SWAT-GHG: a Mechanistic Greenhouse Gas Sub-model for SWAT

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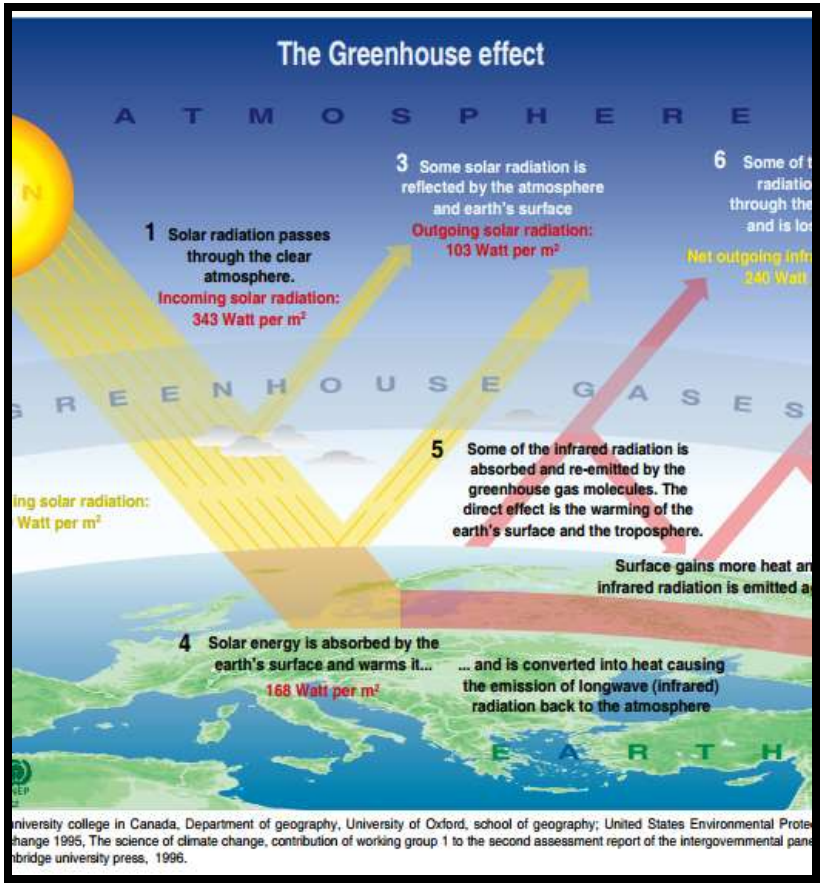
Presentation Outline

- Background on Greenhouse Gases and Denitrification
- How Denitrification is Modeled in N-cycling Models?
- Methodology/ Approach
- Linking GHG Sub-model with SWAT
- GHG Sub Model Testing
- Results and Discussion
- Conclusions

Greenhouse Gases



Source: http://www.grida.no/graphicslib/detail/greenhouse-effect_156e#

- Greenhouse gasses include methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O)
- N_2O is by far the most potent with 310 times the radiative forcing a CO_2
- N_2O is produced during denitrification, the process that converts reactive nitrate (NO_3) to unreactive dinitrogen (N_2)

How Denitrification is Modeled in N-Cycling Models?

- Microbial growth concept; considers the dynamics of microbial organisms responsible for the N cycling processes (e.g. DNDC model, NLOSS model, ECOSYS model)
- Soil structural concept; considers gaseous diffusion of gases into and out of soil aggregates
- Simplified process concept; depends on first-order decay process and measurable parameters such as :
    - Degree of saturation
    - Soil temperature
    - Soil nitrate
    - Soil carbon
    - Soil PH

Methodology/ Approach

- We used the work of Weier et al. (1993), Parton et al. (1996), and Schaefer and Alber (2007) and results from our lab group to develop a new GHG sub-model for SWAT

- Developed a set of equations to model the total denitrification rate (N_2+ N_2O) and then partitioned N_2 from N_2O

Methodology/ Approach, Total Denitrification Products (N_2+N_2O)

- The total denitrification rate, Parton et al. (1996), is given as:

$$Dt = \min[Fd(NO_3), Fd(C)] * Fd(\theta) * Fd(Temp) * Fd(pH)$$

where: *Dt is the denitrification rate per unit ~~area(N2 + N2O)~~*

Methodology/ Approach, Partitioning N_2O

- A ratio method is used to differentiate the N_2O from N_2 produced during denitrification(Dt), Parton et al. (1996)

$$R_{N2/N2O} = min[Fr(NO_3), Fr(C)] * Fr(\theta) * Fr(pH)$$

$R_{N2/N2O}$ is ratio of N_2 to N_2O

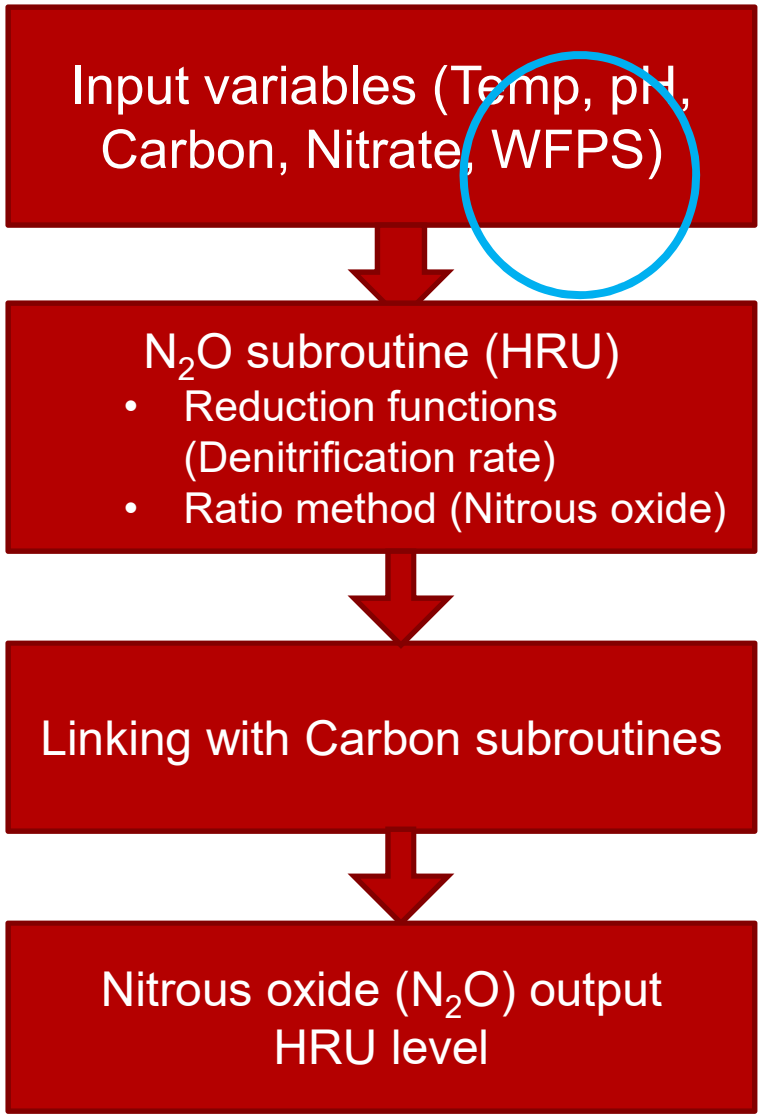
Methodology/ Approach, Partitioning N_2O

- Total N_2O production during denitrification is given by:

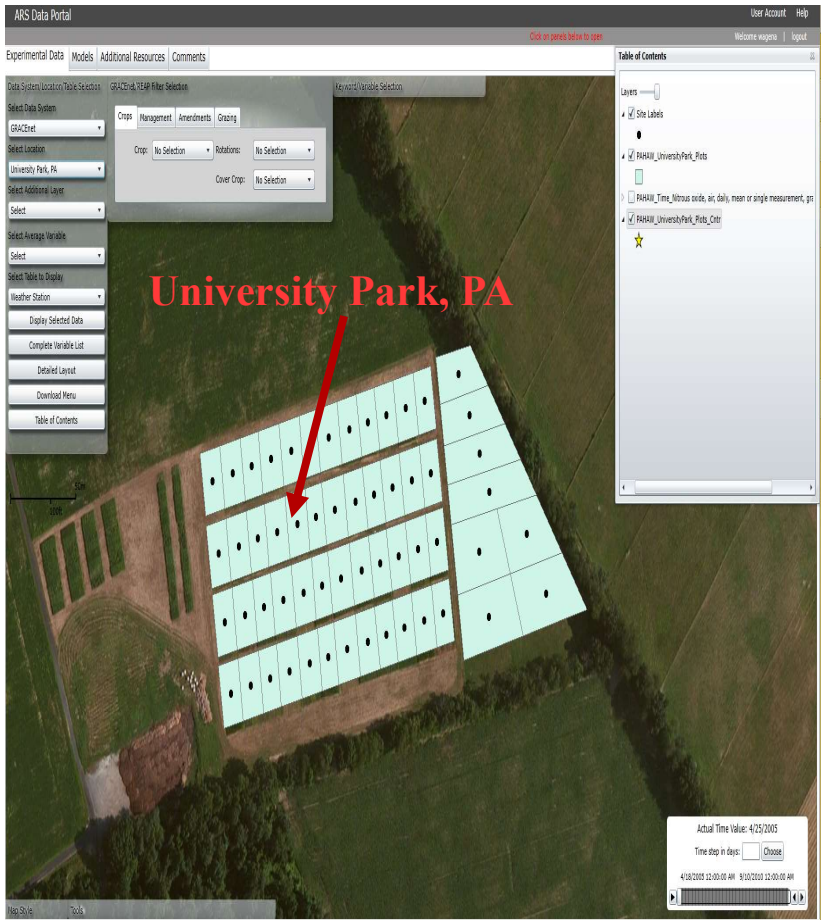
$$DN_2O = \frac{Dt}{1 + R_{N2/N20}}$$

where DN_2O is total N_2O flux per unit area

Linking GHG sub model with SWAT



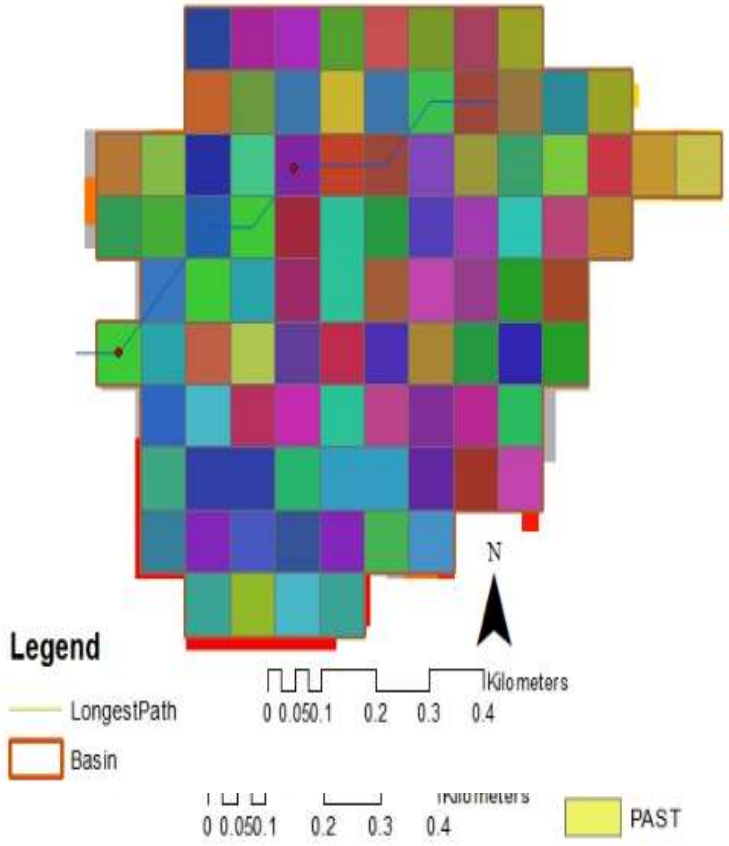
GHG Sub Model testing



http://nrrc.ars.usda.gov/arsdataportal/#/Home

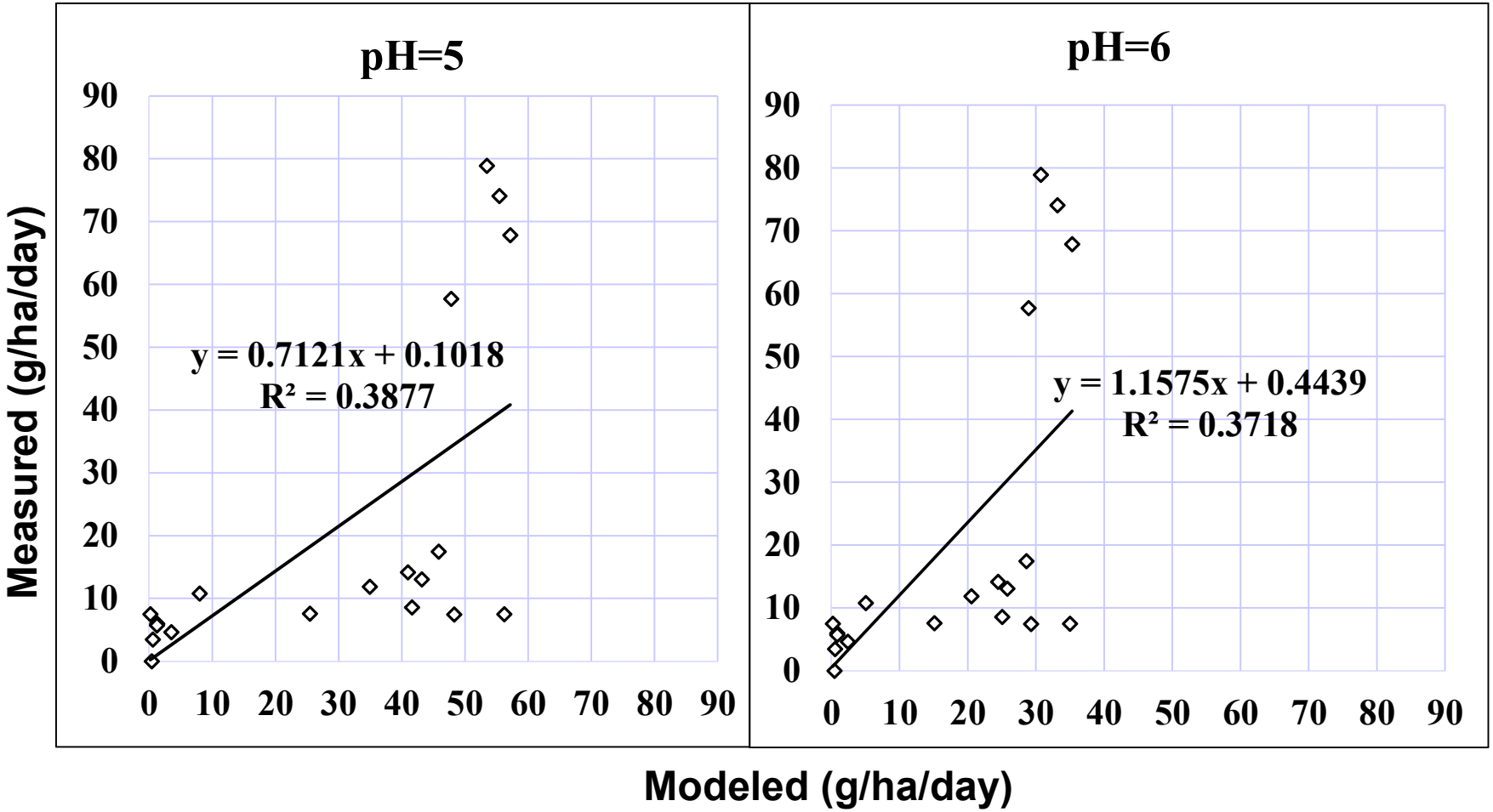
- N_2O sub-model was tested using data from the GRACEnet database in two locations
  - Central Pennsylvania
  - Eastern Kentucky
- 2010 year measured data of N_2O is used for model testing

GHG Sub Model testing

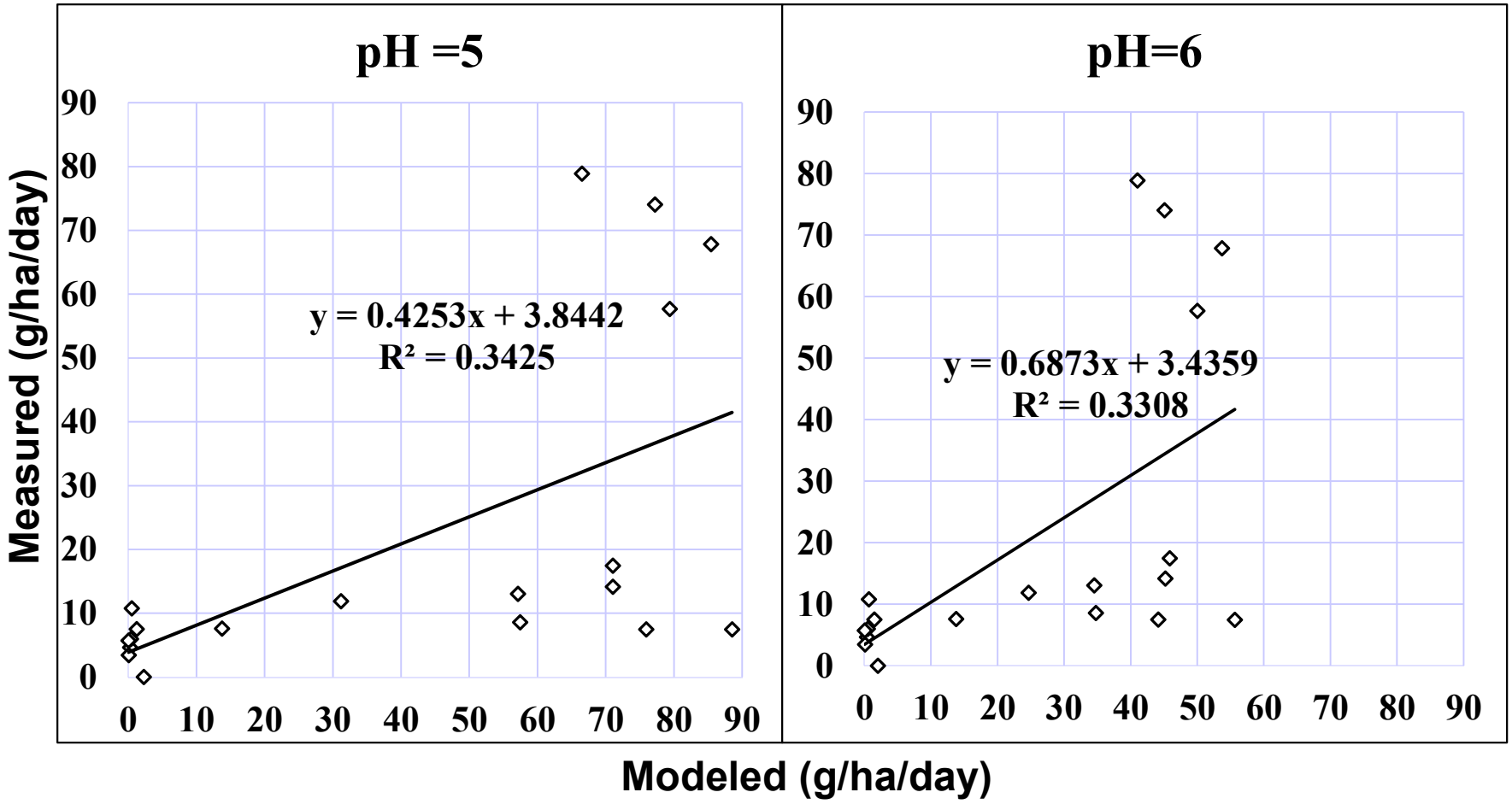


- Model initialization is using SWAT-VSA TI method for input
- Land uses: Corn, Soybean, Alfalfa, Pasture
- Weather input data 2004-2013
- Measured Carbon and Nitrate used as initial condition
- Varied soil pH as it was not measured in database
- SWAT model provided soil moisture

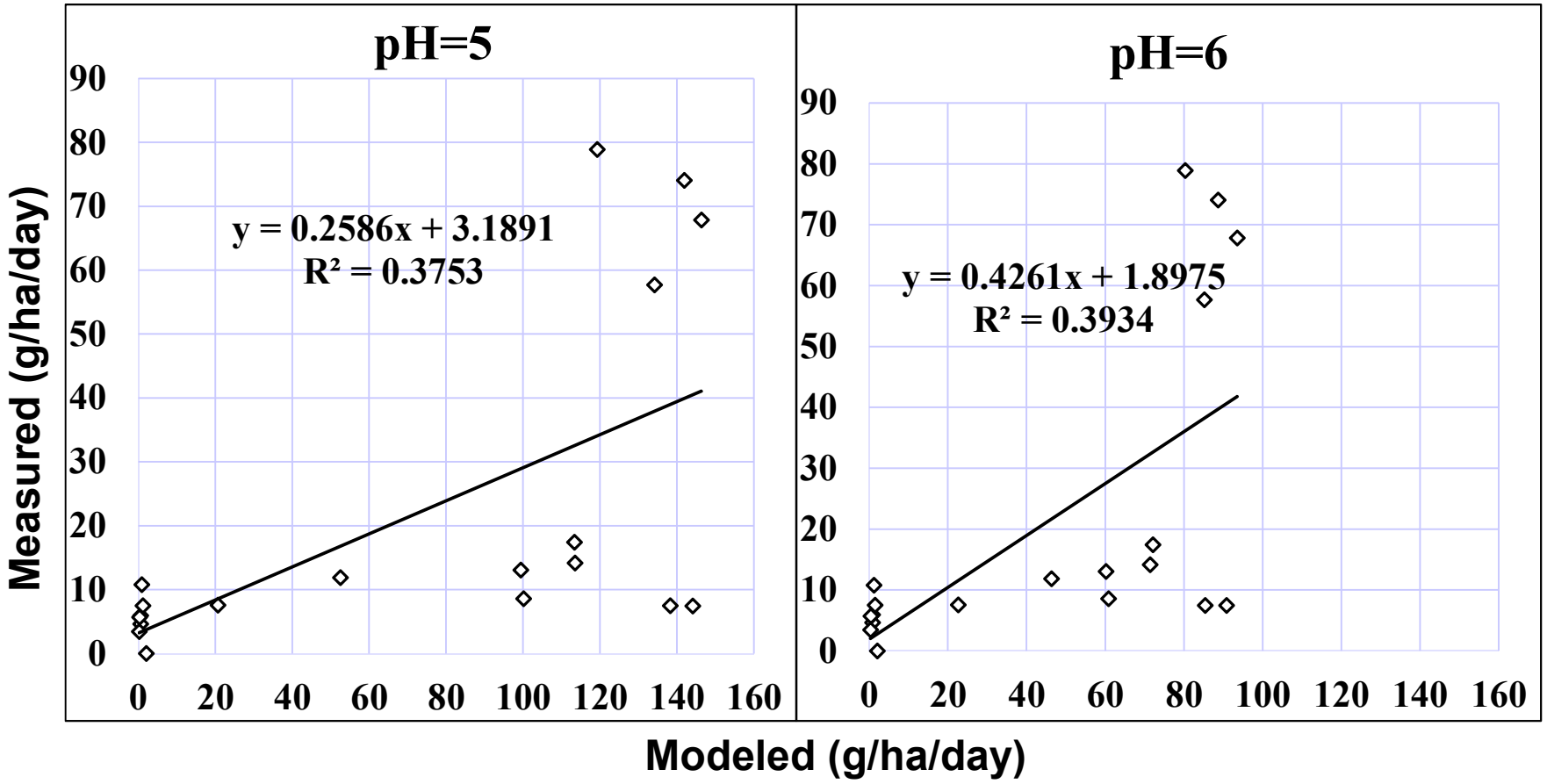
Base Model: No Calibration



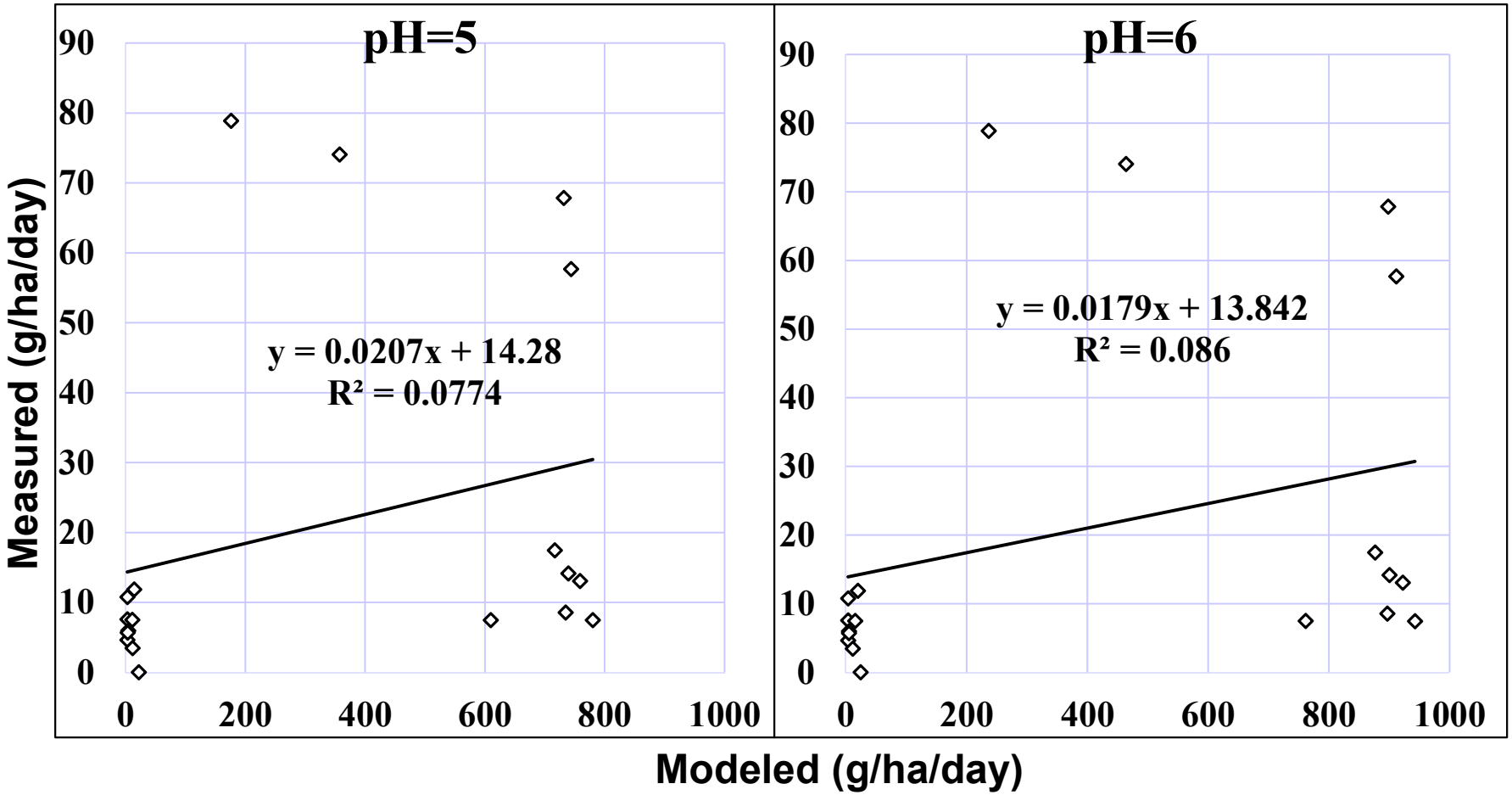
Increase in Soil Moisture:2%



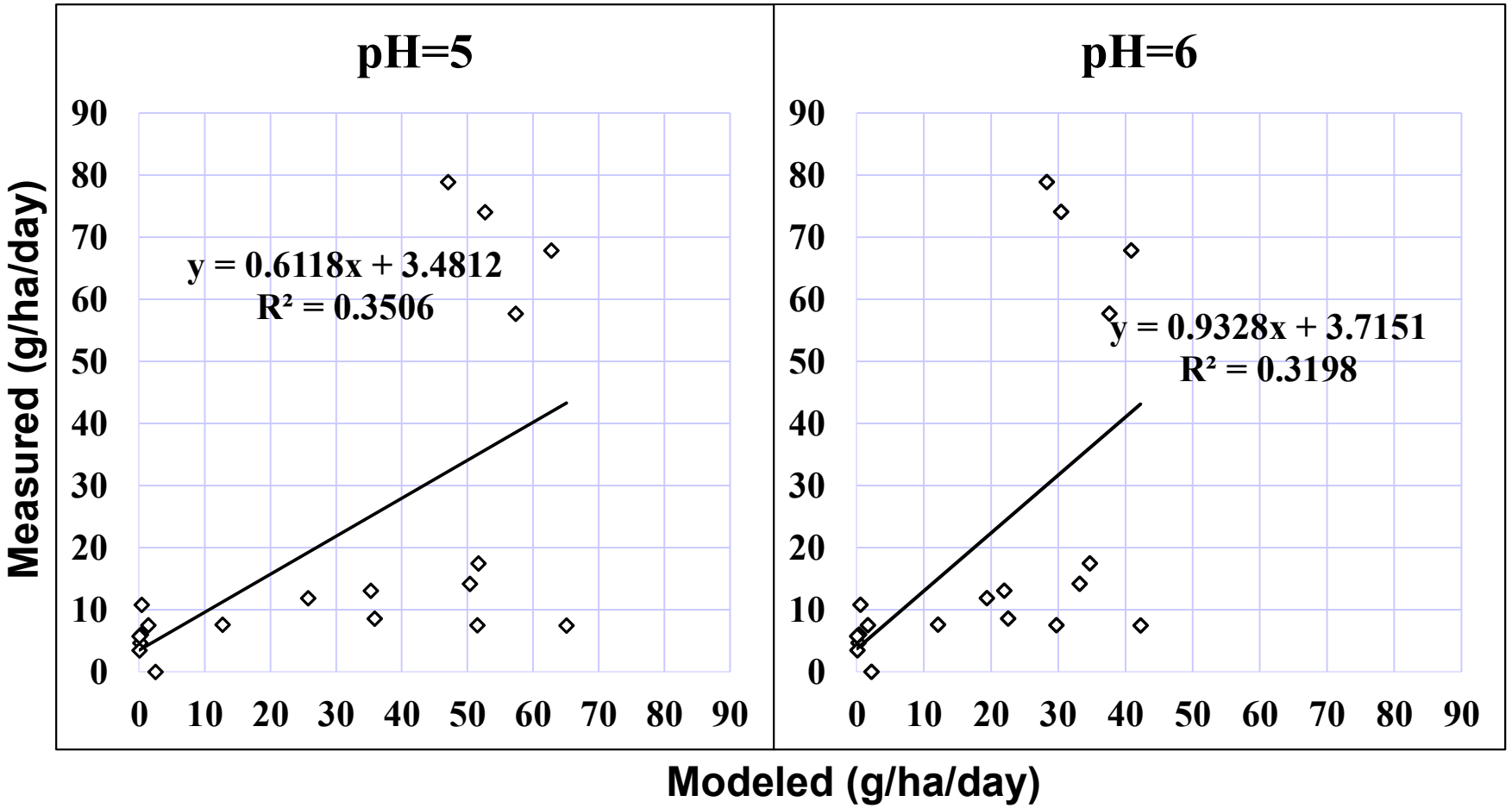
Decrease in Soil Moisture:2%



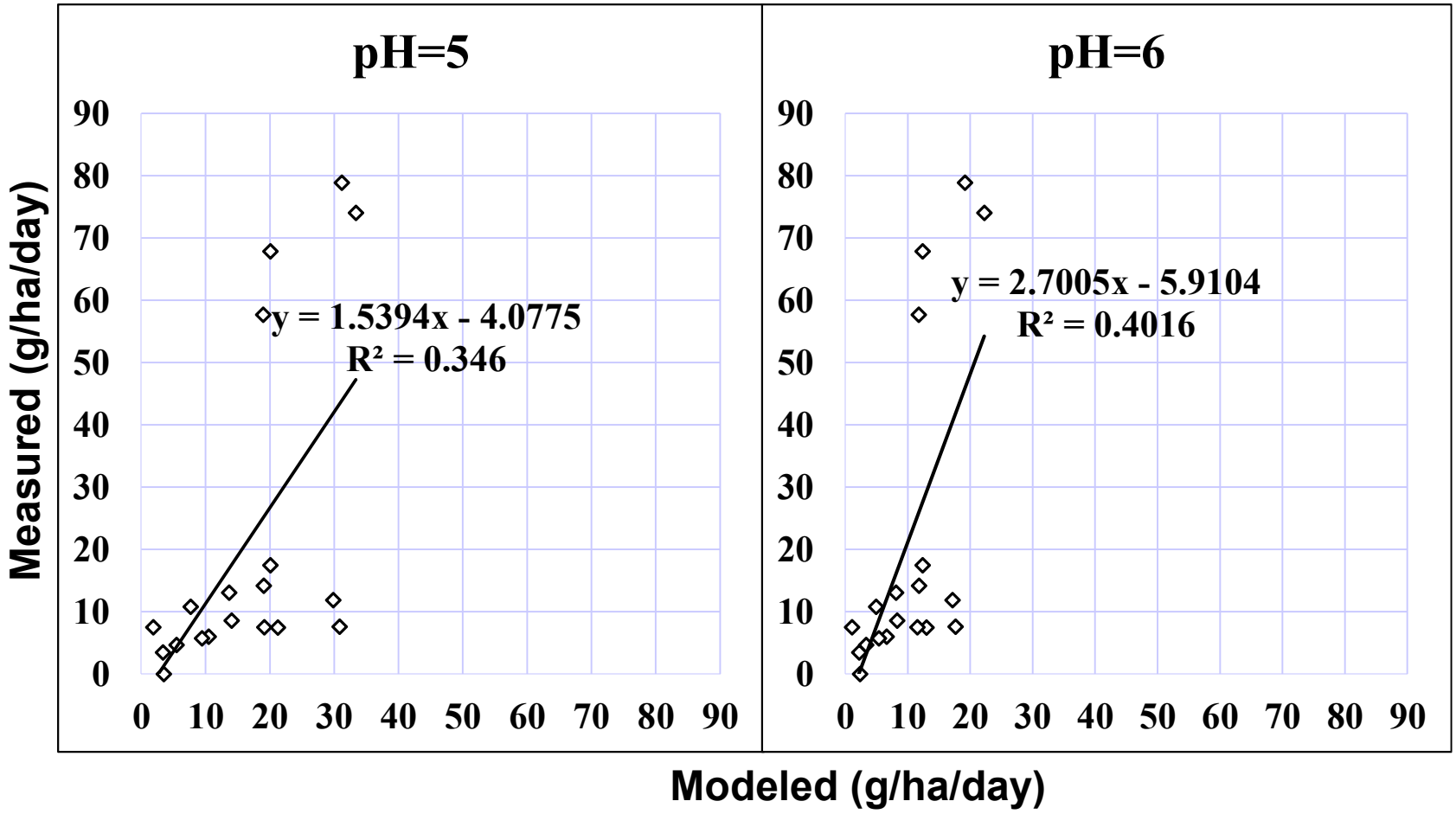
Increase in Temperature: 2%



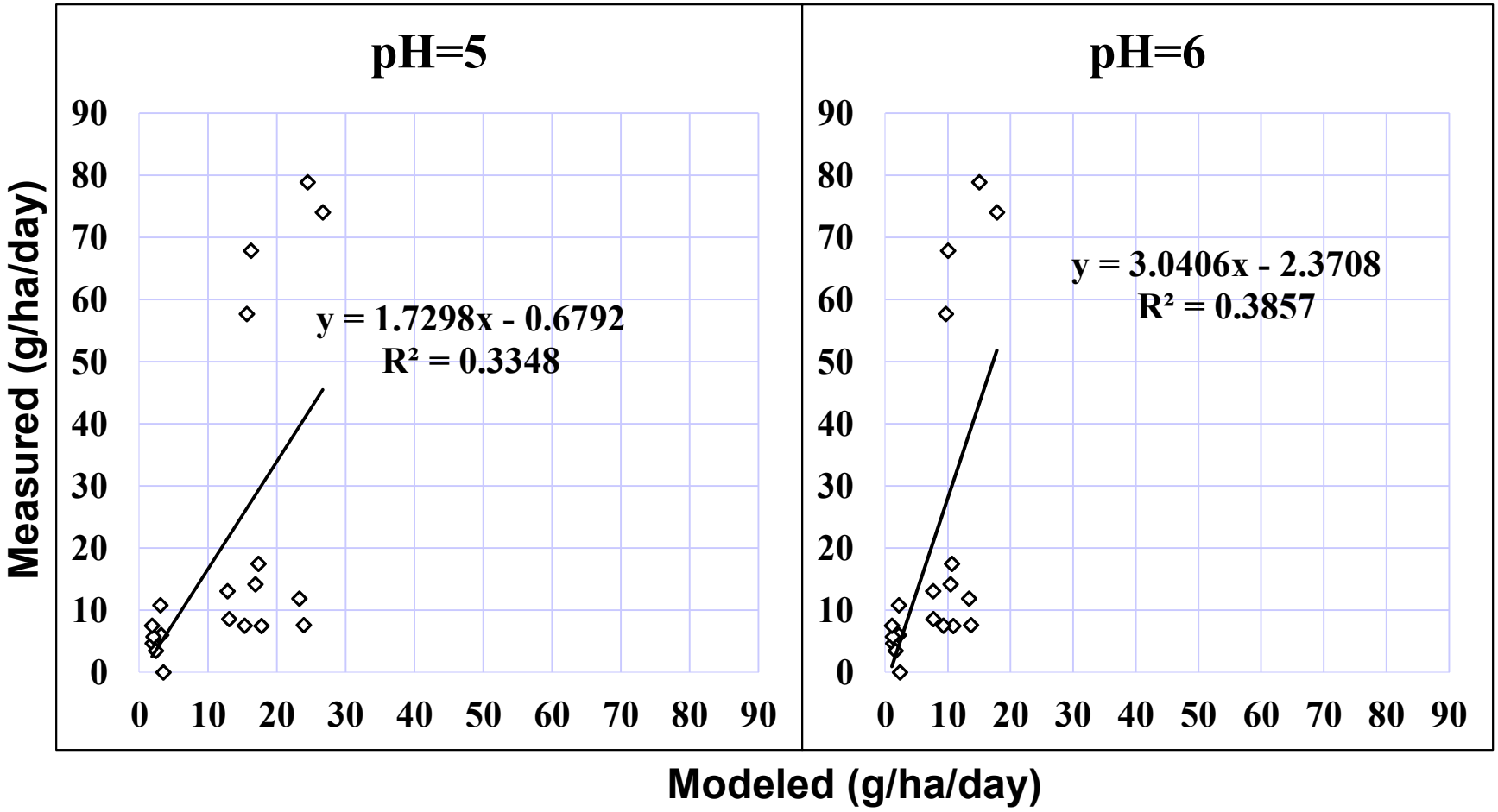
Decrease in Temperature: 2%



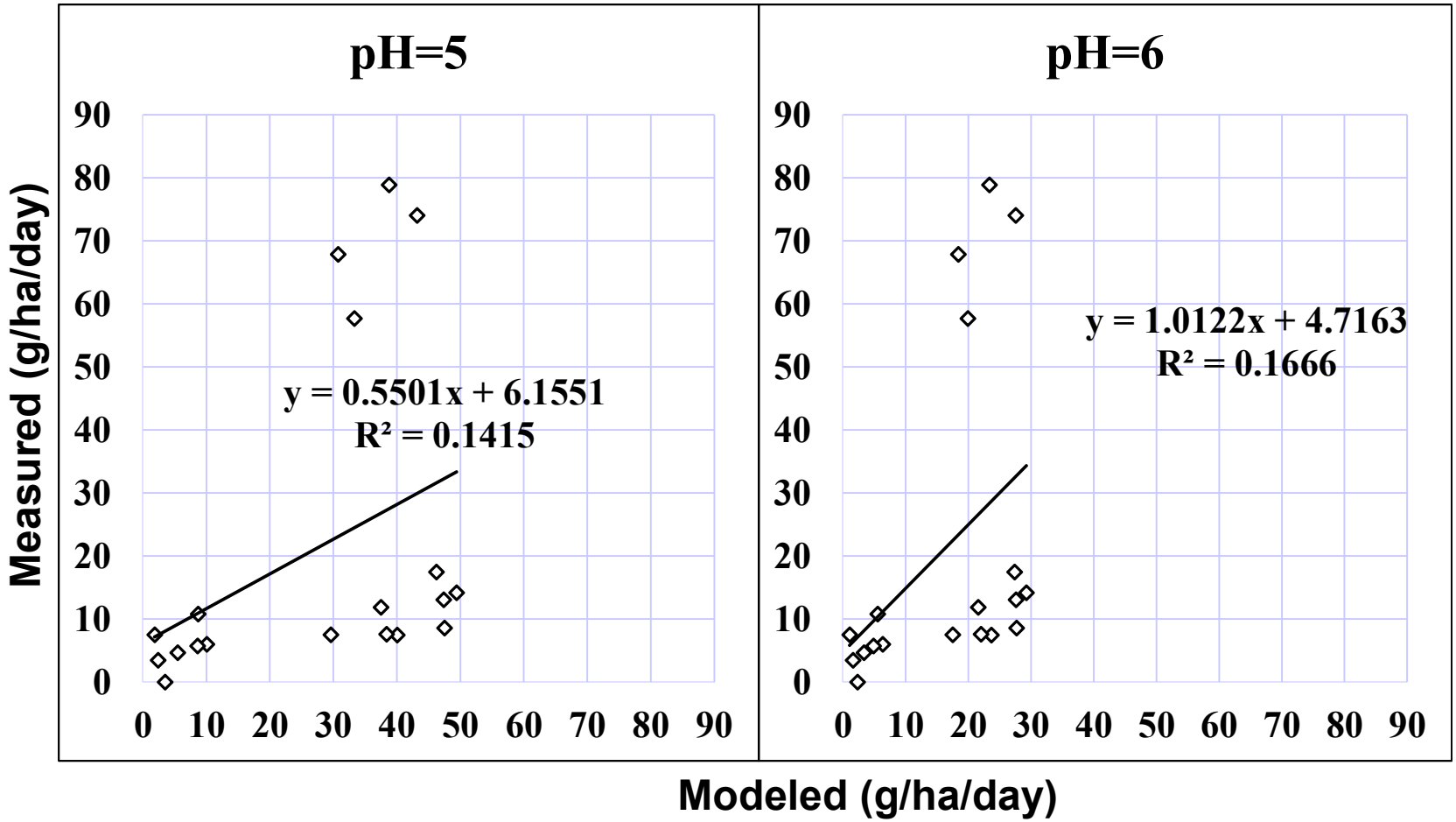
Increase in Soil Carbon: 10%



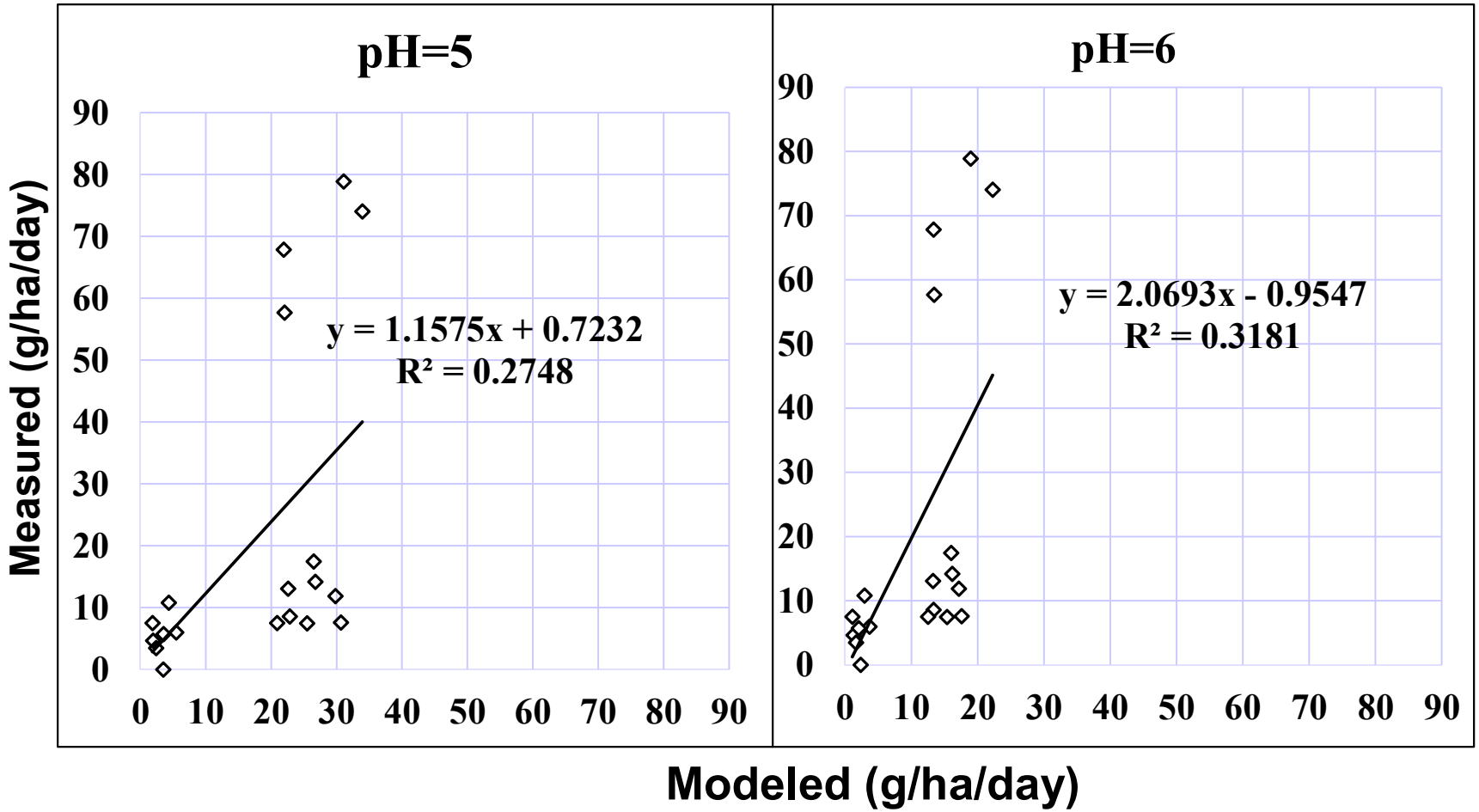
Decrease in Soil Carbon:10%



Increase in Soil Nitrate:20 mg/g



Decrease in Soil Nitrate: 20 mg/g



Results and Discussion

- Denitrification rate increased as soil pH increases but converse is true for N2O production
- Model tends to over predict N_2O at low pH and under predict at high pH
- Ratio of N_2O : N2 decreases exponentially as soil pH increases
- Soil carbon ratio is the main variable that controls N2O production
- Increase in precipitation/soil moisture increased N2O production

Suggestions

- Calibration of crop yield and nitrate to predict carbon mass in soil
- Test GHG model with time series data and include measured soil pH
- Soil pH is kept constant through time and need to change through time

Conclusion

- Model able to capture the correct directionality of N2O emissions, although some error is apparent
  - Model results suggest that N_2O emissions are particularly sensitive to pH, soil temperature, soil carbon and soil moisture levels and not as sensitive to soil N levels
- New GHG model can be used to assess the impacts of management practices such as tillage, drainage water management, nutrient management and soil amendments, in addition to the impact of climate change on N_2O emissions

Thank you and Questions?