Carbon Credit Potential from Intensive Rotational Grazing under Carbon Credit Certification Protocols

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Abstract

Rotational grazing can potentially reduce greenhouse gas (GHG) emissions from animal operations. This study investigates potential GHG reductions from rotational grazing farm operations under alternative procedures for defining a carbon credit. As applied to a case study cow-calf operation, GHG emission credits did not differ substantially under different definitions of entity boundaries. The choice of accounting metric used to report credits (mass load versus load per unit of output), however, would dramatically influence whether a farm would benefit financially from a future market in carbon credits.

Introduction

Intensive rotational grazing systems are being promoted as a better way to increase forage production per unit area. Conventional grazing systems are defined as systems with continuous grazing on a single field. General characteristics of a conventional system usually include a single water source such as a stream, sporadic and inconsistent pasture rest periods, and inconsistent manure spreading. Conversely, rotational grazing systems have multiple, smaller fields (called paddocks) for rotation of livestock, management-dependent forage rest periods, better water distribution within paddocks, and more investment in capital such as fencing and watering systems. Rotational grazing systems can be used by cow-calf, stocker, and dairy operations and have the potential to reduce feed costs, reduce animal maintenance costs and improve stocking rates.

Converting from conventional to rotational grazing systems may also produce environmental benefits. For example, rotational grazing leads to increased soil water holding capacity and reduced sheet and gully erosion. Another potential benefit may involve a reduction in GHG emissions. Rotational grazing could reduce emissions from three primary gases: carbon dioxide, nitrous oxides, and methane. Improved forage quality and animal health may reduce animal methane emissions and increase the carbon sequestration potential of pasture soils. Conversion to intensive rotational grazing systems may entail substitution of grass for harvested feed and reduce on-farm row crop production. Such substitutions have the potential to reduce nitrous oxide emissions (lower fertilizer applications) and further enhance carbon soil sequestration.

There is now widespread speculation that farm operations that reduce GHG emissions may be able to receive financial compensation through the sale of carbon credits. Carbon credits are verifiable reductions in GHG emissions below some reference condition (called baseline). The net change in GHG emissions -- the difference between the farm operating under rotational grazing and the baseline -- is called additionality. A portion or all of these additional reductions in emissions could be certified as a GHG credit.[1] If markets for GHG emissions existed or if a GHG credit subsidy program was established, a landowner would receive payment for the GHG credits created through adoption of conservation practices or changes in farm production.

Currently, there exists no one specific standard by which carbon credits are defined. For example, the effects of boundary conditions and accounting metrics on GHG reductions and compensations are relatively unknown. Boundary conditions concern the scope of relevant operations for which GHG changes are calculated. Accounting metrics refer to the units of production activity or output over which GHG changes are estimated.

The objectives of this paper are 1) to estimate the GHG reduction potential of converting to a rotational grazing system; 2) to estimate the potential financial compensation such GHG

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[1] For ease of discussion, this paper will assume that all GHG reductions would be certified as a credit and available for sale.

reductions could have for grazing livestock operations; and 3) to evaluate the effects of boundary conditions and accounting metrics on estimated GHG reductions and compensations. These objectives are examined through the use of case study analysis. The changes in GHG emissions are estimated under different policy scenarios for a typical part-time cow-calf operation that converted from conventional to rotational grazing.

Defining Greenhouse Gas Credits: Boundaries and Metrics

A typical farm operation will have multiple sources and sinks of GHG emissions. Future GHG accounting protocols will determine how changes in GHG emissions will be estimated. For land-based sources of emissions, these accounting protocols may establish standards for addressing such issues of baselines, measurement uncertainty, boundary conditions, and accounting metrics. The implications of different accounting protocols for boundary conditions and accounting metrics are examined in this paper.

Boundary Conditions

Boundary conditions define the scope of the entity for which to calculate GHG emissions.[2] Because boundary conditions will define which GHG emissions are counted, the definition of the boundary conditions will influence the total amount of GHG credits attributed to the farm operation. For this paper, the entity is defined in three ways: project, farm, and extended-farm boundaries.

First, the entity is defined as the specific GHG reduction project or practice implemented on the portion of the farm operation. GHG emission credits would be calculated by only

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[2] The U.S. Department of Energy recently released proposed guidelines for voluntary green house gas reporting (*Federal Register* December 5, 2003, pp. 68204). The guidelines state "reporting entities would have to provide an "entity statement" that meaningfully defines the operations and facilities covered by the entity-wide reports, and the greenhouse gas sources and sinks encompassed by these operations and facilities."

estimating the changes in net GHG emissions stemming from activities directly occurring on the lands where conservation practices were directly applied. For a rotational grazing project, the project level boundaries would include only the pasture land converted to intensive rotational grazing management and the associated livestock enterprise. The baseline level of emission would be the estimated GHG emissions from sources and sinks from the animals and pasture under conventional grazing system. GHG credits would be defined as the difference in the baseline emissions and the net emissions from land and animals on the land converted to rotational grazing. GHG emissions from all other farm cropland, hayland, or animal management activities not directly associated with the pasture enterprise would not be included in GHG credit calculations.

Second, project boundaries could be defined as all GHG emissions that occur on land and production activities owned by the farm operator. At a conceptual level, a baseline level of emissions would be defined for the entire farm and GHG emissions would be recalculated for the *entire farm* after major changes in farm activities or production practices occur. The rationale for a farm entity boundary is that conservation management practices may stimulate farm level changes in production practices that occur beyond the specific project area. For instance, conversion to intensive rotational grazing may cause changes in cropping practices on lands that are not used for grazing. Dairy farms switching to rotational grazing will frequently opt to completely eliminate production of corn silage and devote this land and to hay or pasture production (Groover 2001). GHG emissions are expected to be different between hay and row crops and a farm boundary definition would reflect these induced management changes in calculating GHG credits (but wouldn't be part of a calculation for a project boundary definition).

Third, an extended-farm boundary defines the farm boundary to include all GHG emissions that are required to support the farm operation, including indirect off-farm emissions. For instance, rotational grazing systems alter the intensity of land use on the farm. In some cases, the conversion may reduce land use intensity by moving from row crops to pasture. This lower intensity use may prompt the farm operator to import more feed from off the farm. Since crop production emits more net GHG emissions per hectare than hay or pasture, the farm operator may be shifting GHG generating activities off the farm. In order to demonstrate the creation of GHG credits under an extended-farm boundary definition, the farm would have to demonstrate that net GHG gas emissions from all on and off-farm activities have been reduced relative to a baseline that includes all on and off-farm emissions. This demonstration would require calculations of net GHG emissions that were released from the production of purchased feed off the farm. Conversely, conversion to rotational grazing systems may intensify land use and reduce the importation of supplemental feed to the farm. For instance, for beef cattle grazing operations, intensive rotational grazing may improve pasture utilization and thus reduce purchases of off-farm hay. In this case, a farm-level boundary definition would not reflect the lower GHG emissions associated with reducing the amount of land necessary to supply the farm with off-farm feed. An extended-farm level boundary definition, on the other hand, would count the reduction in GHG emissions associated with a smaller land area necessary to provide the feed to the animals of the farm operation against the baseline.

Accounting metrics:

GHG reductions for each of the three boundary conditions can be calculated using two different GHG accounting metrics: per management entity and per unit of product (Groenenberg and Blok, 2002). GHG emissions calculated per management entity report emissions in terms of total mass load discharge of GHG emissions (e.g. kilograms or tons). Alternatively, GHG emissions could be calculated per unit of product (e.g. kilograms of beef or milk produced). A per unit of product accounting metric might be justified to reflect the efficiency gains in producing output. A farm conservation practice might increase both farm output and total GHG emissions, but lower emissions per unit of output. Thus a mass load accounting metric would provide different incentives for adoption of a conservation practice than a per unit of product metric.

Conversion to Rotational Grazing System: A Case Study Illustration

Project, farm, and extended farm boundary definitions and per farm and per unit of product accounting metrics are applied to a cow-calf case study farm located in Grayson County, Virginia. This farm is a part-time operation of 26.3 hectares (65 acres) with many characteristics typical of cow-calf farms in this region. Calves are born during February and March and typically sold at the end of October. About 20.2 hectares (50 acres) of the farm are pasture and the remaining 6.1 hectares (15 acres) are devoted to hay production. In 1987 the owner converted the pasture from conventional to rotational grazing. At this time the pasture was divided into seven paddocks and the number of spring-fed watering troughs was increased from one to three. The estimated cost of the materials, installation, and maintenance of the additional fencing and watering systems was approximately $5,000 (Faulkner 2000).

This farm was specifically chosen because it is a good illustration of a well managed rotational grazing system and extensive data has been collected on this particular farm operation prior to this study (Faulkner 2000). The early adoption of the systems allowed time to gather information on the changes induced by an intensive rotational grazing system. Farm interviews and review of technical records including soil maps were used to gather information concerning a rotational grazing system (Hutchins 2003).

The conversion to an intensive rotational system significantly influenced stocking rates, feeding practices, and pasture maintenance practices (see Table 1 for a summary). Compared with a conventional grazing baseline, stocking rates and grass forage utilization rates both increase under rotational grazing. An estimated 23 cow calf units would be grazed on the 20.2 hectares under conventional grazing, compared to 35 units currently being managed under rotational grazing. Furthermore, weight gain is estimated to increase by 34kg (70lbs.) per calf under rotational grazing. The improved weight gain is attributed to improved forage quality since the scheduled timing of grazing keeps plants in a more vegetative/nutritious state. Better forage quality also increases the digestibility of the forage, potentially lowering methane production per animal (Van Nevel and Demeyer 1996). The increased stocking rate and improved weight gain allowed the farm operator to increase the total annual live weight sold on the farm from 5,951kg to 9,878kg (see Table 1).

Higher forage production and the better quality of forage production also resulted in changes in feed use and input requirements (See Table 1). Since animals graze the pasture in a more uniform pattern, rotational grazing more evenly distributes manure and reduces the use of chemical nutrient inputs. More uniform grazing also reduced pasture maintenance costs. Fewer hours are also devoted to cutting under-utilized pasture, reducing fuel consumption. Due to the larger number of animals under rotational grazing overall hay feeding increased and hay sales declined (Table 1). However, the improved pasture utilization rates reduced hay feeding on a per animal basis.

Calculating Net Changes in GHG Emissions

For the case study farm, the net changes in GHG emissions were calculated under the different definitions of entity boundaries and accounting metrics. A spreadsheet model was used to calculate both baseline emissions under conventional management and emissions under rotational grazing. Changes in three GHG gases, methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2), were calculated.

The changes in methane and nitrous oxide emissions were calculated using procedures developed by the Intergovernmental Panel on Climate Change (IPCC 2001). For beef cattle operations, methane emissions arise from two general sources – enteric methane and methane from manure. Enteric methane emissions were based on gross energy requirements of the beef herd multiplied by a methane conversion factor (IPCC 2001). Manure methane was estimated by multiplying the animal's volatile solid excretion rate times a manure methane conversion factor (IPCC 2001). Volatile solids excretion was a function of the difference between the beef herd's gross energy requirements and digestible energy.

Estimated nitrous oxide emissions from manure were based on estimated nitrogen excretion by the herd. Nitrogen excretion was a function of the estimated nitrogen intake from the ration. Nitrogen excretion was multiplied by an emissions factor for manure deposited directly by livestock on pasture (IPCC 2001).

Direct and indirect nitrous oxide emissions from crops were estimated. Direct emissions were based on applications of manure and commercial nitrogen as well as nitrogen fixation, nitrogen in crop and pasture residue, and soil organic matter. Indirect emissions were estimated for the portions of manure and commercial fertilizer nitrogen which volatilize and are subsequently re-deposited. Indirect emissions were also calculated for the portion of nitrogen leaching and runoff which is subject to conversion to N_2O (IPCC 2001). Methane, nitrous oxide, and carbon dioxide emissions from diesel fuel consumption for pasture and crop tillage and harvest activities were also calculated.

Carbon sequestration by plants can partially offset the production of GHGs from agriculture. Carbon sequestration was estimated as 0.1mg per hectare on row crop land, 0.12mg per hectare on conventional pasture and up to 0.4mg per hectare on hay land and intensively rotated pasture (Follett 2001). Carbon sequestration on pasture ranges between 0.12mg and 0.4mg according to the frequency that animals are rotated among paddocks. The sequestration rate for the case study farm under rotational grazing was assumed to be .29mg per hectare based on rotating cows once every four days.

Methane, nitrous oxide, and carbon dioxide emissions are reported in total carbon equivalent based on the heat trapping or global warming potential of each type of emissions. The multiplicative factors are 310 for nitrous oxide, 21 for methane, and 1 for carbon (U.S. Environmental Protection Agency 2002).

Figure 1 summarizes the emission estimates produced under each of the three different entity boundary definitions. Under the project boundary, the emissions on the 20.2ha parcel converted to rotational grazing are calculated. For the case study farm, emissions are calculated under both conventional (baseline) and rotational grazing systems. Total emissions from the 20.2ha include carbon soil sequestration rates, CO_2 emission from fuel consumption for pasture maintenance, methane emissions from animals while feeding on this land, and nitrous emissions from the 20.2ha. Compared the conventional grazing baseline, carbon sequestration rates are expected to increase while CO_2 emissions will decrease. How total methane production might change is uncertain because more animals are being grazed on the 20.2ha under rotational grazing, but each animal is expected to emit less methane because of the improved digestibility of the forage. Total emissions are reported as both total (net) carbon equivalent emitted (expressed in kilograms) on the 20.2ha as well as total kilograms emitted per kilogram of live animal weight sold.

For the farm level boundary conditions, GHG emissions from the 6.1ha of hay land is added to the emission levels calculated under the project boundary conditions (see Figure 1). For this particular case, however, adding the 6.1ha of hay land will not change the differences in emissions between the conventional and rotational systems calculated under the project because production and production practices have not changed on the hay land.

The extended-farm boundary definition includes calculations of indirect GHG emissions from feed imports and exports from the farm (see Figure 1). Under the extended farm boundary definition, the implicit GHG emissions from purchased corn production were calculated for both the conventional and rotational grazing scenarios. Under the conventional and rotational grazing systems, the farm also exports 26.5 and 18.7mt of hay, respectively. The net GHGs released from the hay land to produce these exports were subtracted from the quantities estimated for the farm boundary conditions.

Results

The GHG emission estimates for the case study farm are reported in Table 2. For this case study farm, the conversion to rotational grazing increased total net GHG emissions under all three boundary definitions. Under a project boundary, the 20.2ha of rotational grazing pasture produces an estimated 240,000kg of GHG carbon equivalent per year compared to about 192,000 kg of GHG emissions per year under a conventional system (an increase of about 48,000kg).

Thus under a total mass load definition of carbon credits, a rotational grazing operation would not generate any carbon credits.

The increase in GHG emission load is primarily a factor of the higher stocking rates. Even though methane and nitrous oxide emissions decreased per animal under rotational grazing, the stocking rate increased at a much faster pace. For example, under the project boundary definition, methane and nitrous oxide emissions increased 36% (2,717kg to 3,690kg) and 19% (523kg to 623kg) respectively. By comparison, animal sales from the farm increased by over 60% (Table 1). The increase in methane and nitrous emissions was only partially offset by an increase in carbon sequestration. The total annual carbon sequestration rate for the conventional pastureland was 2,080kg. Under rotational grazing, 5,540kg was estimated to be sequestered.[3]

For this case study farm, the total change in net GHG emissions did not change markedly across boundary definitions. While GHG emissions increased as the farm boundaries were increased from the project to the farm level, the total net increase in emissions from moving to a rotational grazing system was the same (48,015kg) under the project and farm-level boundary conditions (see Table 2). The farm-boundary definition included additional hay land not used for pasture and hay land management did not change with the adoption of rotational grazing. Extending farm boundaries to include off-farm imports and exports slightly reduced the total GHG emissions under both the conventional and rotational management (the GHG's embodied in surplus hay shipped off the farm exceed the GHG's embodied in corn imported to the farm), but these changes did not result in significant differences in the change in GHG emissions between rotational and conventional systems. Compared to project and farm boundary

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[3] Although the carbon sequestration rates seem large relative to the methane and nitrous oxide emissions, recall that the methane and nitrous oxide emissions are multiplied by 21 and 310 respectively to generate a carbon equivalent emission.

definition, the change in emissions from the baseline to rotational grazing increased slightly to 52,045kg because less hay was shipped off the farm.

While total GHG emitted from the case study farm increased under total mass load accounting metric, GHG emissions per unit of output decreased under rotational grazing. Under the project, farm, and extended-farm boundaries, total GHG emissions per kilogram of animals sold (live weight) decreased 8.0kg, 9.5kg, and 8.3kg respectively (see Table 2). For instance, under the project boundary definition, one kilogram of beef produced under rotational grazing generates about 24.3kg of carbon equivalents (239,790kg of carbon equivalents divided by 9,878kg of beef sold). Under conventional pasture management, 32.2kg of carbon equivalent emissions are released for every kilogram of beef produced. Thus, if carbon credits are defined as GHG emissions per unit of output, conversion to rotational grazing would have produced credits.

To calculate the number of carbon equivalent credits produced each year with a per-unit-of-output metric, the total weight of beef supplied by the farm can be multiplied by the estimated reduction in GHG emissions. This calculation assumes that if the animals were not supplied by the case study farm, an equal amount of animals produced under conventional management would be sold in the market (one-to-one replacement). After conversion to rotational grazing, the case study farm supplies 9,878kgs of output (live weight) to the market annually (see Table 1). Assuming a project boundary definition, each kilogram of beef produced under rotational grazing generates 8.0kg fewer GHG emissions (see Table 2). Under a per unit of output accounting metric, total GHG emission credits (additionality) created by the switch to a rotational grazing could be as high as 79,024kg (8.0 x 9,878kg) or 79 metric tons.

The potential financial value of these carbon credits, however, is uncertain. Because there is currently no market for carbon credits in the United States, the future value of carbon equivalent credits must be estimated. Estimates of the possible carbon credit price range from $14-23 per metric ton by the Council of Economic Advisors to $20-30 per metric ton by Sandor and Skees (Antle et al., 2001). For exposition purposes, if a $15 per metric ton value is assumed, the total value of the GHG emission credits produced by the case study farm is almost $1,200 (67 tons x $15/ton). Although $1,200 may appear small, this additional farm income might not be trivial given the small size of the operation.

Summary and Conclusions

In addition to the potential improved productive efficiencies, rotational grazing systems may generate environmental improvements. The potential to reduce GHG emissions was examined under different definitions of farm boundaries and GHG accounting metrics. This research suggests that how GHG credits are calculated will have significant implications for whether farms can turn the environmental improvements into a financial benefit. In the case study farm examined here, the increasing land use intensity resulting from a shift to rotational grazing increased total GHG emissions on a per-project or per-farm basis, but the improved production efficiencies reduced the GHG emissions produced per unit of output.

Table 1: Summary of Changes in Cow-Calf Case Study Farm Operations

Item	Conventional Grazing	Rotational Grazing
Cow calf units	23.0	35.0
Days on pasture	290.0	300.0
Manure nitrogen (kg)	2,626.8	4,082.8
Livestock sales		
Number of calves sold	16.1	24.5
Average weight of sold calves (kg)	243.3	276.9
Number of cull animals sold	3.8	5.7
Average weight of cull animals (kg)	541.4	541.4
Total live weight sold (kg)	5,950.7	9,877.8
Feed fed		
Pasture (kg) (20% DM)	487,872.0	764,814.4
Corn grain (kg) (85% DM)	997.6	1,315.7
Hay (kg) (90% DM)	24,533.9	32,356.3
Crop purchases and sales		
Corn grain purchases (kg)	997.6	1,315.7
Hay sales (kg)	26,495.8	18,673.4
Crop inputs		
Commercial nitrogen (kg)	331.4	331.4
Diesel fuel (liters)	1,100.8	998.4

Table 2. Summary GHG emissions for case study farm

	Summary Project GHG Emissions	Summary Farm GHG Emissions	Summary Extended-Farm Emissions
Intensive Rotational Grazing (Rotational)			
Enteric methane	3,586.7	3,586.7	3,586.7
Manure methane	103.0	103.0	103.0
Methane from fuel	0.1	0.3	0.2
Total Methane (kg)	3,689.8	3,690.0	3,689.9
Manure N2O	128.3	128.3	128.3
Direct N2O (crops)	349.1	430.0	400.7
Indirect N2O (crops)	64.0	64.9	65.3
N2O from fuel	0.0	0.0	0.0
Total N2O (kg)	541.4	623.2	594.3
CO2 sequestration (carbon equiv)	-5,809.3	-8,237.5	-7,275.5
Carbon from fuel	267.9	779.3	600.4
Total Carbon (kg)	-5,541.4	-7,458.2	-6,675.0
SUMMARY			
Carbon equivalents (kg)	239,790.9	263,238.3	255,040.6
Carbon equiv per kg live animal sold	24.3	26.6	25.8
Conventional Grazing (Baseline)			
Enteric methane	2,629.4	2,629.4	2,629.4
Manure methane	87.6	87.6	87.6
Methane from fuel	0.1	0.3	0.2
Total Methane (kg)	2,717.1	2,717.3	2,717.2
Manure N2O	82.6	82.6	82.6
Direct N2O (crops)	316.4	397.3	354.0
Indirect N2O (crops)	42.3	43.2	43.4
N2O from fuel	0.0	0.0	0.0
Total N2O (kg)	441.3	523.1	480.0
CO2 sequestration (carbon equiv)	-2,428.2	-4,856.3	-3,481.2
Carbon from fuel	347.9	859.2	600.0
Total Carbon (kg)	-2,080.3	-3,997.1	-2,881.1
SUMMARY			
Carbon equivalents (kg)	191,775.8	215,223.1	202,995.6
Carbon equiv. per kg live animal sold	32.2	36.2	34.1
NET CHANGES IN GHG EMISSIONS FROM BASELINE TO ROTATIONAL			
Carbon equivalents (kg)	48,015.2	48,015.2	52,044.9
Carbon equiv. per kg live animal sold	-8.0	-9.5	-8.3

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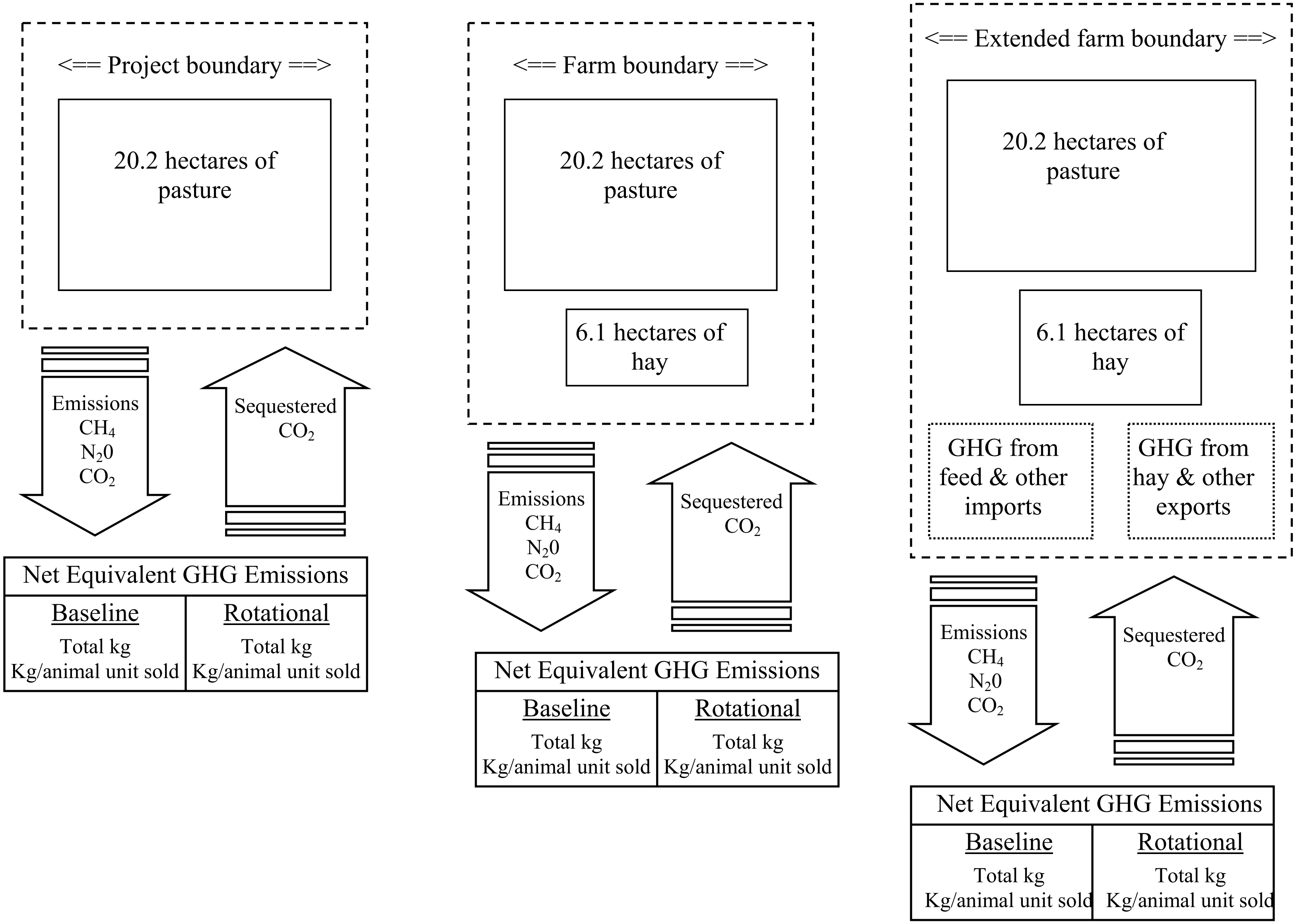

Figure 1: GHG emissions under different boundary definitions for case study farm