Predicting greenhouse gas (GHG) emissions reduction in a dairy farm through dairy digester using a UI based analytical tool

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Introduction

Over 300 million tons of dry dairy waste is generated annually in the USA. California alone produces about 60 million tons of manure/waste [1]. Majority of this manure is collected in lagoons or managed in the open ponds and such practices pose environmental risks. Animal manure emits air pollutants which has methane, which is a greenhouse gas as a major component,. Methane has negative impacts on the environment and it contributes to global warming leading to increase in global annual temperatures.

To treat the animal waste, biological processes such as anaerobic digestion is used in which the bacteria (methanogens) digests the animal waste/organic material in the absence of oxygen. Anaerobic digestion is a sustainable practice for treating the animal waste [2]. It results in the formation of biogas, which is majorly constituted by methane. The biogas contains GHGs, however biogas can be used as a renewable source of energy for the farm operations or even supplied to the energy grid, hence effectively reducing the net GHG emissions.

California Department of Food and Agriculture's (CDFA) Dairy Digester Research and Development Program provides monetary support for the installation of anaerobic dairy digesters at the farms across the state of California to reduce and mitigate the GHG emissions [3]. For implementing the dairy digesters, calculations for total GHG emissions reductions is important to estimate the economic viability of the project.

Objectives

1. To develop a Graphical User Interface (GUI) based quantitative tool (software) which maybe used by the DDRDP fund applicants (dairy farmers) for them to predict the overall reductions in GHG emissions per unit dollar of investment over a 10 year period.
2. To perform a parametric study by varying the farm and project specific inputs in order to develop a greater understanding about the effect of various manure management practices on the total GHG emission reductions.

Methods

A user friendly and interactive software tool is used to estimate the GHG emissions reduction and air pollutant emission co benefits depending on the type of activity/practice adopted. The amount of methane production depends on the amount of manure produced, total volatile solids content, fraction of volatile solids that decompose anaerobically (i.e. the biodegradable organic material in the manure), temperature, and the retention time of manure during treatment and storage.

The developed software will integrate the project-specific data with the default factors to establish the baseline and project scenarios. Baseline Methane Emissions from Anaerobic Storage / Treatment is given as [4]

$$BE_{CH4,AS} = \sum (f_i \times VS_{avail\,AS,L,i} \times B_{0,l}) \times 0.68 \times 0.001 \times 25$$

$BE_{CH4,AS}$	=	Total annual project baseline methane emissions from anaerobic manure storage/treatment systems
$VS_{deg\,AS,L,i}$ $[f_i \times VS_{avail\,AS,L,i}]$	=	Monthly volatile solids degraded in anaerobic manure storage/ treatment system 'AS', from the total available volatile solids for each livestock category 'L' in the month 'i'
$B_{0,l}$	=	Max. methane producing capacity of manure for a livestock
f_I	=	The van't Hoff-Arrhenius factor = % of VS that are biologically available for conversion to methane, depending on the monthly average temperature of the system/location.

0.68=Density of methane (1atm, 60^0F) (*kg/m^3*)   25=Global warming potential of methane

Methods (cont.)

For calculating the GHG emission reduction benefits, the basic quantification methodology is given as:

Net GHG Emission Reductions	=	(Baseline methane(CH_4) and CO_2 emissions) – (Project CH_4 and CO_2 emissions) + (Additional GHG benefit by utilizing methane)*

**Additional GHG benefit can be extracted by using the biogas for electricity generation, producing transportation fuel, offsetting fossil fuel like natural gas or diesel or by using the biogas for thermal energy generation in a boiler.*

Following inputs are required for the calculations:

1. Farm demographics: County Location, Animal population per Livestock category and average monthly and annual temperature (to calculate the methane conversion factor).
2. Current practices and practices to be implemented for manure collection, solid separation, manure management system and the biogas destruction devices.

Following are the input and output windows of the software tool:

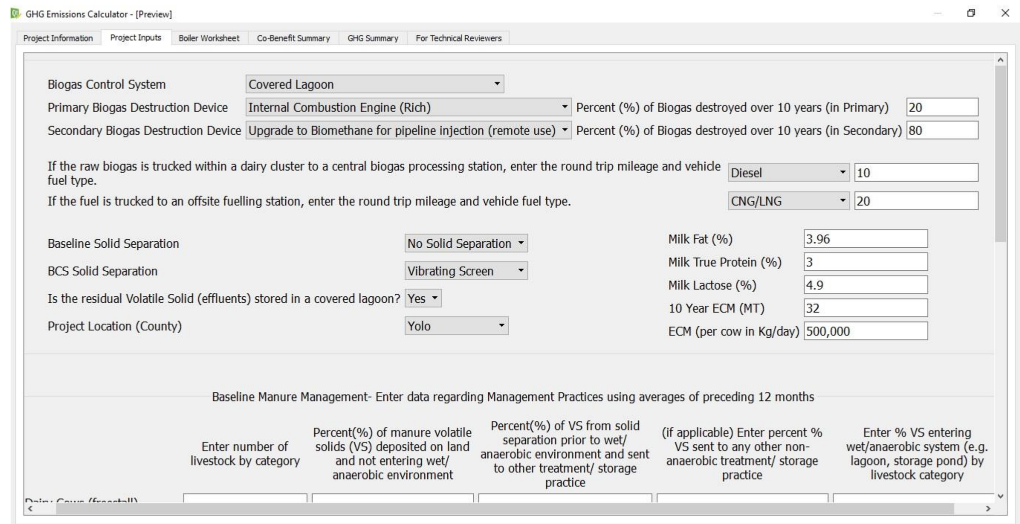

Fig 1. Project Input Window

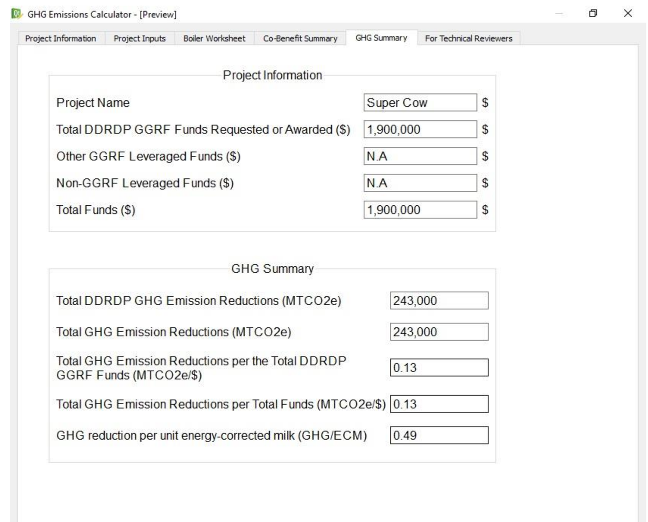

Fig 2. GHG Benefits Summary

Results and Discussion

Fig 3. Dairy farm with animals

Fig 4.

Fig 5. Anaerobic Dairy Digester

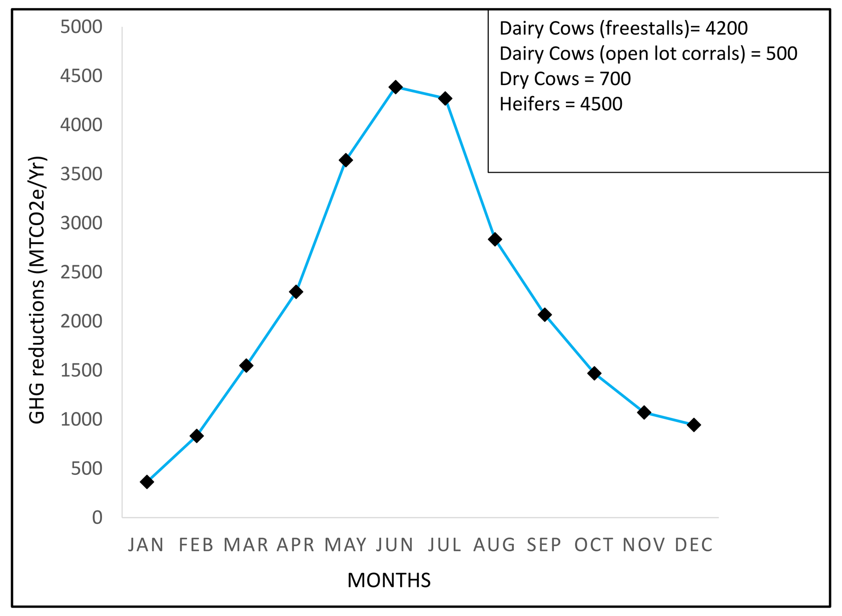

Fig 5. Monthly variation in GHG reductions

Results and Discussion (cont.)

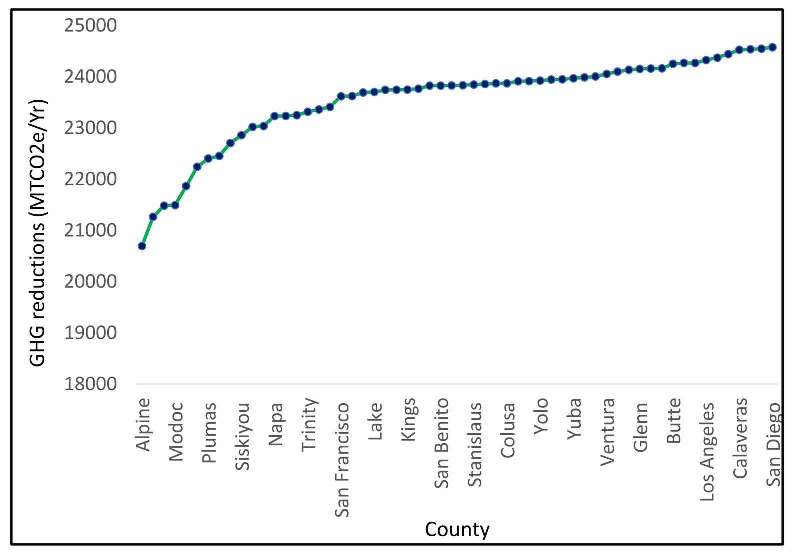

Fig 6. Effect of farm location on the total annual GHG reductions

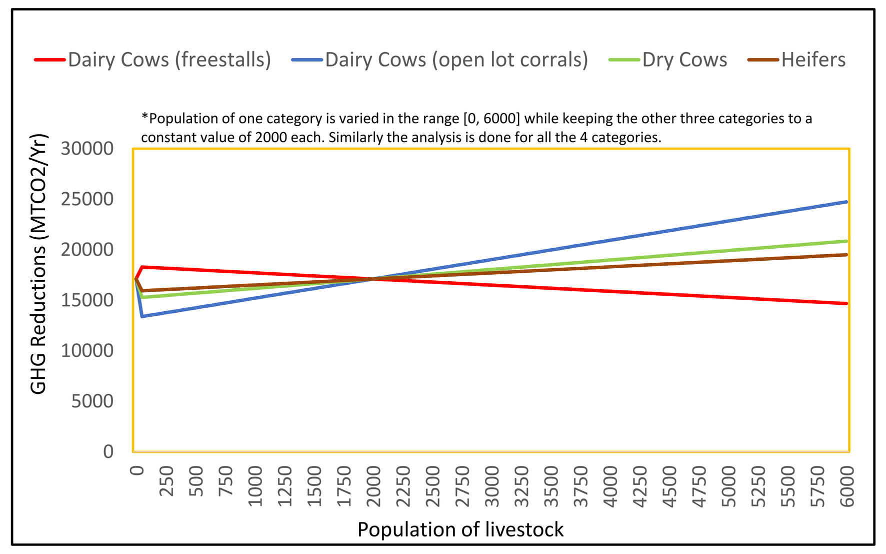

Fig 7. Effect of type of Cattle on total annal GHG reductions

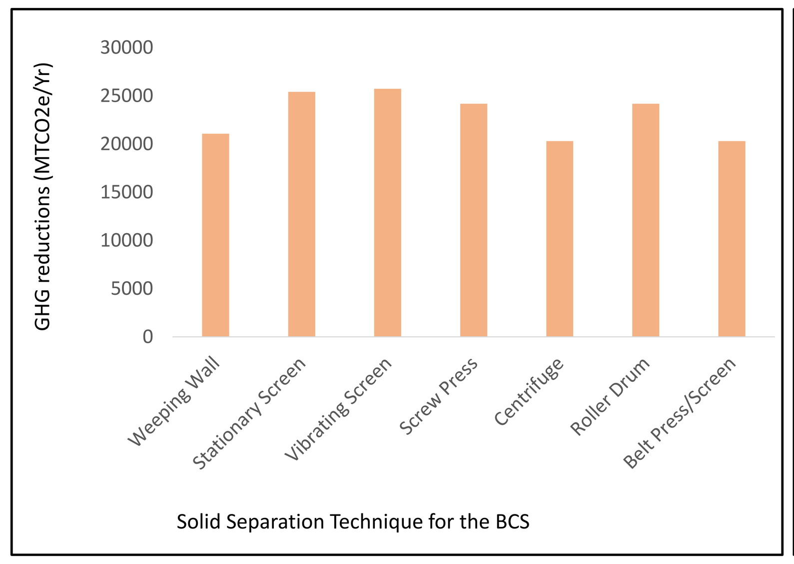

Fig 8. Effect of solid separation techniques on GHG reductions

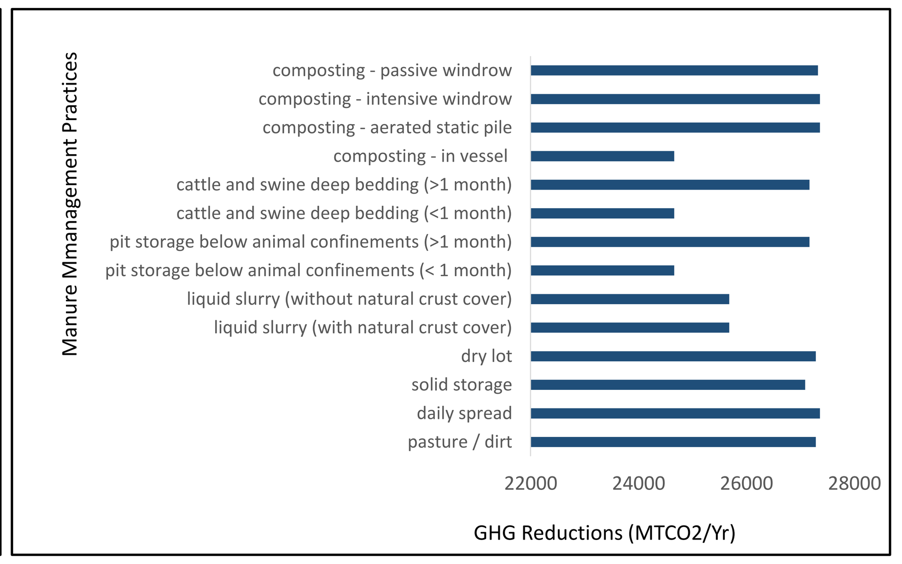

Fig 9. Effect of different manure management practices on GHG reductions

Conclusions

- A user interface based software was developed to predict the reductions in GHG emissions in a dairy farm after the installation of a dairy digester using the equations and default parameters based on CARB guidelines.
- Parametric study was performed and a relationship of the net GHG emission reduction was developed with different inputs including type and population of livestock, county location (based on f-value), solid separation and manure management practices.
- The cost-benefits analysis and results given by the software can be used in decision making of the practices to be implemented for the project.

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References

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