crop nitrogen need is the recommended **N** from **Part 3** of the Worksheet minus the field nitrogen credit (**FNC**) from **Part 4** of the Worksheet. The nitrogen manure application rate (**N-Rate**) is the crop nitrogen need (**N - FNC**) divided by your manure available nitrogen (**AvN**) from **Part 2** of the Worksheet. Your manure application rate must not provide more nitrogen than is needed to produce your crop because the excess nitrogen can degrade water quality.

Step 2. Calculate Phosphorus Removal Manure Application Rate. If you land apply manure at an **N**-Rate you will likely over apply phosphorus to your field. Over repeated crop cycles, manure applications at an **N**-Rate will produce a buildup of soil **P** that can degrade water quality. Therefore, you need to know how much phosphorus your crop will remove and correspondingly how much manure is needed to replace that phosphorus. Applying manure to replace the phosphorus removed by crops will likely prevent soil **P** buildup over time. The phosphorus removal manure application rate (**PR-Rate**) is the crop phosphorus removal (**PR**) from Worksheet **Part 3** divided by your manure phosphorus concentration (**MP**) from Worksheet **Part 2**.

Step 3. Identify Maximum Manure Application Rate. You need to know whether the **N-Rate** or **PR-Rate** is the maximum agronomic manure application rate. If your soil **P** concentration is lower than Very High, your maximum manure application rate is the **N**-Rate. Typically, the **N-Rate** will over apply phosphorus, but this is acceptable because the risk for phosphorus loss to the environment is low so long as the field soil **P** concentration remains lower than Very High. If your soil test **P** concentration is in the Very High range, your maximum manure application rate is either the **N-Rate** or the **PR-Rate**, whichever is lower. Be aware that in certain cases (e.g., when erosion losses are very low) the **Revised Tennessee Phosphorus Risk Index** [13] can be used to justify manure application rates higher than the **PR**-Rate when soil **P** is Very High.

Step 4. Decide which manure application rate you'll use. Your manure application rate has a maximum value that should not be exceeded as identified in Step 3. Manure should never supply more nitrogen than your crop needs, and when the soil **P** is Very High your manure shouldn't supply more phosphorus than the estimated crop phosphorus removal. You can choose to use lower rates, for example to meet recommended crop **P** or **K** application rates. List the manure application rate (**MAR**) you decide to use in Step 4.

PART 6. SUPPLEMENTARY NUTRIENTS

Manure is an unbalanced fertilizer. In **Part 6** of the Worksheet, you will calculate supplemental N, P and K that may be needed to produce your crop and that should be supplied, for example, by chemical fertilizer.

Nitrogen. If you land apply manure at the **N-Rate** calculated in Worksheet **Part 5**, you don't need additional nitrogen from chemical or other fertilizers for maximum economic crop yields. Applying additional nitrogen will increase crop production cost without a reasonable expectation of an economic yield return and may cause the manure application to be considered a disposal practice and/or polluting.

When your soil test **P** is Very High, you will typically land apply manure at the **PR-Rate** calculated in Worksheet **Part 5**. In this case, supplemental nitrogen will likely be required to produce your crop. Calculate the supplemental nitrogen you need by subtracting the amount of nitrogen that will be supplied by your manure (**MAR** x **AvN**) from the nitrogen needed to produce your crop (**N** - **FNC**). The supplemental nitrogen is a maximum application rate in lb-N/ac of chemical or other nitrogen fertilizer. Application of nitrogen fertilizer beyond the supplementary rate may cause the manure application to be considered a disposal practice and/or polluting.

Phosphorus and Potassium. Calculate the supplemental phosphorus you need to produce your crop by subtracting the phosphorus your manure application will provide (**MAR** x **MP**) from the **P** needed to produce your crop. Likewise, the supplemental potassium you need is calculated by subtracting the potassium your manure will supply (**MAR** x **MK**) from the **K** needed to produce your crop.

For some fields, the crop recommendations for phosphorus (**P**) and potassium (**K**) will likely be zero because your field soils will already contain enough **P** and **K** to produce your crop. In this case, the supplemental P and/or K calculation will result in a negative number representing application of P and/or K when none is needed. Applying additional phosphorus will increase crop production cost without a reasonable expectation of an economic yield return. Any calculated supplemental phosphorus is a maximum application rate in lb-P_2O_5/ac that should not be exceeded.

List Additional Fertilizers Used. The intent of this Worksheet is to assure that your manure application rate is agronomic and that you take full credit for the nutrients provided by your manure. Thus, you need to document all supplementary N (lb-N/ac) and P (lb-P_2O_5/ac) fertilizers applied to the field because these are the nutrients that, when applied in excess, degrade water quality. At the end of **Part 6** of the Worksheet list all additional N and P fertilizers that you use to produce your crop.

PART 7. SITE-SPECIFIC CONSERVATION PRACTICES

Application Rate. This Worksheet is used to calculate agronomic manure application rates. To properly target the agronomic manure application rate you choose, consult the manuals of your manure spreading equipment to set, for example, gate openings and travel speeds.

Application Timing. Proper manure nutrient management involves more than estimating the most efficient application rate. Timing your application to coincide with crop nutrient demand is also important. Poorly timed nutrient applications degrade crop nutrient use efficiency, lower crop yield and increase nutrient loss to the environment [14]. For agronomic crops, manure application ideally occurs a week prior to or following planting, but this may not be possible. Manure should not be applied more than four weeks prior to planting an agronomic crop or the target nutrient application dates listed in Appendix **Table 6**. Timing is more variable for forages, but should precede or coincide with the seasonal onset of favorable growth conditions and occur immediately after harvest when an additional harvest is expected. In Tennessee, manure applications between December 15 and February 15 generally should be avoided [15].

Field Conditions. Field conditions that promote manure runoff must be avoided. Do not apply manure to frozen, snow-covered or saturated soils, or to steep (>20 percent) slopes. Liquid dairy manure should never leave the confines of the field (runoff) during application; liquid manure should not pond on the field for more than four hours.

Weather Forecast. Manure applications should not be made during or immediately prior to precipitation capable of producing runoff (≈ ¼"+ rainfall). Manure application should be delayed if precipitation is likely within 24 hours of the planned application time period (≥ 50 percent based on a local weather forecast).

Setbacks/Buffers. Manure application setbacks are a regulatory requirement for large dairy farms (>700 mature animals confined) (**40 C.F.R. §412.4(c)(5)**). All dairy farms that utilize this Worksheet should also abide by the referenced manure setback requirements. A setback is a specified distance to sensitive areas: downgradient surface waters and conduits to surface water or groundwater including ditches, open tile inlets, sinkholes and wells. Manure should not be applied within 100 feet of these unbuffered sensitive areas as illustrated in Worksheet **Part 7**. The setback distance can be reduced to 35 feet if the sensitive area is protected by a 35-foot wide vegetated buffer as illustrated in Worksheet **Part 7** (**40 C.F.R. §412.4(c)(5)**). Vegetated buffers are dense strips of perennial vegetation planted parallel to field slopes and maintained to slow runoff, trap sediment/nutrients and enhance infiltration. Well-established natural riparian areas (streambanks hosting native grasses, shrubs and trees) that are at least 60 feet wide can serve as vegetated buffers.

Spreadable Acres. Use a field map to estimate the field spreadable area in acres (**SAc**) outside of the required setbacks and buffers. Calculate your total planned manure application to the field by multiplying the field spreadable acres (**SAc**) by Manure Application Rate **(MAR**) you choose to use in Worksheet **Part 5**. Do not apply more than this total amount of manure to the field.

SIGNATURE

In order for the Worksheet to meet the Objectives listed in the **Introduction**, you must sign the Worksheet, attesting to your good faith effort to use the Worksheet to apply your dairy manure agronomically while abiding by site-specific conservation practices.

For proper recordkeeping, when you sign the Worksheet also list the date(s) that you land apply manure. Retain the Worksheet for each field and manure application event you perform, along with Appendix **Table 10** if it is used. Recordkeeping is a regulatory requirement for large dairy CAFOs, including unpermitted farms that do not require a CAFO permit in Tennessee because they use a solid manure management system exclusively (**40 C.F.R. §122.23(e)(2)**). This Worksheet meets part of the recordkeeping requirements. Other records that need to be kept include those that ensure proper manure storage, disposal of mortalities, clean water diversion and proper disposal of farm chemicals.

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APPENDIX

Table 1. How often to collect soil samples.

Cropping condition	Frequency (years)
Conventional till continuous row crops	3
Double cropping systems	2
Continuous no-till soybeans	3
Continuous no-till corn or cotton	2
Hay	3
Pastures	5
At the beginning of a different crop or crop rotation	1

Table 2. University of Tennessee Extension soil test calibration levels for soil phosphorus and potassium concentrations [3].

Test Procedure	Calibration Level	Phosphorus, lbs/acre (All crops)	Potassium, lbs/acre (All crops but Cotton)	Potassium, lbs/acre (Cotton)
Mehlich-1	Low (L)	0-18	0-90	0-140
	Medium (M)	19-30	91-160	141-280
	High (H)	31-119	161-319	281-319
	Very High (VH)	120+	320+	320+
Mehlich-3	Low (L)	0-30	0-114	0-178
	Medium (M)	31-60	115-203	179-356
	High (H)	61-210	204-405	357-405
	Very High (VH)	211+	406+	406+

Table 3. How to collect dairy manure samples [16].

Stockpiled solid manure. Collect 10 subsamples from different locations at least 12-18 inches below the pile surface. Mix the subsamples thoroughly in a bucket and place approximately 1-lb of the mixed sample in a heavy duty one-gallon sealable plastic freezer bag. Prior to sealing the bag, squeeze out excess air. Store in a freezer until the sample is shipped for analysis.
During manure removal from a manure pack. Collect at least 5 subsamples from different loads of manure. Mix the subsamples thoroughly in a bucket and place approximately 1-lb of the mixed sample in a heavy duty one-gallon sealable plastic freezer bag. Prior to sealing the bag, squeeze out excess air. Store in a freezer until the sample is shipped for analysis. ***Do not collect manure samples directly from pack manure because representative samples are difficult to obtain.***
While calibrating a solid manure spreader. Spread a tarp in the field at 3 different locations to collect manure from 3 separate passes/loads of a manure spreader. The samples should be gathered from the tarps as soon as practical and always within one hour of application. The weight of these samples can be used to check and/or calibrate a manure spreader's application rate. Mix the subsamples thoroughly in a bucket and place approximately 1-lb of the mixed sample in a heavy duty one-gallon sealable plastic freezer bag. Prior to sealing the bag, squeeze out excess air. Store in a freezer until the sample is shipped for analysis.
Liquid Manure: sampled from manure impoundments. Agitate the manure impoundment thoroughly for at least two hours before and then during sampling. Collect at least 5 one-half gallon subsamples by dipping the sample out of the impoundment over the course of 10 to 15 minutes. Alternatively, you can open a sampling port on a manure application agitator/pipe and collect 5 one-half gallon samples over the course of 10 to 15 minutes. Thoroughly mix the subsamples (e.g. in a five-gallon bucket) and immediately pour the well mixed sample into a sturdy one-quart plastic container – this composite sample is for your manure analysis. Do not let the solids settle from the liquid manure prior to collecting your composite sample. The container should be no more than ¾ full and stored in a freezer until the sample is shipped for analysis. ***Avoid collecting samples from an un-agitated impoundments where possible because a representative sample is difficult to obtain***.
Liquid Manure: sampled during surface application with a spreader. Place shallow pans (e.g. baking pans) around the field in 5 locations to catch manure from the spreader or irrigation equipment. The samples should be gathered as soon as practical from the pans and always within one hour of application. Thoroughly mix the subsamples in a five-gallon bucket and immediately pour a mixed sample into a sturdy one-quart plastic container. Do not let the solids settle from the composited liquid manure prior to collecting your final sample. The container should be no more than ¾ full and stored in a freezer until the sample is shipped for analysis.

Table 4. Dairy manure ammonia nitrogen (AN) volatilization factor (VF).

Manure Application Method	VF
Subsurface Injection	0.95
Partial Injection (e.g., tined aerators used before or during manure application)	0.75
Manure Disked-In Within 24 Hours	0.50
Surface Applied	0.25

Table 5. Dairy manure organic nitrogen (ON) crop availability factor (AF).

Manure Application Method	AF
Un-composted Dairy Manure, Solid or Liquid	0.35
Composted Solid Dairy Manure, Pack Barn Solid Manure	0.20

Table 6. Condensed University of Tennessee Extension crop fertilizer recommendations [8, 9].

Crop Description			Nitrogen (lb/ac) (N)		P_2O_5 (lb/ac) (P)				K_2O (lb/ac) (K)			
			Establish	TopDress / Maintain	L	M	H	VH	L	M	H	VH
AGRONOMIC CROPS												
Corn Grain[1] (grain yield @ 15% moisture)	Maintain=Split Applied @V6 (≈ 16" tall)	100-125 bu/ac	120	0	100	50	0		100	50	0	
		126-150 bu/ac	50	100	120	60			120	60		
		151-175 bu/ac	60	120	140	70			140	70		
		176-200 bu/ac	70	140	160	80			160	80		
		201-225 bu/ac	80	160	180	90			180	90		
Canola[2]			30	110	30	0			30	0		
Cotton			60-80	0	90	60	0		120	90	0	
Sorghum[3]	Grain		60-90	0	60	30	0		60	30	0	
Small Grain[4]			15-30	60-90	80	40	0		40	20	0	
Soybeans[5]			0	0	40	20	0		80	40	0	
Sunflower	Seed	1st Crop	90-120	0	80	40	0		80	40	0	
		2nd Crop	45-60	0	0				0			
Switchgrass[6]	Biofuel		0	0	40	0			80	0		
Tobacco			150-200	0	150	90	30	0	300	180	90	0
FORAGE PASTURE, HAY, AND SILAGE CROPS												
Alfalfa[7]		Establish	0-15	-	150	60	0		240	190	0	
		Maintain	-	0	80	60			240	190		
Bermuda[8-10]	Establish	Common or Hybrid	30/30	-	80	40	0		80	40	0	
	Maintain Pasture	Common	-	60/0-60/0-60	60	40			120	80		
		Hybrid	-	60/60/0-60	90	60						
	Maintain Hay	Common	-	300	120	80			90	60		
		Hybrid	-	400					120			
Corn Silage[11] (silage yield @ 65% moisture)	Maintain=Split Applied @V6 (≈ 16" tall)	15-18 tons/ac	120	0	120	60	0		180	120	0	
		19-25 tons/ac	50	100	160	80			240	160		
		> 25 tons/ac	60	120	200	100			300	200		
Sorghum	Silage		90	0	120	60	0		180	120	0	
Warm Season Pasture/Hay/ Silage[12-14]	Native Grass	Establish	0	-	90	60	0		90	60	0	
		Maintain	-	0-120								
	Annual Grass	Establish	60-120	-	60	30						
	SoybeanMillet	Establish	30	-								
Cool Season Pasture/Hay Silage[15-22]	All Perennials	Establish/Renovate	0-30	-	90	60	0		90	60	0	
	Grass-Clover	Maintain Pasture	-	0-30/0-60	60	30			60	30		
		Maintain Hay	-	30/0-30/0-60								
	Tall Fescue	Maintain Pasture	-	0-60/0-60								
		Maintain Hay	-	60/0-45/0-60								
	Timothy/Orchardgrass		-	60/0-60	60	30			60	30		
	Small Grain-Ryegrass		-	30-60/45-60/45-60	80	40			80	40		
	Small Grain-Ryegrass-Legume		-	15-30/30-45/30-45								
Lespedeza	Annual	Establish	0	0	40	20	0		40	20	0	
	Sericea	Establish			60				60			
		Maintain			40				40			
Clover	Red or White	Establish	0-15	-	90	60	0		90	60	0	
		Maintain	-	0	60	30			60	30		

Table 6. Footnotes (more detail is provided in Savoy and Joines, 2016 and Savoy, 2015).

1. **Corn Grain:** Split applications of nitrogen may be beneficial when nitrogen rates are greater than 120 lb-N/ac.
2. **Canola:** Apply 30 lb-N/ac at seeding in fall and topdress with an additional 110 lb-N/ac before bolt (rapid stem elongation), usually in early to mid-March.
3. **Sorghum Grain:** Response to the higher rate of nitrogen would most likely occur when grain sorghum follows a non-legume, is grown no-till, or is grown on soils with restricted drainage or having textures with more clay than silty clay loam
4. **Small Grains:** For small grain establishment, apply 15 lb-N/ac when following soybeans and 30 lb-N/ac when following corn, grain sorghum or grasses. Topdress small grain February 15 to March 15 with 60 to 90 lb-N/ac of nitrogen. Use lower rates of nitrogen where lodging has been a problem.
5. **Soybeans:** Nitrogen is not recommended since soybeans are legumes and when properly inoculated produce their own nitrogen.
6. **Switchgrass:** Do not apply nitrogen fertilizer at seeding. Beginning in the spring following establishment apply 60 lb-N/ac when grass begins to grow in May following the establishment year.
7. **Alfalfa:** For alfalfa-grass mixtures, where alfalfa is less than 25 percent of the mixture, apply 30 lb-N/ac between March 1 and 30 and again after the first cutting if an additional cutting is expected.
8. **Bermuda (Establish):** Apply 30 lb-N/ac right before sprigging or seeding and 30 lb-N/ac one month later. A more vigorous nitrogen fertilization program may be beneficial with “improved” seeded varieties for hay production during the first year. Consult with your local county Extension office if you are not sure about whether more nitrogen may be needed.
9. **Bermuda (Maintain Pasture):** The rate of nitrogen topdressing depends on the need for forage. Apply one-half of the total recommended nitrogen on May 1 and one-half on July 1. If the higher rates of N are used, use the higher rates of P and K on the hybrid pasture. Split application of the total potash is recommended. One-half of the potash should be applied prior to first spring growth and one-half on July 1.
10. **Bermuda (Maintain Hay):** The rate of nitrogen topdressing depends on the need for forage. Apply up to one-fourth of the total recommended nitrogen May 1 and again after each cutting when conditions favor regrowth. Four cuttings per year are often possible. For better forage quality, harvests should be done within about 30 days of growth or regrowth. Split application of the total potash is recommended. One-half of the potash should be applied prior to first spring growth and one-half after the second harvest.
11. **Corn-Silage:** Split applications of nitrogen may be beneficial when nitrogen rates are greater than 120 lb-N/ac.
12. **Warm Season Pasture, Hay, Silage (Native Grass):** Warm-season perennial grasses include Switchgrass, Big bluestem, Little bluestem, Indiangrass, Eastern Gama grass and Side oats gramma. Do not apply nitrogen fertilizer at seeding. Beginning the spring following establishment, apply 60 lb-N/ac when grass begins growing in May and then again in July if additional growth is desired. No nitrogen is needed for minimal growth or wildlife cover only.
13. **Warm Season Pasture, Hay, Silage (Annual Grass):** Summer annual grasses included are Teff grass, sudangrass, pearlmillet and forage sorghum hybrids. Apply 60 lb-N/ac at time of seeding. For Teff grass apply an additional 30 lb-N/ac if conditions favor an additional cutting for hay or additional pasture growth. If pearlmillet and forage sorghum hybrids are seeded before June 20, apply an additional 60 lb-N/ac as topdressing after harvest in July.
14. **Warm Season Pasture, Hay, Silage (Soybean-Millet):** Apply only 30 lb-N/ac at seeding for soybeans and millet hay.
15. **Cool Season Pasture, Hay, Silage (Renovate Perennial Pasture/Hay Fields):** If renovation involves the addition of legumes to grass pastures/hay, the nitrogen should be omitted.
16. **Cool Season Pasture, Hay, Silage (Grass-Clover Maintain Pasture):** The nitrogen should be omitted on pastures containing more than 30 percent clover in the spring; otherwise, if clover is less than 30 percent of the pasture, apply 30 lb-N/ac between March 1-30. For fall stockpiling of fescue apply 60 pounds of N per acre August 15 to September 15 to all fescue-clover mixtures.
17. **Cool Season Pasture, Hay, Silage (Grass-Clover Maintain Hay):** Apply 30 lb-N/ac March 1-30 and again after the first cutting if an additional cutting is expected. For fall stockpiling of fescue, apply 60 lb-N/ac from August 15 to September 15 to all fescue clover mixtures
18. **Cool Season Pasture, Hay, Silage (Tall Fescue Maintain Pasture):** Apply 60 lbsN/ac from August 15 to September 15 and from March 1 to March 30. If additional growth is only needed during one season, apply nitrogen for that season only.
19. **Cool Season Pasture, Hay, Silage (Tall Fescue Maintain Hay):** Apply 60 lb-N/ac per acre March 1-30. Where a second cutting is expected, apply an additional 45 lb-N/ac immediately after the first cutting. If fescue is stockpiled in the fall, apply 60 lb-N/ac from August 15 to September 15.
20. **Cool Season Pasture, Hay, Silage (Timothy/Orchardgrass):** If renovation involves the addition of legumes, the nitrogen should be omitted. Where one cutting per year is made, apply 60 lb-N/ac from March 15 to April 1. When more than one cutting is made, apply 60 lb-N/ac from March 15 to April 1 and 60 lb-N/ac immediately after first cutting.
21. **Cool Season Pasture, Hay, Silage (Small Grain-Ryegrass):** For fall grazing, apply 60 lb-N/ac at seeding. For fall and spring grazing, apply an additional 45 lb-N/ac about March 1 and 45 lb-N/ac on April 15. For fall grazing and spring hay or silage, apply 60 lb-N/ac at seeding and 60 lb-N/ac March 1-15. For spring hay or silage only, apply 45 lb-N/ac at seeding and 60 lb-N/ac on March 15. Where ryegrass is in the mixture and an additional cutting is expected in the spring, apply an additional 60 lb-N/ac immediately after the first cutting. For spring grazing only, apply 30 lb-N/ac at seeding, 45 lb-N/ac on March 1, and 45 lb-N/ac on April 15.
22. **Cool Season Pasture, Hay, Silage (Small Grain-Ryegrass-Legume):** For fall grazing, apply 30 lb-N/ac at seeding. For fall and spring grazing, apply an additional 30 to 45 lb-N/ac about March 1 and again on April 15. Use the 45 lb-N/ac when the mixture contains less than 30 percent clover in the spring. For fall grazing and spring hay or silage, apply 30 lb-N/ac at seeding and 30 to 45 lb-N/ac March 1-15. For spring hay or silage only, apply 15 lb-N/ac and 30 to 45 lb-N/ac March 1-15. Where ryegrass is in the mixture and an additional cutting is expected in the spring, apply an additional 30 to 45 lb-N/ac immediately after the first cutting. In each case, the 45 lb-N/ac is used instead of the 30 lb-N/ac when the mixture contains less than 30 percent clover in the spring.

Table 7. University of Tennessee Extension recommendations for a legume nitrogen credit (LNC) provided by a prior soybean or legume cover crop and when legumes are interseeded into forages that do not include ryegrass and/or small grains.

<table>
<tr><th colspan="4">Prior Legume Crop N-Credit</th></tr>
<tr><th colspan="2">Legume</th><th>Crop Receiving Credit</th><th>Credit</th></tr>
<tr><td colspan="2">Soybeans > 20 bu/ac</td><td>• Small grain establishment</td><td>15 lb-N/ac</td></tr>
<tr><td colspan="2"></td><td>• Sunflower for seed</td><td>0-20 lb-N/ac</td></tr>
<tr><td colspan="2">Winter cover crop of crimson clover or hairy vetch that has reached early bloom stage</td><td>• Corn Grain & Silage
• Cotton
• Grain Sorghum
• Small Grain
• Sunflower, seed
• Tobacco</td><td>60-80 lb-N/ac</td></tr>
<tr><th colspan="4">Incorporated Legume N-Credit</th></tr>
<tr><th colspan="3">Crop</th><th>Nitrogen Credit</th></tr>
<tr><td colspan="3">Alfalfa-grass mixture</td><td>0-30 lb-N/ac
Where grass is integrated into alfalfa, nitrogen is only required for maintenance if alfalfa is < 25% of the stand. If alfalfa is present at < 25% of the stand, apply 30 lb-N/ac in March and again after the first cutting if an additional cutting is expected. A 30 lb-N/ac credit should be used if following the grass nitrogen fertilizer recommendations.</td></tr>
<tr><td colspan="3">Soybean & Millet Hay</td><td>0 lb-N/ac
See Table 6 Footnote 14. A 30 lb-N/ac credit is reflected in the nitrogen application rate recommendation.</td></tr>
<tr><td rowspan="2">Cool Season Pasture/Hay/Silage</td><td>Perennial</td><td>Renovate</td><td>0-30 lb-N/ac
See Table 6 Footnotes 15 and 20.</td></tr>
<tr><td>Grass-Clover</td><td>Maintain</td><td>0-60 lb-N/ac
See Table 6-Footnotes 16 and 17. For the March nitrogen application to pasture, apply no nitrogen when pasture contains > 30% clover; apply 30 lb-N/ac if clover is less than 30% of the stand. For the March nitrogen application to hay, apply only 30 lb-N/ac; apply only 30 lb-N/ac after the first cutting if an additional cutting is expected. A 30 lb-N/ac credit should be taken both in March and for the second cutting in April, depending on % clover in the stand.</td></tr>
</table>

Table 8. University of Tennessee Extension nitrogen fertilization details for small grain and/or ryegrass forages with and without legumes interseeded both below and above 30% of the forage stand. Recommended nitrogen application rates are listed in lb-N/ac. Recommendations for an interseeded legume nitrogen credit (LNC) are listed in parentheses in lbs-N/ac.

Legume	Timing	Management Scenarios					
		Fall Grazing Only	Fall + Spring Grazing	Fall Grazing + Spring Hay or Silage	Spring Hay or Silage Only	Spring Hay or Silage, Ryegrass, 2 Cuts	Spring Grazing Only
No Legumes Present	Fall	60	60	60	45	45	30
	March	-	45	60	60	60	45
	April	-	45	-	-	60	45
Legumes < 30% Stand	Fall	30	30 (30)	30 (30)	15 (30)	15 (30)	15 (15)
	March	-	45 (0)	45 (15)	45 (15)	45 (15)	45 (0)
	April	-	45 (0)	-	-	45 (15)	45 (0)
Legumes > 30% Stand	Fall	30	30 (30)	30 (30)	15 (30)	15 (30)	15 (15)
	March	-	30 (15)	30 (30)	30 (30)	30 (30)	30 (15)
	April	-	30 (15)	-	-	30 (30)	30 (15)

Table 9. Estimated Crop Phosphorus Removal Rates (CPRR).

AGRONOMIC CROPS							
Crop	Harvest	Unit[1]	CPRR	Small Grain			
				Crop	Harvest	Unit[1]	CPRR
Corn[2]	Grain	bu	0.35	**Barley**[2]	Grain	bu	0.40
Canola[2]	Seed	bu	0.8	**Oat**[2]	Grain	bu	0.28
Cotton[2]	Lint	Bale	12	**Rye**[2]	Grain	bu	0.46
Sorghum[2]	Grain	bu	0.39	**Triticale**[2]	Grain	bu	0.48
Soybeans[2]	Grain	bu	0.73	**Wheat**[2]	Grain	bu	0.48
Sunflower[2]	Seed, Oil	cwt	0.97				
Switchgrass[2]	Biofuel	Ton (**DM**)	12				
Tobacco[2]	Burley	cwt	0.90				

FORAGE CROPS							
Crop	Harvest	Unit	CPRR	Cool Season Pasture/Hay/Silage			
				Crop	Harvest	Unit[1]	CPRR
Alfalfa[2]	Green chop	ton (**DM**)	12	**Grass + Clover**[3]	Hay (10% moisture)	ton	9.4
	Hay				Pasture	-	
	Silage			**Tall Fescue**[2]	Hay (10% moisture)	ton	11
Bermuda[2]	Common Hay	ton (**DM**)	12		Pasture	-	
	Common Past			**Timothy**[2]	Hay	Ton (**DM**)	11
	Hybrid Hay				Silage		
	Hybrid Past				+ Alfalfa Hay		
Clover[3] **(10% moisture)**	Crimson, Hay	ton	9.2		+ Clover Hay		
	Red, Hay	ton	11	**Orchardgrass**	Hay (10% moisture)	ton	12
	White, Hay	ton	15	**Small Grain**[3, 6]	Fall-Hay	ton	8.1
Corn Silage[4]	65% moisture	ton	4.4		Fall+Spring Graze	-	
Lespedeza[3] **(10% moisture)**	Annual, Hay	ton	12		Fall Graze+Spring Hay	ton	
	Sericea, Hay	ton	10		Spring Graze	-	
Sorghum Silage[3]	**(72% moisture)**	ton	2.7		Spring Hay	ton	
Warm Season Pasture/Hay/Silage					Silage (70% moisture)	ton	3.9
Native Grass[3,5]	Hay (10% moisture)	ton	11	**Small Grain + Ryegrass**[2]	Fall Graze+Spring Hay	Ton (**DM**)	12
	Pasture				Spring Hay		
Annual Grass[3]	Hay (10% moisture)	ton	12		+ Legume Spring Hay		
	Millet-Pearl Silage	ton	2.6	**Small Grain + Legume**[3]	Fall Graze	-	8.1
	Millet-Foxtail Silage	ton	2.3		Fall+Spring Graze		
Soybean+Millet[3]	Hay (10% moisture)	ton	10		Fall Graze+Spring Hay	ton	
					Spring Hay		

1. DM = dry matter; nutrient removal is for only the dry matter yield rather than at a specified moisture content. To correct to a specified moisture content, multiply CPRR by the %DM at harvest divided by 100.
2. International Plant Nutrition Institute Crop Nutrient Removal Calculator. Triticale values adapted from Winter Wheat.
3. USDA Crop Nutrient Tool. Eastern Gammagrass hay, boot, cut 1 values used for Native Grass. Sourgham/Sudangrass hay used for Annual Grass Hay. Soybean hay values used for Soybean+Millet hay. Wheat hay values at 10% moisture used for Small Grain Cool Season Pasture/Hay and small grain + legume.
4. University of Tennessee Extension research data.
5. The convention from the Manure Management Planner software is adopted herein to use reference values for hay for the corresponding pastured/grazed crop.
6. Wheat silage values are at 70% moisture at the soft dough stage [17].

Table 10. Worksheet to estimate a Field Nitrogen Credit (FNC) for prior manure or other organic fertilizer applications.

FARM: _____ **FIELD:** _____ **DATE:** _____

Retain this worksheet for recordkeeping with the matching Tennessee Dairy Manure Land Application Rate Worksheet

Date Range of Manure Applications for Prior Crops[1]	Prior Application Date	Application Rate (in tons/ac or 1,000 gallons/ac) **R**	Manure Organic Nitrogen (lbs-N per ton or 1,000 gallons) **ON**[2]	Carryover Factor **CF**	Residual Nitrogen **R** × **ON** × **CF**
0-12 months pior				0.10	
Between 1-2 years prior				0.05	
			FNC = Sum of Residual Nitrogen		

1. Also use this worksheet to estimate the **FNC** for organic fertilizers other than manure that you have applied within the last two years, for example litter or biosolids.
2. If you don't have the Organic Nitrogen (**ON**) concentration for your prior manure/organic fertilizer applications, estimate the **ON** concentration as 50% of the Total Nitrogen for a current or prior analysis.

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