Whole Farm Simulation and Nutrient Management

C. Alan Rotz

USDA, Agricultural Research Service
University Park, Pennsylvania
Descriptive Information

Tool Name: Dairy Forage System Model
Integrated Farm System Model

Purpose: Research and teaching tool for long-term evaluation of farm production systems

Contact Person: Al Rotz

Stage of Development: Recent versions available on the Internet; Continuing development
Focus and Scale

Focus: Whole-farm (Soil, crops, animals, equipment processes, etc.)

Scale: Whole-farm

Area of Concern: Nitrogen losses (volatilization, leaching and denitrification) and phosphorus balance
Integrated Farm System Model

- **Crop**
  - Establish
  - Harvest

- **Soil**
  - Fixed nitrogen
  - Volatile loss
  - Purchased fertilizer
  - Runoff & Leaching loss

- **Manure**
  - Volatile loss

- **Animal**
  - Grazing
  - Feed sold
  - Volatile loss
  - Purchased feed, bedding, etc.
  - Milk sold
  - Animals sold

- **Storage**

**USDA / ARS**
Weather
Crops

- Alfalfa pasture, hay and silage
- Grass pasture, hay and silage
- Corn grain and silage
- Barley, wheat, oats or rye grain, silage, or mulch
- Soybean grain
Crop Growth

- Phenological stage
- Yield
- Nutritive content
- Nutrient uptake
Harvest

- Machinery use
- Timeliness of operations
- Fuel and labor use
- Harvest losses and nutritive changes
Storage

- Types of storage
- Storage losses and nutritive changes
- Silo capacity and fill
Feeding and Use

- Feed allocation
- Balanced ration
- Machinery, fuel, and labor use
- Animal intake
- Production

USDA / ARS
Manure

- Quantity and nutrient content
- Bedding and feed loss
- Nitrogen volatilization and loss
- Machinery, fuel, and labor use
- Timeliness of operations
- Date to begin tillage
Tillage and Planting

- Type of tillage (sequence of operations)
- Machinery, fuel, and labor use
- Timeliness of operations
- Planting date
Soil

- Predominant soil type
- Moisture balance in soil profile
- Nitrogen balance in soil profile
  - Leaching
  - Mineralization
  - Denitrification
- Farm level balance of P and K

USDA / ARS
Economics

- Annual production costs
- Annual incomes
- Annual net return
- Mean and standard deviation in costs and returns across years

USDA / ARS
Environmental Impact

- Nitrogen loss to atmosphere
- Nitrogen loss to ground water
- Phosphorus accumulation
- Potassium accumulation
Application

Users: Researchers, Teaching faculty, Extension, NRCS, etc.

Format: Windows (version 95 and up)

Documentation: Integrated help system

- User guide – Guidance on input, output and use
- Reference Manual – Description of model including major equations and references
Regional Application

- Primarily developed and validated for the northern temperate regions of the U.S.
- Has been used for a number of locations in Canada and Europe
- Most recent version can simulate areas in the southern hemisphere
Recent Applications

- Alternative strategies for manure handling
- Protein supplementation strategies for dairy cattle
- Soybean production and feeding on dairy farms
- Small grain production and use on dairy farms
- Pasture and confined feeding systems
- Reduced levels of grain feeding
- Intensity of pasture management
- Global climate change
- Corn silage processing
- Robotic Milking
Inputs

- Farm parameters
- Machinery parameters
- Weather data
Farm Parameters

- Crop types & areas
- Predominant soil type
- Equipment and structures used
- Number of animals at various ages
- Animal feeding & maintenance strategies
- Harvest, tillage & manure handling strategies
- Prices for various farm inputs and outputs
Machinery Parameters

- Size
- Age
- Initial cost
- Field speed
- Operating capacity
- Power requirements
- Repair factors
Weather Data

- Daily data for solar radiation, maximum and minimum temperature, and precipitation
- Weather files are available for many locations across the northern U.S., Canada and Europe
- Weather files can be created for other locations
Outputs

- Summary tables
- Report tables
- Parameter tables
- Optional tables
Summary & Report
Performance Output

- Crop yields & quality
- Feeds produced
- Feeds bought and sold
- Milk or meat produced
- Manure produced
- Labor, fuel & equipment use
Summary & Report
Environmental Output

- Volatile N loss
- Leaching N loss
- Denitrification N loss
- N concentration in groundwater
- P balance
- K balance
Summary & Report

Economic Output

- Manure handling costs
- Feed production costs
- Other farm costs
- Income from milk, meat and animals sold
- Net return or profitability
Optional Output

- Daily values of crop growth and development
- Pasture availability by month
- Suitable days for fieldwork by month
- Daily values of forage harvest operations
- Annual summaries of machine, fuel, and labor use
- Animal group characteristics and diets
Example Application

Whole Farm Management to Reduce Nitrogen Losses from Dairy Farms

C. A. Rotz
J. Oenema
H. van Keulen
Objectives

To evaluate the potential long-term environmental benefits and economics of N conservation practices for dairy farms

- Calibrate and verify our farm model through simulation of the De Marke farm
- Evaluate these N conservation practices on simulated 100- and 1000-cow dairy farms for southern Pennsylvania
De Marke Farm

- 78 cows
- 8,600 kg/cow
- 57 young stock
- 55 ha of land
- Grass, corn and triticale
- Deep sandy soil
Nitrogen Conserving Technologies

- Efficient protein feeding
- Low emission barn floor
- Covered manure storage
- Manure injection
- Grass catch crop
Model Calibration

Simulation of De Marke farm for weather years 1996-99

- N in precipitation
- Soil organic N in grassland
- N volatilization from pasture
- Animal intake of forage
- Base temperature for corn growth
Model Evaluation

Simulation of De Marke farm for weather years 2000-01

- 6.5 ha of corn switched to triticale
- Reduced grazing time and area
- More clover in pasture
Pennsylvania Farm

- 100 cows
- 8,600 kg/cow
- 67 young stock
- 100 ha of land
- Corn, alfalfa and grass pasture
- Medium silt loam soil
- Daily manure hauling
Nitrogen Conservation Technologies
100 Cow Farm

- N imported
- N volatile loss
- N leaching loss
- N denitrification loss
- N exported
- P accumulated

Loss or balance, kg/ha

- Base farm
- With N conservation

USDA / ARS
Pennsylvania Farm

- 1000 cows
- 11,300 kg/cow
- 770 young stock
- 600 ha of land
- Corn and alfalfa
- Medium silt loam soil
- Long-term manure storage
1000 Cow Farm

Cost or return, $/cow

- Feed production cost
- Manure handling costs
- Purchased feed cost
- Net return

Base farm
With N conservation

USDA / ARS
Conclusions

- The IFS model satisfactorily reproduced the long-term feed production and use and the N and P flows of the De Marke dairy farm.
- Simulation of N conservation technologies on Pennsylvania farms illustrated that N loss, primarily in the form of ammonia emissions, could be reduced by about 35%.
- The cost of this technology exceeded the value of the N saved, causing a reduction in annual net return of about $80/cow.
Limitations

- What limits the tool from use by a wider audience?

Model complexity!
Limitations

- Identifiable weaknesses in terms of technical abilities?
  - Other crops
  - Other animal species
  - Subtropical regions
  - Need for further validation/verification
Limitations

- Aspect of nutrient management fulfilled by the model?

Integration with other aspects of the farm (Performance and economics)

Ability to evaluate nutrient management in whole farm systems
Usefulness

- Gaps in the abilities of the model to balance nutrients or predict nutrient outcomes?

Phosphorus loss
Usefulness

- Quality of results with respect to nutrient handling?
  - Nitrogen volatilization
  - Nitrogen leaching
  - Denitrification
  - Unaccounted nitrogen loss
Usefulness

- Confidence level in the output?

Practical expertise is required to use the model

Some calibration/verification is helpful

Simulated nutrient flows and losses are at least as accurate as measured values
Usefulness

- Has there been any field validation?

Farm level validation is very difficult

All component models are carefully evaluated, verified, or validated

Many farms have been represented with the model with at least reasonable results
Usefulness

- Who has used this tool and in what capacity?
  - Researchers
  - Teaching faculty
  - Extension faculty/specialists
  - Machinery industry
  - Producers, etc.

- Estimated number of users???
Usefulness

- Has the tool been useful in meeting regulatory requirements or policy?
  Not directly
  Provides a great educational tool that could influence farm design/regulation
  Use of the model for this purpose could be abused

- Does the tool produce a nutrient management plan?
  No
Future Plans

- Validate beef component
- Upgrade N volatilization loss
- Predict P loss (crops, diet, tillage, etc.)
- Upgrade pasture model (multiple plant species)
- Add carbon balance?
- Add other animal species?
Model Availability

http://pswmru.arsup.psu.edu
Pasture Systems and Watershed Management Research Unit

University Park, Pennsylvania