

**Title:** Integrated Sustainability Modeling for Swine Farm Operations –NPB #14-190

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### Industry Summary:

The Pig Production Environmental Footprint Calculator Version 3 has been completed and will soon be made available to producers. This software enables the user to calculate the greenhouse gas emissions, water usage and crop land requirements for an existing or proposed pork production operation. The model further breaks down the contributions from all significant aspects of the operation including: emissions from manure systems, electricity usage (pumps, fans, heaters, lights), feed production, feed delivery, fuels used and water used (drinking, cooling, barn washing, feed production). Additionally, the calculator estimates the operating costs associated with all of these factors to enable the user to identify the economic tradeoffs of various equipment and procedural options and their impacts on emissions and associated incremental costs. For example, a user designing new feed mixes can use the calculator to simultaneously evaluate the costs and footprints associated with various feed ingredients. Input to the calculator consists of a description of the facilities and how the farm is operated; unlike other calculators of this type the Pig Production Environmental Footprint Calculator automatically estimates the required usage of feed, electricity, water, and fuels instead of requiring the user to input this information. The calculator runs on Windows machines from XP up and requires no internet connection for use.

**Keywords:** environmental impact, greenhouse gases, carbon footprint, water usage, modeling

### Scientific Abstract:

This project built on Version 2 of the Pig Production Environmental Footprint Model to produce Version 3 with substantially increased capability and scope. The goal of this work was to provide producers with an easy-to-use tool that will enable them to evaluate the sustainability and environmental footprint of their operations. The calculator is both a tool for identifying cost-effective methods for reducing the environmental impact of pig production operations and a demonstration of the commitment of the industry to that cause. The improvements diversion to include the addition of new computational features, more accurate animal performance modeling, an improved interface, and expansion of the existing model from barn-based to farm-based. The water and land footprint work previously performed under separate contract at University of Arkansas was integrated into the model to expand it from a greenhouse gas emissions calculator to one that enables the identification and evaluation of tradeoffs between carbon, water and land footprints. The economic assessment tools were expanded to provide a financial metric for any proposed impact mitigation strategies.

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## **Introduction:**

This program calculates greenhouse gas (GHG) emissions, water usage, land usage and operating costs associated with a swine production operation. This farm-level model simulates operations and animal performance at very high time resolution. It utilizes numerous sub-models from the literature and our own research to give predictive outputs of:

- Cradle-to-farm-gate usage of crop land, water, feed, electricity, gas, propane, and diesel.
- On-Farm emissions of GHGs including CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O.
- On-Farm operating (day to day) costs.

The combination of costing and footprinting capabilities enables economic evaluation of strategies to reduce the environmental impacts of swine production. The calculator is designed to be used by producers and researchers to identify sources of significant environmental issues in the operation, how these impacts are affected by changes in operational procedures and/or hardware, and the economic benefits or costs associated with changes resulting in reductions of environmental impacts. The various components of the calculator can also be used separately, for example, if calculating just the GHG emissions, the costs or just the water usage. The calculator displays results in a number of formats including per farm, per barn, per market pig, per sold pound and per pig space.

Most environmental calculators in agriculture and industry require that the user input the amount consumed per year for fuels, electricity, water, feed, etc. These calculators then essentially multiply these amounts by impact factors and report the resulting footprints. *The Pig Production Environmental Footprint Calculator* works at a more fundamental level by predicting the yearly use of consumables from a detailed description of the farm including information such as herd size, feed composition, manure handling systems, farm location, barn sizes, and characteristics of the heating/cooling systems. This description of the operation is processed through fundamental models of pig nutrition, growth and excretion, chemical reactions in the manure handling systems, barn heating and cooling, and water usage to calculate the consumption of utilities and commodities. It then uses these amounts with the applicable impact and price factors to calculate the environmental and cost impacts. In this way it is possible to evaluate operation and management practices that will minimize negative environmental effects from the farm.

Version 3 simulates a production farm with up to ten barns of combinations of four possible type barns (sow, grow, gestation and farrowing). The grow barn can be: 1) a nursery-to-feeder operation, 2) a nursery-to-finish, 3) feeder-to-finish or 4) any combination depending on the specified entering and leaving weights of the pigs. Each barn can have a subfloor, deep pit or dry bedding manure system. The farm can have downstream manure systems consisting of lagoons, outside storage or digesters. The calculator utilizes climate data from each county in the U.S. to calculate barn heating/cooling needs and temperature dependent emissions from manure handling systems. The scope for pigs is cradle-to-farm-gate and for manure is through application to fields.

## **Objectives:**

1. New user interface written in the same language as the rest of the calculator, removing the Version 2 requirement of also having Excel active on the user's machine.
2. Improved climate database to better capture the impact of temperature on animal performance and provide scenarios for projected future climates.

3. Integration of the water and land footprint models.
4. Conversion of all Version 2 economic components to the C# code.
5. Integration of regional feed prices into the calculator.
6. Enabling of the creation of saved farm reports as PDF files.
7. Integration of DNDC to calculate gas emissions from fields after application manure from the farm.

### **Materials & Methods:**

Model development was aimed for Windows machines from XP and up.

### **Results:**

1. New user interface written in the same language as the rest of the calculator, removing the Version 2 requirement of also having Excel active on the user's machine.

Fully accomplished. The interface is now completely integrated with the rest of the calculator as one seamless program. The interface provides a comprehensive check of all input values so that it will not be possible for the user to "crash" the program. Help buttons and tool tips were added on individual screen panes to aid the user in providing appropriate input without having to refer to a user's manual. A user's manual is provided for either the expert or casual user. Programming documentation is provided at both the code and the manual level so that subsequent programmers can pick up the project with little introduction time.

2. Improved climate database to better capture the impact of temperature on animal performance and provide scenarios for projected future climates.

Fully accomplished. The calculator now has a database that provides hourly temperature, humidity, solar flux, precipitation and evaporation rate throughout the year for 3202 county centroid locations in all 50 states.

3. Integration of the water and land footprint models.

Fully accomplished. The water and land footprint work previously performed under separate contract at University of Arkansas was integrated into the calculator. Water usage is calculated for drinking, cooling (for cooling cells, sprinkle or drip applications), barn washing and feed production. Land acreage is calculated for feed production required by this farm.

4. Conversion of all Version 2 economic components to the C# code.

Fully accomplished. In Version 2 of the calculator, all economic components were compiled in Excel. For Version 3, all existing 200+ economic algorithms were reviewed and converted into C# for compatibility with the rest of the source code. Additionally, new economic algorithms were developed as needed to account for costs associated with additional feed ingredients and activities added to Version 3. Making this conversion has greatly improved the run time and overall integrity of this complex software.

5. Integration of regional feed prices into the calculator.

Fully accomplished. Like most economic models, Version 2 of the model used national average prices as default prices for all feed ingredients. Realistically however, prices for most major commodity feed ingredients vary greatly by region. In Version 3, we have expanded the calculator's prices databases to better reflect those prices relevant to a pork farm's geographical location. A new database has been developed that collects weekly (where available) prices from up to 13 locations for major feed ingredient commodities. New algorithms were developed that link each county location with its relevant major commodity market. Locations for diet ingredients with no regional market draw from the calculated national average prices. For other non-feed farm utilities and activities (electricity, gasoline, diesel, propane, water and dead animal disposal) databases have been developed that calculate state level prices. These databases are updated weekly or monthly internally and housed within the UA Division of Agriculture Center for Agricultural and Rural Sustainability. Updates to these databases will be made online quarterly for user download for at least one year after Version 3 release.

6. Enable the creation of saved farm reports as PDF files.

Fully accomplished. After a simulated farm has been run the user can now save the results in short or long form as a PDF file that can be viewed on any computer without having to have the model available.

7. Integration of DNDC to calculate gas emissions from fields after application manure from the farm.

This was not accomplished because the makers of DNDC did not want to contribute to this task.

### **Discussion:**

The calculator is both a tool for identifying cost-effective methods for reducing the environmental impact of pig production operations and a demonstration of the commitment of the industry to sustainable pork production. This project unites the life cycle assessments of the greenhouse gas (GHG) footprint work and the land footprint and water footprint work already completed under separate contracts at the University of Arkansas. We combined these into one tool to help producers and planners take the various environmental and economic impacts into consideration for existing or proposed projects. The water and land footprint portions extend these capabilities to other sustainability metrics. The inclusion of economic assessment models enables the quantification of tradeoffs between impact categories so that the producer can optimize their operation with regard to present or future conditions. In the event that there ever is a carbon tax that would impact the industry, the emissions and cost modeling components provide a metric for the amount of GHG release that is produced and provides both a fair accounting of those emissions as well as potential costs and a means to evaluate possible pathways for their reduction.