AjiPro®-L Dairy Cattle Amino Acid Balanced Low-Protein Feed Protocol

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PRO-00000004	1.0	February 24, 2025

Athian

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This protocol was developed by Ajinomoto Co., Inc.

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1 Introduction

The AjiPro®-L Dairy Cattle Amino Acid Balanced Low-protein Feed Protocol was developed by Ajinomoto Co. to provide guidance for the creation of greenhouse gas (GHG) reductions by replacing conventional feed with amino acid balanced low-protein feed which includes AjiPro®-L for US dairy cattle. AjiPro®-L is rumen-protected lysine. Its rumen-protection technology allows the lysine to bypass the rumen and be absorbed in the hindgut. Amino acid balanced low-protein feed which includes AjiPro®-L reduces N_2O emission reduction from cattle excreta disposal. It also has an effect on reducing GHG emissions from feed cultivation.

Nitrous oxide (N_2O) is a GHG with a global warming potential 273 times that of CO_2 on a 100-year time horizon (IPCC AR6). According to FAO, N_2O emissions from manure management account for 5% of the total GHG emissions from livestock worldwide. Additionally, based on data from 2013, N_2O emissions from manure management in the cattle milk and beef supply chains make up 5.4% and 3.6% respectively, of the total emissions. In the United States, N_2O emissions from manure management account for 2.9% of the total emissions from the agricultural sector in 2021, and N_2O emissions from manure management from dairy and beef cattle have increased by 19.6% and 59.6% respectively from 1990 to 2021.

In 2021, the Pathways to Dairy Net Zero initiative was launched to accelerate climate change action and reduce GHG emissions across the dairy sector. This initiative is partnered by the Global Dairy Platform, International Dairy Federation, Sustainable Agriculture Initiative Platform, International Livestock Research Institute, Dairy Sustainability Framework, and IFCN Dairy Research Network, and is dedicated to reducing dairy's GHG emissions over the next 30 years. Meeting these goals will be challenging because rising global demand for meat and milk has contributed to an increase in N_2O emissions since 1990. Looking ahead, the United Nations Food and Agriculture Organization (FAO) estimates that the demand for meat and milk in 2050 will be 73 and 58 percent more, respectively, than the demand in 2010. To combat climate change, the agriculture sector needs to dramatically reduce N_2O emissions.

Ajinomoto Co. developed this protocol to provide guidance and quantifications of GHG reductions by replacing conventional feed with amino acid balanced low-protein feed which includes AjiPro®-L for US dairy cattle.

2 Project Definition

This protocol credits the GHG reductions created by the practice of replacing conventional feed with amino acid balanced low-protein feed which includes AjiPro®-L for US dairy cattle (lactating, dry, heifers). AjiPro®-L is rumen-protected lysine. Its rumen-protection technology allows the lysine to bypass the rumen and be absorbed in the hindgut.

Amino acid balanced low-protein feed which includes AjiPro®-L contributes to improving the health of cattle and leads to improved feed efficiency. High feed efficiency enables the reduction of the burden of excessive nitrogen metabolism in cattle's body. In addition to that, it can reduce GHG emissions. Furthermore, changing the composition of daily feed is a simple and effective manner to decrease GHG emissions in cattle production without the need for significant upfront investment. Targeting emissions at origin, from the main component of the value chain (the milk) is the most efficient way to decrease the global emissions of the dairy value chain.

2.1 Impact on Yield

There is no anticipated effect on yield or productivity associated with this program. Higuchi et al. (2016) have demonstrated that improving amino acid balance and reducing the percentage of crude protein in dry matter intake reduces nitrogen excretion and does not affect productivity. Additionally, there is no anticipated negative impact on any external (i.e. not covered by this protocol) environmental factors or stakeholder interests. To ensure this, producers must attest that their participation and intervention meet all legal and regulatory compliance standards in their locality.

2.2 Causality

Amino acid balanced low-protein feed which includes AjiPro®-L reduces absolute emissions in the production of a consumer good along the value chain. Reducing total emissions in feed by reducing feed use with higher emission factors and increasing use with lower emission factors is permanent and cannot be reversed. Furthermore, N_2O from manure management is generated from excreted N. The amount of excreted N depends on the protein content of the feed an animal consumes at regular intervals throughout the day. Therefore, amino acid balanced low-protein feed which includes AjiPro®-L acts by reducing N_2O from manure management and the reductions in greenhouse gas emissions associated with this feed are permanent and cannot be reversed.

A feeding method that includes adding AjiPro®-L to the feed without reducing crude protein by more than 1%, for the purpose of improving dairy cattle productivity, has already become widespread in the US. On the other hand, the feeding method for GHG reduction, that reduce the use of feed with a high emission factor and increase the use of feed with a low emission factor and reduce crude protein significantly by replacing conventional feed with amino acid balanced low-protein feed, in general, is a relatively new field with few fully commercial technologies. Therefore, there could be psychological barriers for users when implementing this method, which might prevent its widespread adoption. To overcome these barriers and promote the method among users, it's necessary to utilize a carbon market.

According to Ishimaru, S. et al. (2019) and Ji, P. et al. (2016), AjiPro®-L is superior in its rumen-protected effect among bypass amino acid preparations compared to products from other companies. However, there is a risk that the desired GHG reduction effect may not be fully achieved if low-priced alternative products with insufficient rumen-protected effects become prevalent in the market.

Eligibility and use of this protocol creates a data stream the supply chain will need for credibly delivering on greenhouse gas reduction commitments. This additional financial support from the supply chain for the GHG emissions reduction assures incentivizes amino acid balanced low-protein feed which includes AjiPro®-L use and its benefits to the climate. Thus, Ajinomoto Co. proposes this protocol and subsequent projects be considered for quantifying and incentivizing GHG emissions reductions from feeding amino acid balanced low-protein feed which includes AjiPro®-L.

3 Eligibility

To be eligible to participate in this intervention, the following criteria must be met:

1. Animals included in the project located on a dairy operation
2. Animal types included; lactating and dry cattle and heifers
3. Evidence the dairy farm is located in the US or US Tribal Lands
4. Evidence of the presence or purchase of AjiPro®-L consistent with the dietary information provided.
5. Evidence of the manure management systems in place on the dairy farm.
6. Evidence of the reduction in crude protein of the diet in conjunction with the feeding of AjiPro®-L

3.1 Voluntary Compliance & Performance Standard

This protocol is intended to only calculate GHG reductions that are beyond what would have occurred in the absence of the implementation of the practices listed in Section 2. Direct and indirect reduction of GHG emissions resulting from the feeding of AjiPro®-L are the only projects eligible for this protocol.

Projects must demonstrate a scenario that is “better than business-as-usual.”

All projects are subject to a legal requirement test to ensure that the GHG reductions achieved by this intervention are not required by federal, state, or local laws or regulations (e.g., air, water quality, water discharge, safety, labor, endangered species protection), or other legally binding mandates. The legal requirement test is applied to each project enrolled in the program. Therefore, if interventions at one project become legally required, it does not affect the other projects in the program.

To satisfy the legal requirement test, each producer whose dairy operation is a project within the program must sign an attestation of voluntary compliance. Attestations must be signed prior to the commencement of verification activities each time the intervention is verified. In addition, the Monitoring Plan must include procedures that the producer will follow to review existing legal requirements for the intervention location and ascertain and demonstrate that the project passes the legal requirement test.

3.2 Project Start Date

The implementation start date for this intervention is January 1, 2025 or the first active use date of the intervention activity, whichever is later.

3.3 Reporting Period

The preferred monitoring period is at least one calendar month, and the preferred project duration is at least 12 months. Producers do have the option of choosing a quarterly monitoring period if that best fits the needs of their business, in consultation with Athian and the verifier assigned to their intervention. After 12 months using this protocol, a project may continue, but it must use the most recent version of this protocol.

3.4 Location

Only projects located in the U.S., or on U.S. tribal lands, are eligible to generate credits under this protocol.

4 GHG Assessment Boundary

Amino acid balanced low-protein feed which includes AjiPro®-L can lower the percentage of crude protein in dry matter intake compared to conventional feed. After considering all the impacts percentage of crude protein may have on GHG emissions, it was determined that the intervention (AjiPro®-L) impacts N_2O from manure management from dairy cows (lactating, dry, heifers). N_2O emissions also occur because of nitrogen loss through volatilization and leaching.

Furthermore, replacing conventional feed with amino acid-balanced low-protein feed that includes AjiPro®-L can reduce the amount of feed with high emission factors that is consumed and replace it with feed that has lower emission factors. This can reduce GHG emissions from feed cultivation. Higuchi et al. (2016) have demonstrated that improving amino acid balance and reducing the percentage of crude protein in dry matter intake reduces natural protein consumption. GHG emissions associated with the manufacturing and transport of AjiPro®-L itself are included in the calculation of emissions from feed cultivation.

No sinks are included in this program, as it solely focuses on reduction, not removals.

Table 4.1 *Description of all sources, sinks, and reservoirs evaluated for the protocol*

SSR	GHG	Included or Excluded	Justification
Feed Cultivation	CO_2, N_2O	Included	Emissions from the transportation, production, and harvesting of cattle feed are reduced by the practices included in this protocol.
Manure Management	CH_4, N_2O	Included	N_2O emissions from the management of manure are reduced by the practices included in this protocol. CH_4 emissions from the management of manure do not change between the baseline and project scenario.
Enteric Fermentation	CH_4	Excluded	Emissions from enteric fermentation in cattle do not change between the baseline and project scenario.
Fuel & Electricity Use	CO_2, CH_4, N_2O	Excluded	Fossil fuel emissions from electricity and stationary fuel use do not change between the baseline and project scenario.
Bedding	CO_2, CH_4, N_2O	Excluded	Emissions from the use of different bedding materials do not change between the baseline and project scenario.
Waste Processing	CO_2, CH_4, N_2O	Excluded	Emissions from the management of dead animals do not change between the baseline and project scenario.
Direct Land Use	CO_2	Excluded	Emissions from changes in land use do not change between the baseline and project scenario.

5 GHG Quantification

GHG reductions from the intervention are quantified by comparing actual project emissions to baseline emissions. Baseline emissions are a quantification of the GHG emissions from sources within the GHG Assessment Boundary that would have occurred in the absence of the intervention. Project emissions are the actual GHG emissions that occur at sources within the GHG Assessment Boundary during the reporting period. Project emissions must be subtracted from baseline emissions to quantify the project's total net GHG emission reductions.

$$GHG_i = \sum_{i=0}^{n} \left(GHG_{bsl,i} - GHG_{pjt,i} \right) \qquad \text{(Equation 5.1)}$$

Where:

GHG_i	=	Total GHG emission reductions due to project activities during the monitoring period (t CO_2e)
$GHG_{bsl,i}$	=	Total GHG emissions in the baseline scenario for farm *i* during the monitoring period (t CO_2e)
$GHG_{pjt,i}$	=	Total GHG emissions in the project scenario for farm *i* during the monitoring period (t CO_2e)

5.1 Quantification Approach

Emissions from feed cultivation are calculated on an as-fed mass basis by using GFLI database. This is because the GFLI database is listed as a commonly used LCI database for the carbon footprint of dairy products in the IDF Carbon Footprint Standard and can be regarded as an industry standard database. Furthermore, the GFLI database offers a fine granularity of data and enables the acquisition of LCA data of feed ingredients grown and processed in various parts of the world.

The equations and calculation methodology of N_2O from manure management and default values for U.S. dairies in this protocol are based on Volume 4, Chapter 10 and 11: Emissions from Livestock and Manure Management of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. For both the baseline and project equations, a Tier 2 approach is used.

5.2 Project GHG Emissions

Project GHG emissions are calculated according to Equation 5.2:

$$GHG_{pjt,i} = Feed_{pjt,i} + N2O_{md_{pjt,i}} \qquad \text{(Equation 5.2)}$$

Where:

$GHG_{pjt,i}$	=	Total GHG emissions in the project scenario for farm *i* during the monitoring period (t CO_2e). Where the project includes multiple farms, emissions in the project scenario are estimated as the sum of emissions from each farm *i*
$Feed_{pjt,i}$	=	GHG emissions from the cultivation of cattle feed in the project scenario for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{pjt,i}}$	=	N_2O emissions due to manure deposition in the project scenario for farm *i* during the monitoring period (t CO_2e)

5.2.1 Feed Cultivation

Emission factors for feed production per feed type shall be documented. If no specific emissions factors are available for a feed type, default emissions factors may be applied (e.g., GFLI database). Equation 5.3 and 5.4 are used to calculate GHG emissions from feed cultivation. Example GHG emissions from the cultivation of common feedstuffs are calculated using data from GFLI database. Feed emissions factors should be relevant to the project location, estimated using economic allocation, and include GHG emissions associated with cultivation, harvest, processing, transport, and upstream sources. Feed emissions factors will not differ between feeds grown on-farm and purchased feeds. The use of AjiPro®-L does not appreciably affect feed emissions factors because AjiPro®-L is included in the diet in an extremely small quantity, therefore the supplement in Adom, F. et al. (2013) (of which amino acid is included) can be used as a proxy for AjiPro®-L inclusion.

$$Feed_{pjt,i} = \frac{1}{1000} \times \left(\sum_{k=1}^{n} EF_{af,k} \times AF_k^{total,pjt} \right) \quad \text{(Equation 5.3)}$$

$$AF_k^{total,pjt} = \sum_{j=1}^{n} \left(AF_{pjt,j} \times N_{i,j} \times \varphi_{af,pjt,k,j} \times Days_{i,j} \right) \quad \text{(Equation 5.4)}$$

Where:

$Feed_{pjt,i}$	=	GHG emissions from the cultivation of cattle feed in the project scenario for farm *i* during the monitoring period (t CO_2e)
$EF_{af,k}$	=	Emissions factor (kg CO_2e per kg AF) for feed *k*
$AF_k^{total,pjt}$	=	Total as-fed mass of feed *k* during the monitoring period (kg)
$AF_{pjt,j}$	=	Average as-fed mass of feed in the project scenario consumed by cattle group *j* in a given day (kg/head/day)
$N_{i,j}$	=	Average number of head in cattle group *j* on farm *i* during the monitoring period (head)
$\varphi_{af,pjt,k,j}$	=	Fractional makeup of feed *k* based on as-fed mass data in the project scenario consumed by cattle group *j*
$Days_{i,j}$	=	Number of days spent on farm *i* by each cattle in group *j* during the monitoring period (day)
j	=	Cattle group

5.2.2 N_2O From Manure Management

N_2O emissions from manure management in the project scenario are estimated as the sum of emissions from direct and indirect N_2O emissions from manure deposition.

$$N2O_{md_{pjt,i}} = N2O_{md_{pjt,direct,i}} + N2O_{md_{pjt,indirect,i}} \qquad \text{(Equation 5.5)}$$

Where:

$N2O_{md_{pjt,i}}$	=	N_2O emissions due to manure deposition in the project scenario for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{pjt,direct,i}}$	=	Direct N_2O emissions due to manure deposition in the project scenario for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{pjt,indirect,i}}$	=	Indirect N_2O emissions due to manure deposition in the project scenario for farm *i* during the monitoring period (t CO_2e)

5.2.2.1 Direct N_2O Emissions From Manure Management

Direct N_2O emissions due to manure deposition in the project scenario are quantified using Equation 5.6, Equation 5.7, Equation 5.8, and Equation 5.9:

$$N2O_{md_{pjt,direct,i}} = \sum_{s=1}^{n}\sum_{j=1}^{n} F_{pjt,manure,i,j,s} \times \left(EF_{N2O,i,s} + EF_{N2O,l,i}\right) \times \frac{44}{28} \times GWP_{N2O} \qquad \text{(Equation 5.6)}$$

$$F_{pjt,manure,i,j,s} = \frac{1}{1000} \times \left(N_{i,j} \times Nex_j \times \frac{PS_{i,j,s}}{100}\right) \qquad \text{(Equation 5.7)}$$

$$Nex_j = N_{intake,j} \times \left(1 - N_{retention_{frac},j}\right) \times Days_{i,j} \qquad \text{(Equation 5.8)}$$

$$N_{intake,j} = DMI_{pjt,j} \times \left(\frac{\frac{CP\%_{pjt,j}}{100}}{6.25}\right) \qquad \text{(Equation 5.9)}$$

Where:

$N2O_{md_{pjt,direct,i}}$	=	Direct N_2O emissions due to manure deposition in the project scenario for farm *i* during the monitoring period (t CO_2e)
$F_{pjt,manure,i,j,s}$	=	Amount of nitrogen in manure and urine deposited by cattle group *j* managed by manure management system *s* in farm *i* during the monitoring period (t N)
$N_{i,j}$	=	Average number of head in cattle group *j* on farm *i* during the monitoring period (head)

Nex_j	=	Average nitrogen excretion per head of cattle in cattle group *j* (kg N/head)
$PS_{i,j,s}$	=	Percent of manure set to (managed in) manure management system *s* in cattle group *j* on farm *i* during the monitoring period
s	=	Type of manure management system
$EF_{N2O,i,s}$	=	Emission factor for direct N_2O emissions from manure management system *s* on farm *i* (kg N_2O-N/kg N input) (Table 5.1)
$EF_{N2O,l,i}$	=	Emission factor for direct N_2O emissions from manure deposited on managed lands on farm *i* (kg N_2O-N/kg N input) (Table 5.2)
GWP_{N2O}	=	273; Global warming potential for N_2O (kg CO_2e kg N_2O^{-1})
j	=	Cattle group
$\frac{44}{28}$	=	Ratio of molecular weight of N_2O to molecular weight of N applied to convert N_2O-N emissions to N_2O emissions
$N_{intake,j}$	=	N intake per head of cattle group *j* (kg N/head/day)
$N_{retention_{frac},j}$	=	Fraction of N intake that is retained by cattle group *j* (dimensionless). Default value for dairy cattle is 0.27 (IPCC Chapter 10, Table 10.20)
$DMI_{pjt,j}$	=	Average dry matter intake in the project scenario for cattle group *j* in a given day (kg/head/day)
$CP\%_{pjt,j}$	=	Percent crude protein in dry matter in the project scenario by cattle group *j* (%)
$Days_{i,j}$	=	Number of days spent on farm *i* by each cattle in group *j* during the monitoring period (day)

Table 5.1 *Default Emission Factors for Direct N2O Emissions from Manure Management*

System	Definition	$EF_{N2O,i}$
Pasture/ Range/ Paddock	The manure from pasture and range grazing animals is allowed to lie as-is and is not managed.	Direct and indirect N_2O emissions associated with the manure deposited on agricultural soils and pasture, range, and paddock systems are not included in this protocol.
Daily Spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion. N_2O emissions during storage and treatment are assumed to be zero.	0

Solid Storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.		0.010
Solid Storage – Covered/Compacted	Similar to solid storage, but the manure pile is a) covered with a plastic sheet to reduce the surface of manure exposed to air and/or b) compacted to increase the density and reduce the free air space within the material.		0.01
Solid Storage – Bulking Agent Addition	Specific materials (bulking agents) are mixed with the manure to provide structural support. This allows the natural aeration of the pile, thus enhancing decomposition. (e.g. sawdust, straw, coffee husks, maize stover)		0.005
Solid Storage – Additives	The addition of specific substances to the pile in order to reduce gaseous emissions. Addition of certain compounds such as attapulgite, dicyandiamide or mature compost have shown to reduce N_2O emissions; while phosphogypsum reduce CH_4 emission		0.005
Dry Lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically. Dry lots are most typically found in dry climates but also are used in humid climates.		0.02
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water to facilitate handling and is stored in either tanks or earthen ponds.	With natural crust cover	0.005
		Without natural crust cover	0
		Cover	0.005
Uncovered Anaerobic Lagoon	Anaerobic lagoons are designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.		0
Pit Storage Below Animal Confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility.		0.002

Anaerobic Digester	Anaerobic digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CH_4 and CO_2, which is captured and flared or used as a fuel.		0.0006
Deep Bedding	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture.	No mixing	0.01
		Active mixing	0.07
Composting – In-Vessel	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.		0.006
Composting – Static Pile (Forced Aeration)	Composting in piles with forced aeration but no mixing.		0.010
Composting – Intensive Window (Frequent Turning)	Composting in windrows with regular turning for mixing and aeration.		0.005
Composting – Passive Window (Infrequent Turning)	Composting in windrows with infrequent turning for mixing and aeration.		0.005
Aerobic Treatment	The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.	Natural aeration systems	0.01
		Forced aeration systems	0.005

***Table 5.2** Default Emission Factors to Estimate Direct N2O Emissions from Managed Soils*

Emission Factor	Aggregated		Disaggregated		
	Default Value	Uncertainty Range	Disaggregation	Default Value	Uncertainty Range
EF_1 for N additions from synthetic fertilizers, organic amendments and crop residues, and N mineralized from mineral soil as a result of loss of soil carbon [kg N_2O–N (kg N)$^{-1}$]	0.01	0.002-0.018	Synthetic fertilizer inputs in wet climates	0.016	0.013-0.019
			Other N inputs in wet climates	0.006	0.001-0.011
			All N inputs in dry climates	0.005	0.000-0.011

EF_{1FR} for flooded rice fields [kg N_2O–N (kg N)$^{-1}$]	0.004	0.000-0.029	Continuous flooding	0.003	0.000-0.010
			Single and multiple drainage	0.005	0.000-0.016
$EF_{3PRP,\ CPP}$ for cattle (dairy, non-dairy and buffalo), poultry and pigs [kg N_2O–N (kg N)$^{-1}$]	0.004	0.000-0.0014	Wet climates	0.006	0.000-0.0027
			Dry climates	0.002	0.000-0.007
$EF_{3PRP,\ SO}$ for sheep and other animals [kg N_2O–N (kg N)$^{-1}$]	0.003	0.000-0.010	-	-	-

5.2.2.2 Indirect N_2O Emissions From Manure Management

Indirect N_2O emissions due to manure deposition in the project scenario are quantified using Equation 5.10, Equation 5.11, and Equation 5.12:

$$N2O_{md_{pjt,indirect,i}} = N2O_{md_{pjt,volat,i}} + N2O_{md_{pjt,leach,i}} \qquad \text{(Equation 5.10)}$$

$$N2O_{md_{pjt,volat,i}} = \sum_{s=1}^{n} \sum_{j=1}^{n} F_{pjt,manure,i,j,s} \times \left(Frac_{GASM,i,s} + Frac_{GASM,l,i}\right) \times EF_{Nvolat} \times \frac{44}{28} \times GWP_{N2O} \qquad \text{(Equation 5.11)}$$

$$N2O_{md_{pjt,leach,i}} = \sum_{s=1}^{n} \sum_{j=1}^{n} F_{pjt,manure,i,j,s} \times \left(Frac_{LEACH,i,s} + Frac_{LEACH,l,i}\right) \times EF_{Nleach} \times \frac{44}{28} \times GWP_{N2O} \qquad \text{(Equation 5.12)}$$

Where:

$N2O_{md_{pjt,indirect,i}}$	=	Indirect N_2O emissions due to manure deposition in the project scenario for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{pjt,volat,i}}$	=	Indirect N_2O emissions produced from atmospheric deposition of N volatilized due to manure deposition for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{pjt,leach,i}}$	=	Indirect N_2O emissions produced from leaching and runoff of N, in regions where leaching and runoff occurs, as a result of manure deposition for farm *i* during the monitoring period. Equal to 0 where annual precipitation is less than potential evapotranspiration, unless irrigation is employed (t CO_2e)

$F_{pjt,manure,i,j,s}$	=	Amount of nitrogen in manure and urine deposited by cattle group *j* managed by manure management system *s* in farm *i* during the monitoring period (t N)
$Frac_{GASM,i,s}$	=	Fraction of managed manure nitrogen for cattle that volatilizes as NH_3 and NO_x in the manure management system *s* on farm *i* (dimensionless) (Table 5.3)
$Frac_{GASM,l,i}$	=	Fraction of managed manure nitrogen for cattle that volatilizes as NH_3 and NO_x from manure deposited on managed lands on farm *i* (dimensionless) (Table 5.4)
EF_{Nvolat}	=	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces (t N_2O-N /(t NH_3-N + NO_x-N volatilized)) (Table 5.4)
$Frac_{LEACH,i,s}$	=	Fraction of managed manure nitrogen for cattle that is leached from the manure management system *s* on farm *i* (dimensionless) (Table 5.3)
$Frac_{LEACH,l,i}$	=	Fraction of managed manure nitrogen for cattle that is leached from manure deposited on managed lands on farm *i* (dimensionless) (Table 5.4)
EF_{Nleach}	=	Emission factor for N_2O emissions from leaching and runoff (t N_2O-N / t N leached and runoff) (Table 5.4)
GWP_{N2O}	=	273; Global warming potential for N_2O (kg CO_2e kg N_2O^{-1})
j	=	Cattle group
$\frac{44}{28}$	=	Ratio of molecular weight of N_2O to molecular weight of N applied to convert N_2O-N emissions to N_2O emissions

***Table 5.3** Default Values for Nitrogen Loss Due to Volatilization and Leaching of NH_3 and NO_X from Manure Management*

Manure management system	Fraction of managed manure nitrogen for cattle that volatilizes as NH_3 and NO_x	N loss from MMS due to leaching of N-NH_3 and N-NO_x (%)
Uncovered Anaerobic Lagoon	0.350	0.000
Liquid/Slurry - With Natural Crust Cover	0.300	0.000
Liquid/Slurry - Without Natural Crust Cover	0.480	0.000
Liquid/Slurry - With Cover	0.100	0.000
Pit Storage Below Animal Confinements	0.280	0.000
Daily Spread	0.070	0.000
Solid Storage	0.300	0.020
Solid Storage - Covered/Compacted	0.140	0.000
Solid Storage - Bulking Agent Addition	0.380	0.020
Solid Storage - Additives	0.11	0.02
Dry Lot	0.3	0.035
Anaerobic Digester	0.005-0.5	0

Cattle And Swine Deep Bedding	0.25	0.035
Composting - In-Vessel	0.45	0
Composting - Static Pile	0.5	0.06
Composting - Intensive Windrow	0.5	0.06
Composting - Passive Windrow	0.45	0.04
Aerobic Treatment - Natural Aeration Systems	No data	0
Aerobic Treatment - Forced Aeration Systems	0.85	0

Table 5.4 *Default Emission, Volatilization, and Leaching Factors for Indirect Soil N_2O Emissions*

Emission Factor	Aggregated		Disaggregated		
	Default Value	Uncertainty Range	Disaggregation	Default Value	Uncertainty Range
EF_4 [N volatilization and redeposition], kg N_2O–N (kg NH_3–N + NO_x–N volatilized)$^{-1}$	0.01	0.002-0.018	Wet climate	0.014	0.011-0.017
			Dry climate	0.005	0.000-0.011
EF_5 [leaching/runoff], kg N_2O–N (kg N leaching/runoff)$^{-1}$	0.011	0.000-0.020	-	-	-
$Frac_{GASF}$ [Volatilization from synthetic fertilizer], (kg NH_3–N + NO_x–N) (kg N applied)$^{-1}$	0.11	0.02-0.33	Urea	0.15	0.03-0.43
			Ammonium-based	0.08	0.02-0.30
			Nitrate-based	0.01	0.00-0.02
			Ammonium-nitrate-based	0.05	0.00-0.20
$Frac_{GASM}$ [Volatilization from all organic N fertilizers applied, and dung and urine deposited by grazing animals], (kg NH_3–N + NO_x–N) (kg N applied or deposited)$^{-1}$	0.21	0.00-0.31	-	-	-
$Frac_{LEACH-(H)}$ [N losses by leaching/runoff in wet climates], kg N (kg N additions or deposition by grazing animals)$^{-1}$	0.24	0.01-0.73	-	-	-

5.3 Baseline GHG Emissions

Baseline GHG emissions are calculated according to Equation 5.13:

$$GHG_{bsl,i} = Feed_{bsl,i} + N2O_{md_{bsl,i}} \quad \text{(Equation 5.13)}$$

Where:

$GHG_{bls,i}$	=	Total GHG emissions in the baseline scenario for farm *i* during the monitoring period (t CO_2e). Where the baseline includes multiple farms, emissions in the baseline scenario are estimated as the sum of emissions from each farm *i*
$Feed_{bsl,i}$	=	GHG emissions from the cultivation of cattle feed in the baseline scenario for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{bsl,i}}$	=	N_2O emissions due to manure deposition in the baseline scenario for farm *i* during the monitoring period (t CO_2e)

5.3.1 Feed Cultivation

Equation 5.14 and 5.15 are used to calculate GHG emissions from feed cultivation.

$$Feed_{bsl,i} = \frac{1}{1000} \times \left(\sum_{k=1}^{n} EF_{af,k} \times AF_k^{total,bsl} \right) \quad \text{(Equation 5.14)}$$

$$AF_k^{total,bsl} = \sum_{j=1}^{n} \left(AF_{bsl,j} \times N_{i,j} \times \varphi_{af,bsl,k,j} \times Days_{i,j} \right) \quad \text{(Equation 5.15)}$$

Where:

$Feed_{bsl,i}$	=	GHG emissions from the cultivation of cattle feed in the baseline scenario for farm *i* during the monitoring period (t CO_2e)
$EF_{af,k}$	=	Emissions factor (kg CO_2e per kg AF) for feed *k*
$AF_k^{total,bsl}$	=	Total as-fed mass of feed *k* during the monitoring period (kg)
$AF_{bsl,j}$	=	Average as-fed mass of feed in the baseline scenario consumed by cattle group *j* in a given day (kg/head/day)
$N_{i,j}$	=	Average number of head in cattle group *j* on farm *i* during the monitoring period (head)
$\varphi_{af,bsl,k,j}$	=	Fractional makeup of feed *k* based on as-fed mass data in the baseline scenario consumed by cattle group *j*
$Days_{i,j}$	=	Number of days spent on farm *i* by each cattle in group *j* during the monitoring period (day)
j	=	Cattle group

5.3.2 N_2O From Manure Management

N_2O emissions from manure management in the baseline scenario are estimated as the sum of emissions from direct and indirect N_2O emissions from manure deposition.

$$N2O_{md_{bsl,i}} = N2O_{md_{bsl,direct,i}} + N2O_{md_{bsl,indirect,i}} \quad \text{(Equation 5.16)}$$

Where:

$N2O_{md_{bsl,i}}$	=	N_2O emissions due to manure deposition in the baseline scenario for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{bsl,direct,i}}$	=	Direct N_2O emissions due to manure deposition in the baseline scenario for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{bsl,indirect,i}}$	=	Indirect N_2O emissions due to manure deposition in the baseline scenario for farm *i* during the monitoring period (t CO_2e)

5.3.2.1 Direct N_2O Emissions From Manure Management

Direct N_2O emissions due to manure deposition in the baseline scenario are quantified using Equation 5.17, Equation 5.18, Equation 5.19, and Equation 5.20.

$$N2O_{md_{bsl,direct,i}} = \sum_{s=1}^{n}\sum_{j=1}^{n} F_{bsl,manure,i,j,s} \times \left(EF_{N2O,i,s} + EF_{N2O,l,i}\right) \times \frac{44}{28} \times GWP_{N2O} \quad \text{(Equation 5.17)}$$

$$F_{bsl,manure,i,j,s} = \frac{1}{1000} \times \left(N_{i,j} \times Nex_j \times \frac{PS_{i,j,s}}{100}\right) \quad \text{(Equation 5.18)}$$

$$Nex_j = N_{intake,j} \times \left(1 - N_{retention_{frac},j}\right) \times Days_{i,j} \quad \text{(Equation 5.19)}$$

$$N_{intake,j} = DMI_{bsl,j} \times \left(\frac{\frac{CP\%_{bsl,j}}{100}}{6.25}\right) \quad \text{(Equation 5.20)}$$

Where:

$N2O_{md_{bsl,direct,i}}$	=	Direct N_2O emissions due to manure deposition in the baseline scenario for farm *i* during the monitoring period (t CO_2e)
$F_{bsl,manure,i,j,s}$	=	Amount of nitrogen in manure and urine deposited by cattle group *j* managed by manure management system *s* in farm *i* during the monitoring period (t N)

$N_{i,j}$	=	Average number of head in cattle group *j* on farm *i* during the monitoring period (head)
Nex_j	=	Average nitrogen excretion per head of cattle in cattle group *j* (kg N/head)
$PS_{i,j,s}$	=	Percent of manure set to (managed in) manure management system *s* in cattle group *j* on farm *i* during the monitoring period
s	=	Type of manure management system
$EF_{N2O,i,s}$	=	Emission factor for direct N_2O emissions from manure management system *s* on farm *i* (kg N_2O-N/kg N input) (Table 5.1)
$EF_{N2O,l,i}$	=	Emission factor for direct N_2O emissions from manure deposited on managed lands on farm *i* (kg N_2O-N/kg N input) (Table 5.2)
GWP_{N2O}	=	273; Global warming potential for N_2O (kg CO_2e kg N_2O^{-1})
j	=	Cattle group
$\frac{44}{28}$	=	Ratio of molecular weight of N_2O to molecular weight of N applied to convert N_2O-N emissions to N_2O emissions
$N_{intake,j}$	=	N intake per head of cattle group *j* (kg N/head/day)
$N_{retention_{frac},j}$	=	Fraction of N intake that is retained by cattle group *j* (dimensionless). Default value for dairy cattle is 0.27 (IPCC Chapter 10, Table 10.20)
$DMI_{bsl,j}$	=	Average dry matter intake in the baseline scenario for cattle group *j* in a given day (kg/head/day)
$CP\%_{bsl,j}$	=	Percent crude protein in dry matter in the baseline scenario by cattle group *j* (%)
$Days_{i,j}$	=	Number of days spent on farm *i* by each cattle in group *j* during the monitoring period (day)

5.3.2.2 Indirect N_2O Emissions From Manure Management

Indirect N_2O emissions due to manure deposition in the baseline scenario are quantified using Equation 5.21, Equation 5.22, and Equation 5.23.

$$N2O_{md_{bsl,indirect,i}} = N2O_{md_{bsl,volat,i}} + N2O_{md_{bsl,leach,i}} \quad \text{(Equation 5.21)}$$

$$N2O_{md_{bsl,volat,i}} = \sum_{s=1}^{n} \sum_{j=1}^{n} F_{bsl,manure,i,j,s} \times \left(Frac_{GASM,i,s} + Frac_{GASM,l,i}\right) \times EF_{Nvolat} \times \frac{44}{28} \times GWP_{N2O} \quad \text{(Equation 5.22)}$$

$$N2O_{md_{bsl,leach,i}} = \sum_{s=1}^{n} \sum_{j=1}^{n} F_{bsl,manure,i,j,s} \times \left(Frac_{LEACH,i,s} + Frac_{LEACH,l,i}\right) \times EF_{Nleach} \times \frac{44}{28} \times GWP_{N2O} \quad \text{(Equation 5.23)}$$

Where:

$N2O_{md_{bsl,indirect,i}}$	=	Indirect N_2O emissions due to manure deposition in the baseline scenario for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{bsl,volat,i}}$	=	Indirect N_2O emissions produced from atmospheric deposition of N volatilized due to manure deposition for farm *i* during the monitoring period (t CO_2e)
$N2O_{md_{bsl,leach,i}}$	=	Indirect N_2O emissions produced from leaching and runoff of N, in regions where leaching and runoff occurs, as a result of manure deposition for farm *i* during the monitoring period. Equal to 0 where annual precipitation is less than potential evapotranspiration, unless irrigation is employed (t CO_2e)
$F_{bsl,manure,i,j,s}$	=	Amount of nitrogen in manure and urine deposited by cattle group *j* managed by manure management system *s* in farm *i* during the monitoring period (t N)
$Frac_{GASM,i,s}$	=	Fraction of managed manure nitrogen for cattle that volatilizes as NH_3 and NO_x in the manure management system *s* on farm *i* (dimensionless) (Table 5.3)
$Frac_{GASM,l,i}$	=	Fraction of managed manure nitrogen for cattle that volatilizes as NH_3 and NO_x from manure deposited on managed lands on farm *i* (dimensionless) (Table 5.4)
EF_{Nvolat}	=	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces (t N_2O-N /(t NH_3-N + NO_x-N volatilized)) (Table 5.4)
$Frac_{LEACH,i,s}$	=	Fraction of managed manure nitrogen for cattle that is leached from the manure management system *s* on farm *i* (dimensionless) (Table 5.3)
$Frac_{LEACH,l,i}$	=	Fraction of managed manure nitrogen for cattle that is leached from manure deposited on managed lands on farm *i* (dimensionless) (Table 5.4)
EF_{Nleach}	=	Emission factor for N_2O emissions from leaching and runoff (t N_2O-N / t N leached and runoff) (Table 5.4)
GWP_{N2O}	=	273; Global warming potential for N_2O (kg CO_2e kg N_2O^{-1})
j	=	Cattle group
$\frac{44}{28}$	=	Ratio of molecular weight of N_2O to molecular weight of N applied to convert N_2O-N emissions to N_2O emissions

5.4 Energy Corrected Milk (ECM)

Emissions factors shall be assessed against volume of Energy Corrected Milk (ECM) per Equation 5.24 below. This protocol is not expected to have any impact on the volume of ECM, however, baseline EF may still be compared to intervention EF for record keeping purposes. It should be noted that this protocol addresses absolute emissions, not intensity emissions, and should have no effect on milk production.

$$ECM = (0.327 \times M) + \left(12.95 \times M_f \times M\right) + \left(7.65 \times M_p \times M\right) \times \frac{1}{2.2046} \qquad \text{(Equation 5.24)}$$

Where:

ECM	=	Energy Corrected Milk in the reporting period (kg/cow/day)
0.327	=	Milk quantity factor (dimensionless)
M	=	Average milk produced in the reporting period (lbs/cow/day)
12.95	=	Energetic value for fat (dimensionless)
M_f	=	Average percent milk fat in the reporting period (%)
7.65	=	Energetic value for protein (dimensionless)
M_p	=	Average percent milk true protein in the reporting period (%)

5.5 Leakage & Permanence

The account for market-shifting leakage associated with reductions in feed to cattle is needed. The principle of leakage suggests that the reduction in feed due to project implementation will be moved to other uses and the associated GHG emissions are shifted, not eliminated. In this protocol, there is no risk of more than 5% reduction in crop production. The dry matter intake of amino acid balanced low-protein feed which includes AjiPro®-L is the same as that of conventional feed. Because the maximum reduction in feed production within this protocol is less than 5%, leakage is not relevant to this project and no deductions will be applied to credits generated according to this protocol.

Furthermore, leakage could also potentially consist of a change in the number of cattle in the livestock operation due to impacts on cattle performance from introducing the feed ingredient, thereby necessitating changes in livestock populations in non-project operations to fulfill market demand. While amino acid balanced low-protein feed are generally expected to have an insignificant impact on livestock performance. Any resulting productivity improvements are not expected to impact emissions reductions and thus do not need to be accounted for. Additionally, due to the economics of livestock production, it is unlikely that the costs and risks associated with increasing or decreasing the number of cattle in the operation are justified from the minimal expected changes in cattle performance alone. Therefore, leakage is considered to be zero.

Because the activities in this protocol act to reduce the emissions nitrous oxide and carbon dioxide, the reductions in greenhouse gas emissions associated with the protocol are permanent and cannot be reversed, representing no threat to permanence.

5.6 Uncertainty

A quantitative uncertainty assessment for across farm-level parameters was conducted. For the default values obtained from the IPCC, the uncertainty ranges which are explained in the IPCC are referred. In accordance with data quality guideline for the ecoinvent database version 3.0, a pedigree matrix approach was used to quantify uncertainty where parameters obtained from operating records and emission factors for each feed ingredient obtained from GFLI database, etc. because these uncertainties are unknown. The uncertainty of this protocol is less than 20% and considered to be low. Therefore, it is concluded that it is not necessary to deduct the uncertainty.

5.7 Deviations from Protocol Methodologies

Deviations from the methodologies in Section 5 of this protocol are not allowed.

6 Monitoring

This program is 100% monitoring. All producers participating in the program will go through verification of their baseline data and verification of monitoring periods. A monitoring plan has been developed for all monitoring and reporting activities associated with the project, standardized across all participating farms.

Verifiers will use the monitoring plan and report to confirm that the requirements of this program have been met. This monitoring plan provides the processes, requirements, and sources of information necessary to assess the GHG reductions created by the practices included in this protocol.

This includes:

1. The procedures for collecting data on intervention activities related to implementation.
2. The data points collected to verify emission reduction, project, and baseline calculations.
3. The QC/QA processes to ensure the accuracy and consistency of the data collected.

The monitoring reports described in the monitoring plan include the following elements:

1. General description of the project, including the location of the cattle operations
2. List of the practices implemented
3. Description of the process and frequency of data collection and the archiving procedures
4. Recordkeeping plan
5. Role of any individuals performing activities related to the practices implemented
6. Quality assurance/quality control (QA/QC) procedures to ensure the accurate collection and entry of data in quantification systems
7. Monitoring reports must include the monitoring time period.

8. Monitoring reports must include the list of parameters measured and monitored.
9. Monitoring reports must include the types of data and information reported, including units of measurement.
10. Monitoring reports must include the origin of the data.
11. The monitoring report must include an attestation as to regulatory compliance.
12. The monitoring report should be submitted no less frequently than annually and no more frequently than 30 days.
13. The monitoring period can be as short as 30 days. The maximum monitoring period is 12 months.
14. The monitoring report must be submitted and shared with Athian, as the program administrator.

A monitoring period represents a calendar month. Where necessary, multiple months may be combined at the discretion of the verifier. When the monitoring period is over (i.e. the month has fully passed), data from operating records are input into the Athian quantification tool to assess the impact of the intervention for that monitoring period. Supporting documents are collected concurrently. Once all required inputs and supporting documentation are collected, a third-party verifier receives the information to assess the validity of the reported inputs as well as verify the quantification themself. Participating producers are given the opportunity to produce further documentation of any values the verifier determines to be non-compliant before a final decision on the results of the monitoring period is rendered, either verified or not.

This monitoring plan provides the requirements and sources of information necessary to assess the GHG reductions created using this protocol. This monitoring plan describes the procedures for collecting data on intervention activities related to the implementation of protocol practices. The data collected will support emission reduction and baseline calculations. This monitoring plan also outlines the QC/QA processes to ensure the accuracy and consistency of the data collected that will be used to verify emissions reduction outcomes.

6.1 Data Quality Assurance

The Athian Data Quality Management Plan aims to ensure that a producer's data is accurate, reliable, and fit for its intended purpose to assess the impact of the practices included in this protocol on CO_2e emissions associated with the management of manure and feed cultivation. The goals and objectives of a can be categorized into several key areas, each targeting different aspects of data quality management. These include accuracy, timeliness, comparability, and creditability.

Accuracy:

- Data Collection Methods: Data will be provided by the farm directly based on various on farm systems.
- Consistency Checks: Input forms will check for data type and range preventing grossly invalid data from being entered.

- Method Validation: Based on type, input may be limited to certain ranges or values. Additionally, producers must attest to and confirm accuracy.

Timeliness:

- Data Collection Frequency: As defined by the protocol
- Data Reporting Schedule: Specific schedules are defined by the protocol monitoring plan.
- Response Procedures for Data Variations: Significant data issues should be prevented at entry. Additionally identified issues can be corrected by Athian staff as needed.

Comparability:

- Standardized Methods Used: Form input is used to collect quantitative data from on farm systems.
- Benchmarking: Per the Athian Data Retention Policy, all GHG related data is kept for a minimum of 10 years. Data, in aggregated and anonymized form, can be used for benchmarking if/when applicable.

Creditability:

- Documentation of Data Processes: All data processes are ultimately governed by the Athian Data Protection, Data Retention, and Software Development Lifecycle (SDLC) policies. These policies are maintained as controlled documents in the Athian compliance system (Drata) and are reviewed and updated at least annually.
- Transparency Measures: Data transparency is critical to credibility and integral to the data collection process. Data input directly in the platform from producers requires an attestation from the producer as to the accuracy before being submitted for verification. Data collected via an integration to a 3rd party data collection software also requires the producer to attest to the accuracy. In addition, producers have visibility as to the data provided to 3rd party verifiers and can see the status of the verification of each element of data submitted. All verification reports include each data element collected and reviewed as part of the verification process for complete transparency in the reporting of the emissions result.

The Athian platform has a comprehensive set of automated processes that confirm the integrity, correctness, and completeness of data. These include checking the data upon ingestion from any 3rd party data source, inclusive of data delivered via API or manually entered, for completeness and accuracy. These checks include verification of appropriate formatting, field-level requirements that ensure the presence of all required data, and identification of any data variance from the previously verified data. If errors are identified, notifications are generated and delivered to engineering, product management, and service management for resolution. Those parties then determine the source and scope of the issue(s), engage any necessary participating party, resolve and document the identified issues.

In addition to the data validation checks identified above, Athian has implemented a service-driven approach for applying logic consistently, significantly reducing the potential for error in the process. The programmatic logic used reduces or replaces much of the process that is prone to human error. The Athian platform hosts the mechanisms for documenting any data discrepancy as well as their respective severity and solution. The platform retains a complete transaction history for all data ingested, inclusive of date/time stamp and the individual user or software supplying the information. This ensures that Athian will have a complete history/picture of all data used when rendering a decision or result.

All data used to meet GHG carbon accounting standards for impact units must be retained for a minimum of ten years. This includes producer business contact information, location information, monitoring period information, and all verification information. All of the aforementioned processes and procedures adhere to industry best practices, including SOC 2 review. The quantification tool for this program is thoroughly tested against known results of data sets any time updates to the quantification methodology or tool are made. The tests follow the same methods as used for the Simulated Quantification Model and are checked against the quantification methodology for accuracy by the Athian development team.

Athian

***Table 6.1** Monitoring parameters*[1]

Data/ Parameter	Description	Data Unit	Values Applied	Data Source	Measurement Frequency	Measurement methods and procedures, including QA/QC	Roles and Responsible
$DMI_{pjt,j}$	Average dry matter intake in the project scenario for cattle group j in a given day	kg/head/day	Approx. 19 to 23	Operating records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$N_{i,j}$	Average number of head in cattle group j on farm i during the monitoring period. This number is applied to both the baseline and project quantification during each monitoring period to reflect a true counterfactual.	Head	Number of cattle	Operating Records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$Days_{i,j}$	Number of days during which project activity is implemented in cattle group j on farm i. This number is applied to both the baseline and project quantification during each monitoring period to reflect a true counterfactual.	Days	Number of days in the period; ≥ 28	Operating Records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.

[1] All data & monitoring parameters are subject to the Athian platform data management plan in Section 5.1.1. Data is stored by Athian and accessible through the platform by producers and verifiers. Reference values and constants are also available as part of the published protocol.

j	Cattle group	Type of cattle	Type of cattle	Operating Records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$EF_{af,k}$	Emissions factor for feed k	kg CO_2e per kg AF	Dependent on feed component	Reference	Constant	N/A	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
$AF_{pjt,j}$	Average as-fed mass of feed in the project scenario consumed by cattle group j in a given day	kg/head/day	Approx. 19 to 23	Operating records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$\varphi_{af,pjt,k,j}$	Fractional makeup of feed k based on as-fed mass data in the project scenario consumed by cattle group j	Dimensionless	0 to 100	Operating records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$EF_{N2O,i,s}$	Emission factor for direct N_2O emissions from manure management systems on farm i	kg N_2O-N/kg N input	0 to 10	Reference	Constant	Determined based on farm's manure management systems	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.

$EF_{N2O,l,i}$	Emission factor for direct N_2O emissions from manure deposited on managed lands on farm i	kg N_2O-N/kg N input	0 to 10	Reference	Constant	N/A	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
GWP_{N2O}	Global warming potential for N2O	T CO_2e per T N_2O	273	Reference	Constant	N/A	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
$N_{retention,frac,j}$	Fraction of N intake that is retained by cattle group j	Dimensionless	0 to 100	Reference	Constant	N/A	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
$CP\%_{pjt,j}$	Percent crude protein in dry matter in the project scenario by cattle group j	%	0 to 100	Operating Records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$Frac_{GASM,i,s}$	Fraction of managed manure nitrogen for cattle that volatilizes as NH_3 and NO_x in the manure management systems on farm i	Dimensionless	0 to 100	Reference	Constant	Determined based on farm's manure management systems	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
$Frac_{GASM,l,i}$	Fraction of managed manure nitrogen for cattle that volatilizes as NH_3 and NO_x from manure deposited on managed lands on farm i	Dimensionless	0 to 100	Reference	Constant	Determined based on farm's manure management system	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.

EF_{Nvolat}	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces	t N_2O-N / (t NH_3-N + NO_x-N volatilized)	0 to 100	Reference	Constant	N/A	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
$Frac_{LEACH,i,s}$	Fraction of managed manure nitrogen for cattle that is leached from the manure management systems on farm i	Dimensionless	0 to 100	Reference	Constant	Determined based on farm's manure management systems	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
$Frac_{LEACH,l,i}$	Fraction of managed manure nitrogen for cattle that is leached from manure deposited on managed lands on farm i	Dimensionless	0 to 100	Reference	Constant	Determined based on farm's manure management system	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
EF_{Nleach}	Emission factor for N_2O emissions from leaching and runoff	t N_2O-N / t N leached and runoff	0 to 100	Reference	Constant	N/A	Athian is responsible for ensuring these values are correct in their platform with regular checks of the quantification tool.
$DMI_{bsl,j}$	Average dry matter intake in the baseline scenario for cattle group j in a given day	kg/head/day	Approx. 19 to 23	Operating records	At the start of the project	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.

$AF_{bsl,j}$	Average as-fed mass of feed in the baseline scenario consumed by cattle group j in a given day	kg/head/day	Approx. 19 to 23	Operating records	At the start of the project	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$\varphi_{af,bsl,k,j}$	Fractional makeup of feed k based on as-fed mass data in the baseline scenario consumed by cattle group j	Dimensionless	0 to 100	Operating records	At the start of the project	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$CP\%_{bsl,j}$	Percent crude protein in dry matter in the baseline scenario by cattle group j	%	0 to 100	Operating Records	At the start of the project	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
M_f	Percentage of fat in the milk during the reporting period	%	Approx. 3.5 to 4.5	Operating records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
M_p	Percentage of protein in the milk during the reporting period	%	0 to 100	Operating records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.

M	Average milk production per cow during the reporting period	kg $head^{-1}$ day^{-1}	Approx. 25 to 31	Operating records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
$PS_{i,j,s}$	Percent of manure sent to (managed in) manure management system s in cattle group j on farm i during the monitoring period. This number is applied to both the baseline and project quantification during each monitoring period to reflect a true counterfactual.	%	0 to 100	Operating records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.
s	Manure management system	Type of manure management system	Type of manageme nt system	Operating records	Every reporting period	Obtained from producer records, confirmed and stored by Athian and accessible through the platform by producers and verifiers.	The producer is responsible for inputting these values and ensuring they are correct, the verifier is responsible for corroborating them against documentation.

7 Reporting

Project developers must provide the following documentation each reporting period to generate credits from this protocol:

1. Name and address of the project developer
2. List of all of the operations included in the project including the owner/operator contact information and address of the operation
3. Regulatory compliance documentation and attestation
4. Monitoring plan
5. Monitoring report with all the data used in the calculations for Section 5 of the protocol
6. Monitoring report must include the intended use and user of the monitoring report.

7.1 Record Keeping

For purposes of third-party verification and historical documentation, project developers must keep all information listed in this protocol for a period of 10 years after the information is generated. The information the project developer should retain includes:

1. All data inputs for the calculation of the project emission reductions as well as the results of emission reduction calculations
2. Copies of all permits, Notices of Violations (NOVs), and any relevant administrative or legal orders dating back at least 3 years prior to the project start date
3. All verification records and results
4. All maintenance records relevant to the monitoring equipment

8 Verification

Verification bodies will contract directly with Athian for all validation and verification engagements.

Projects verified under this protocol will meet, at minimum, the auditing standard of limited assurance and adhere to 14064-3. The verification body must provide a factual statement expressing the outcome of the verification.

Issues identified during verification must be classified by verification bodies as either material (significant) or immaterial (insignificant). To be verified successfully, all reported emissions reductions must be free of material misstatements.

All projects developed under this protocol must achieve >95 percent level of accuracy. This means that the project's calculated emission reductions must be less than 5 percent different than those calculated by the verifier.

8.1 Verification Body Requirements

To conduct verification under this protocol, all Validation and Verification Bodies (VVB) must meet the following criteria:

1. Accreditation under International Organization for Standardization (ISO) 14065: 2013 with conformance to all accreditation requirements under ISO 14065, ISO 14064-3: 2006, IAF MD 6: 2014 and all other accreditation requirements, or Acceptance in the American National Standards Institute (ANSI) accreditation program, having filed a full application for ISO 14065: 2020
2. Demonstrated/documented subject matter expertise in the on-farm operations related to an approved protocol (e.g., Dairy Operations; Feed Lot Operations)
3. Demonstrated/documented experience in a particular region or state where the verification will occur
4. Monitoring conducted in accordance with the requirements of the relevant protocol
5. Monitoring conducted in a manner that allows for a complete and transparent quantification of GHG reductions

8.2 Conflict of Interest

When conducting verification under this protocol verifiers must be seen as credible, independent, and transparent. To meet this requirement, a conflict of interest (COI) determination must be made prior to starting any verification activities. A COI occurs in any situation that compromises the verifier's ability to perform an independent verification. Every verifier must provide information about its organizational relationships, internal structures, and management systems for identifying potential COIs. Verifiers must evaluate any potential conflicting services it has provided to the project developer, including any advice or consulting provided outside of the verification process.

8.3 Verification Process

To verify the project, the verifier must develop a risk-based verification plan that considers the size and complexity of the project and the relevant sector, technology, and processes. The verifier must follow the following process:

1. Complete a COI evaluation. If there is a potential COI, the verifier is not allowed to conduct the verification.
2. Prepare a verification plan that includes, at a minimum:
    a. A list of people from the VVB involved in the verification
    b. A list of the location and dates of any on-site visits that will be conducted
    c. The types of data and documents that will be reviewed by the verifier
    d. A list of the people who are expected to be interviewed as a part of the verification
3. Conduct a kick-off meeting with all parties to lay out the timeline and process of the verification.
4. Conduct, at minimum, one annual on-site visit to confirm practice implementation
5. Undertake a desk review of the data from the project.
6. Prepare a verification report that includes:
    a. A verification statement documenting the outcome of the assessment (reduction results) and if there was any material discrepancy noted
    b. Key details about the project including: producer and farm operation identification, verifying body and lead verifier contact information, protocol information, and intervention information
    c. A description of the protocol, the objectives and criteria used to arrive at the final result, the scope of the project, the level of assurance associated with the project, and any details about the implementation of the practices observed
    d. Detail about the verification process used to complete the assessment including approach and methods and also noting any conflict of interest
    e. Verification findings including confirmation of producer eligibility, adherence to the criteria established in the protocol, the verified emissions quantification values, and the final written opinion of the verifier(s)
    f. An issue log capturing any issues identified during the verification and their classification as either material (significant) or immaterial (insignificant)
    g. A representation of all data / documents used in the process of verification

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