# Quantifying golf course resource use efficiency

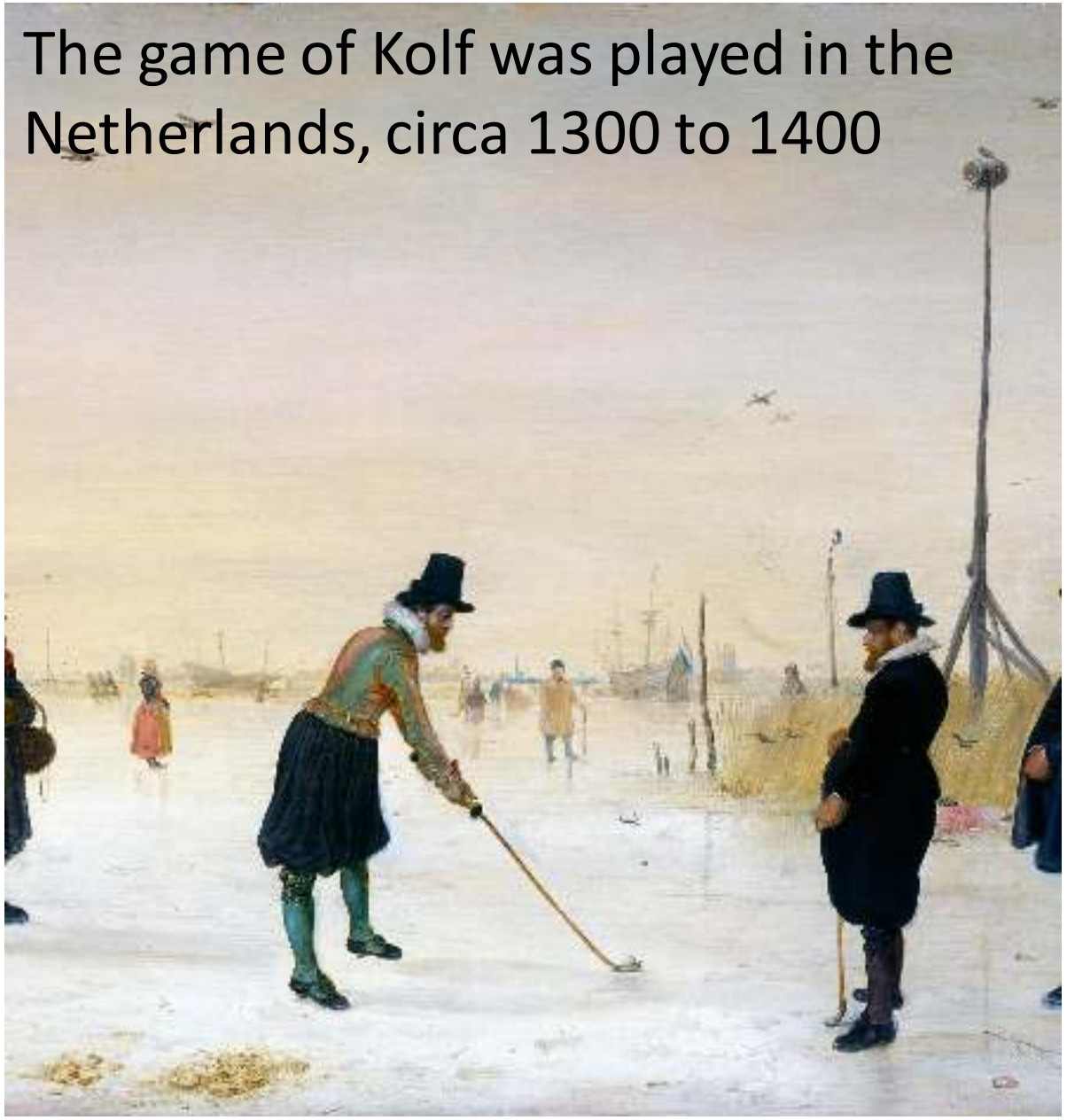
**Michael Bekken**

Photo Credit:  GEO Foundation

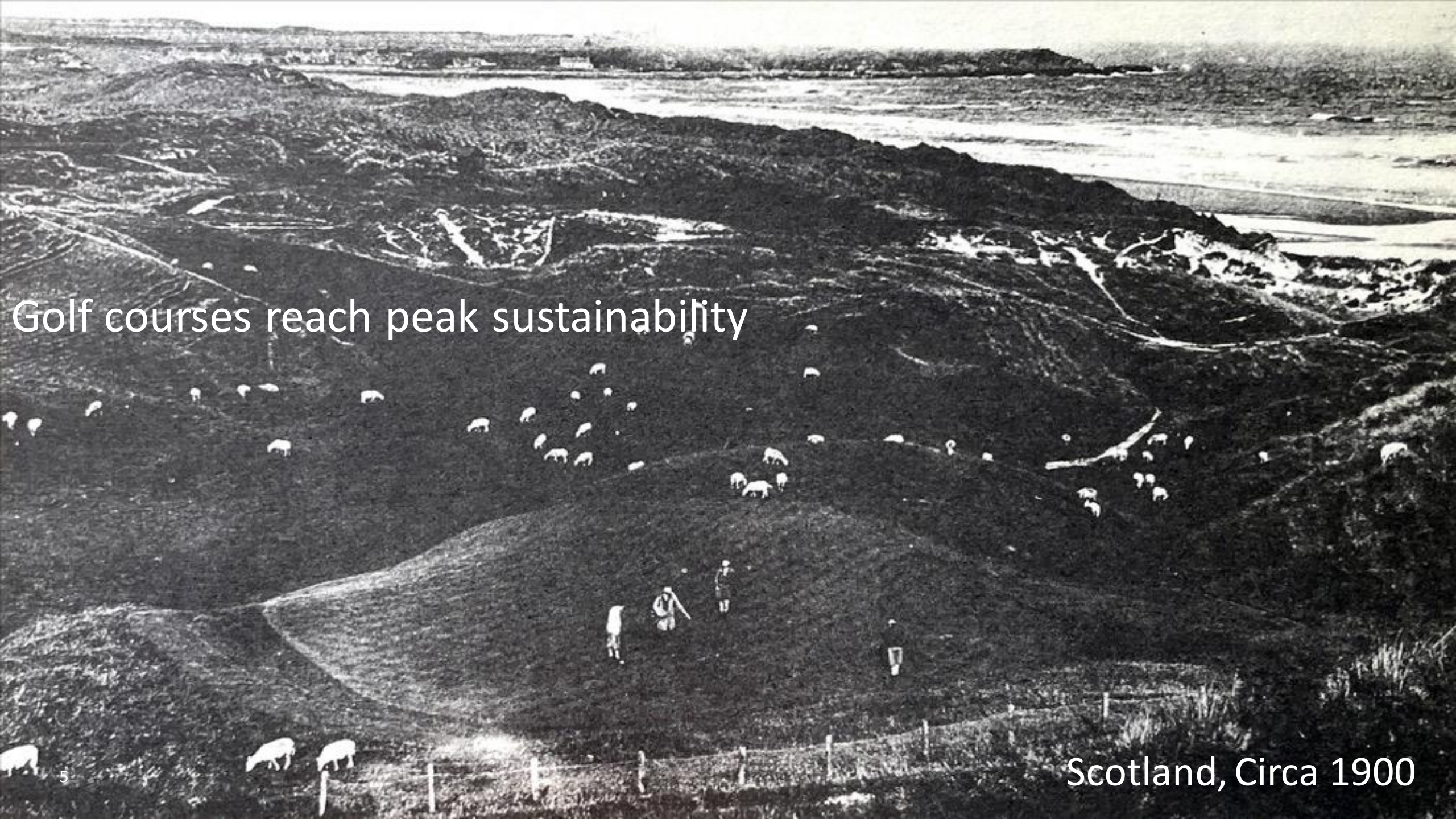
# What are the grand challenges for golf in the future?

- Resource use
  - Water
  - Pesticide
- Climate change
  - Unpredictable weather
  - Drought
- Economic sustainability
  - Cost of maintenance
  - Labor

The game of Kolf was played in the Netherlands, circa 1300 to 1400



# Mary, Queen of Scots, avid golfer (1542-1587)


Golf courses reach peak sustainability
Scotland, Circa 1900

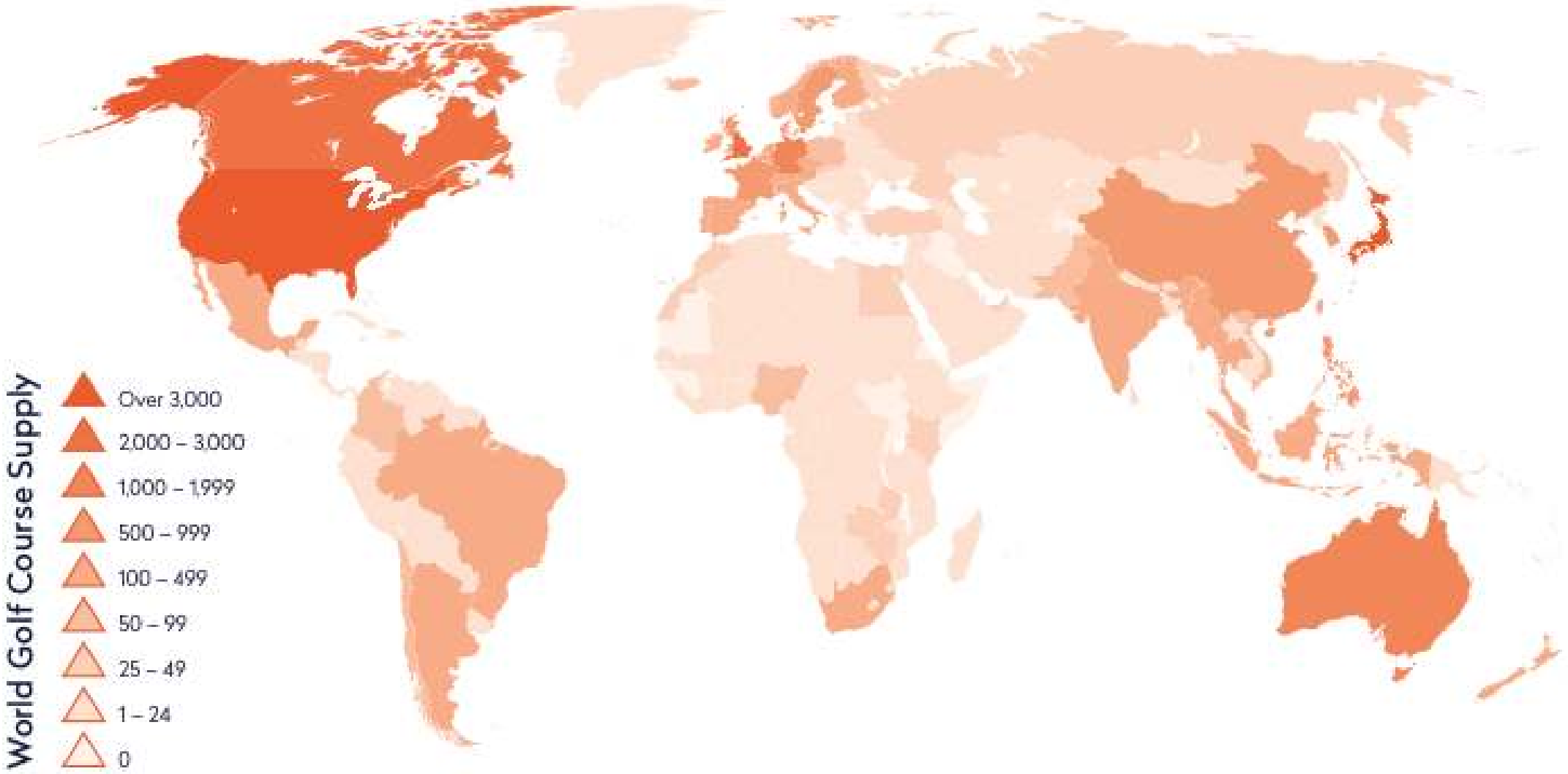
# Golf circa 1950: higher resource inputs needed for a uniform playing surface.

Golf Digest

# Golf courses are more resource intensive than their Scottish forebears

Drone Videos

# Golf is global game



# The global golf land area is slightly smaller than the area of Denmark

# As more resources are used, concern about golf's environmental impact becomes widespread

Search ▾ **The Guardian** US edition ▾

Opinion
Golf

## The case against golf

*Ben Adler*

The game bores most people senseless. so why are so many of the planet's resources dedicated to it?

## Why the Decline of Golf is Good News for the Environment

October 12, 2014 by **Elizabeth Klusinske** 9 Comments

## Could the Golf Course Green be Poisoning You and Your Child?

Golf / Sports

## Pesticides on golf course may cause cancer

**Dave Hilson**
Mar 01, 2017 • March 1, 2017 • 3 minute read

# Future of golf depends on the sports ability to use resources efficiently

Proposal for a

**REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL**

**on the sustainable use of plant protection products and amending Regulation (EU) 2021/2115**

Why the Decline of Golf is Good News for the Environment

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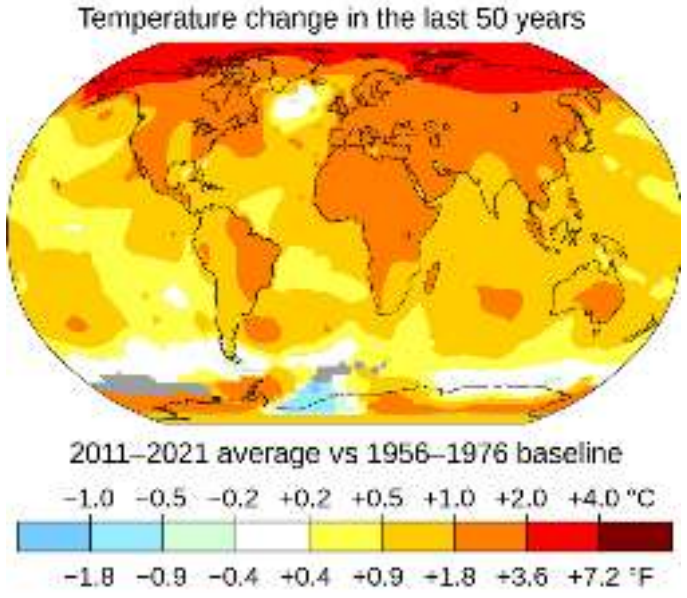
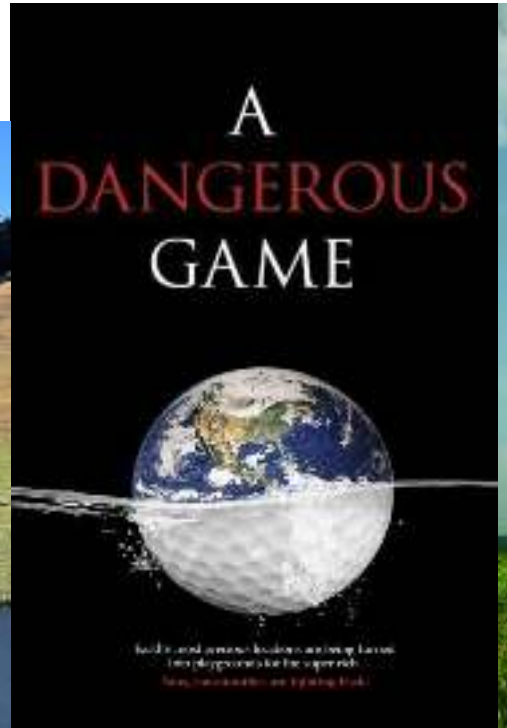


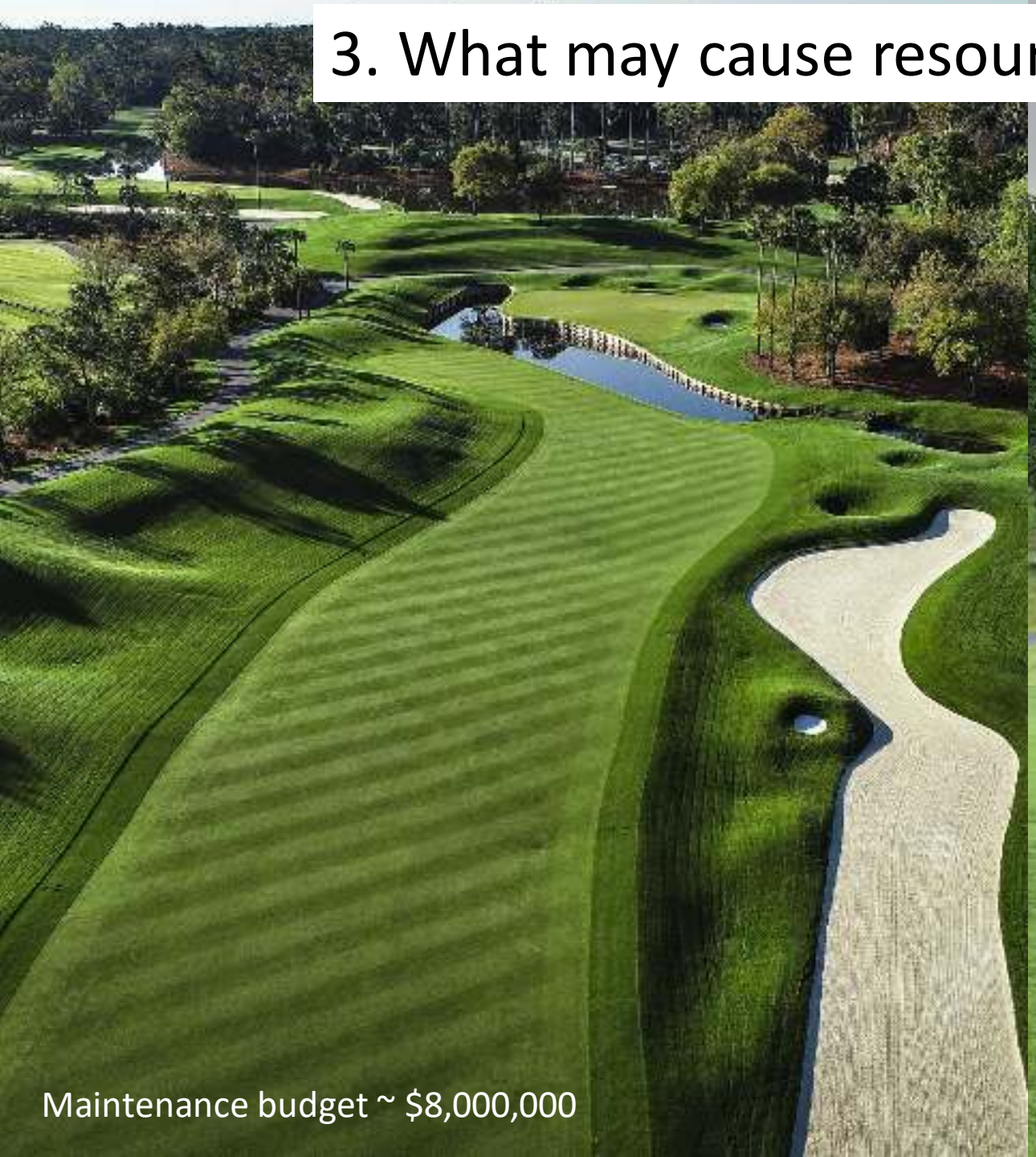

# 1. How to quantify golf course resource use (water, energy, fertilizer, pesticide)?





## 2. How to quantify the efficiency of golf course resource use?


# 3. What may cause resource efficiencies to vary?



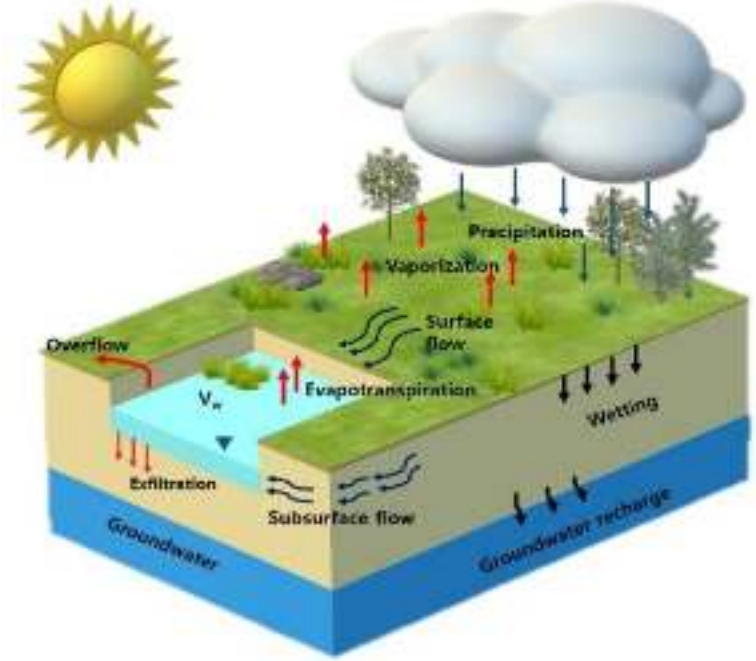
Maintenance budget ~ $8,000,000

Management practices
Economic factors
Regulatory environment

Maintenance budget ~ $500,000

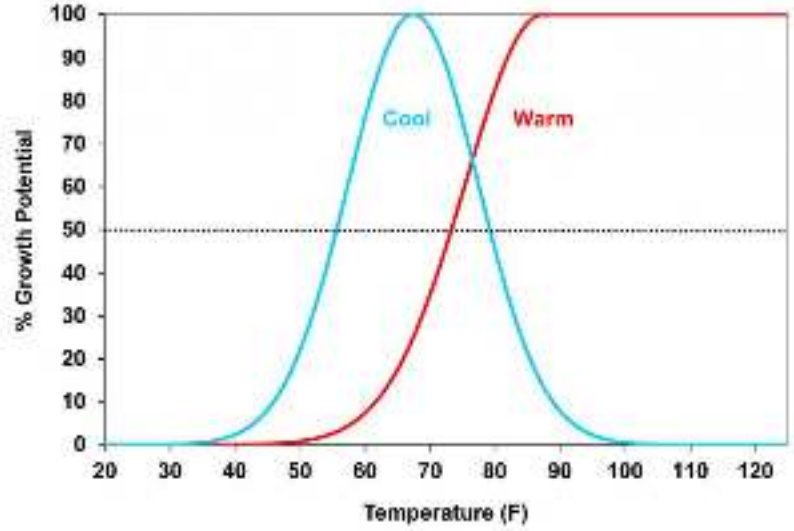
| Research Questions 1 and 2 | Water and Fertilizer (Nitrogen) | Pesticide and Energy |
|---|---|---|
| Difficulty of quantifying use? | Easy | Hard |
| How to quantify use? | • Water ($m^3$)<br>• Nitrogen (kg) | • Pesticide Risk Indicator Model<br>• Carbon footprint |
| How to define efficiency? | Ecosystem model | Growing season length calculation |
| Efficiency equation | Actual use / target use | Actual use / growing season length |

# Water Modeled by Water Balance




# Energy Modeled by Carbon LCA

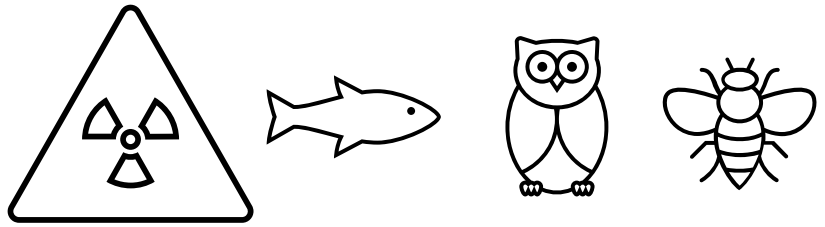

# Fertilizer (N) Modeled by Growth Eqns.




# Pesticide Modeled by Risk Eqns.

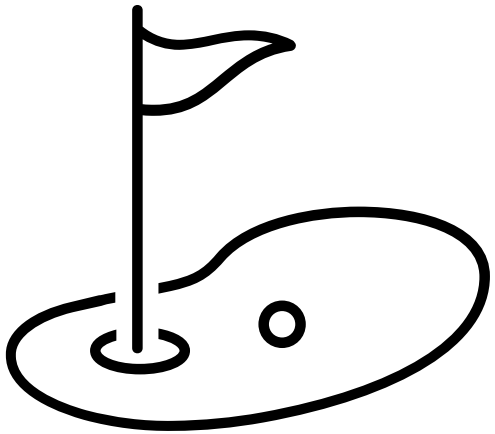
Pesticide risk to non target organisms

Pesticide risk = exposure * toxicity



# We created a survey to collect data on golf course resource use

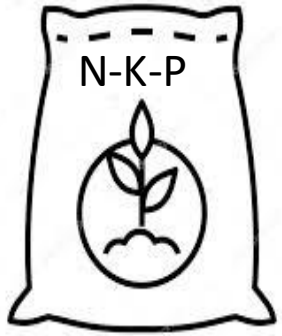
Demographics



Course type
Maintenance budget
Green Fee
Revenue

Water

Fertilizer

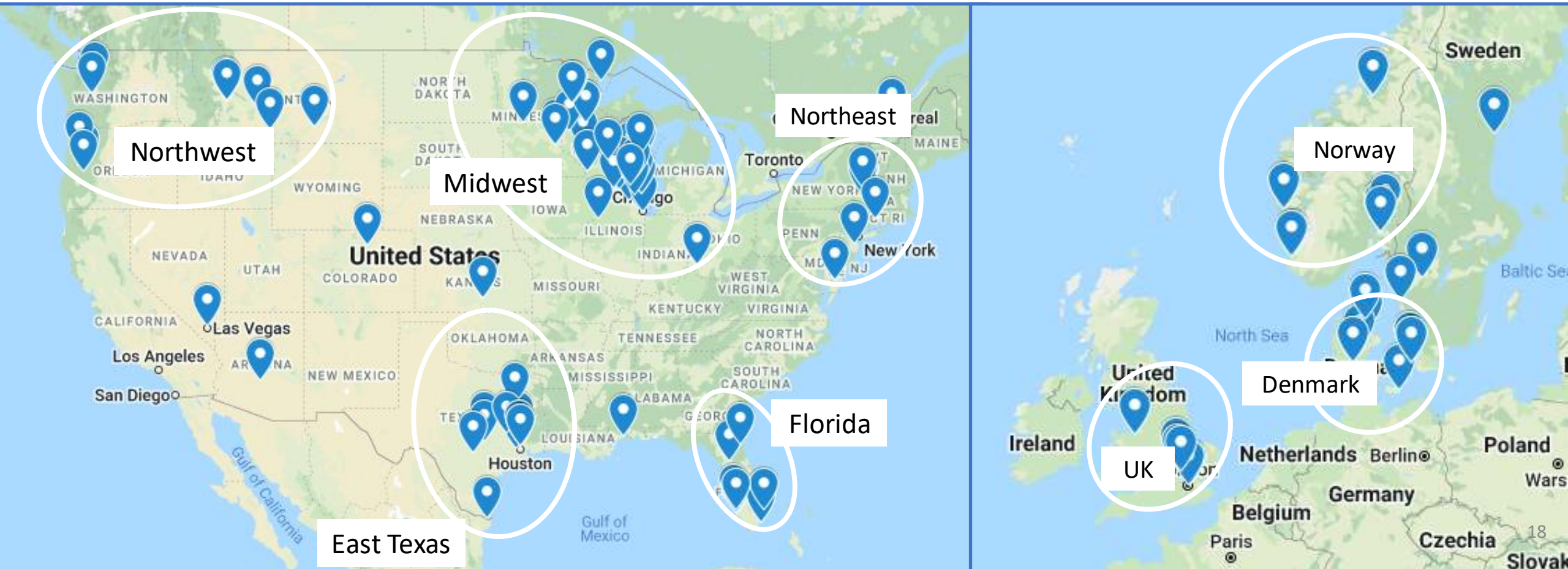



Pesticide


Energy

Resource Efficiency Best Management Practices

# Golf courses surveyed across these regions in the US (5) and Europe (3)



# Highlights of our findings for each of the four resources

Water

Fertilizer (Nitrogen)

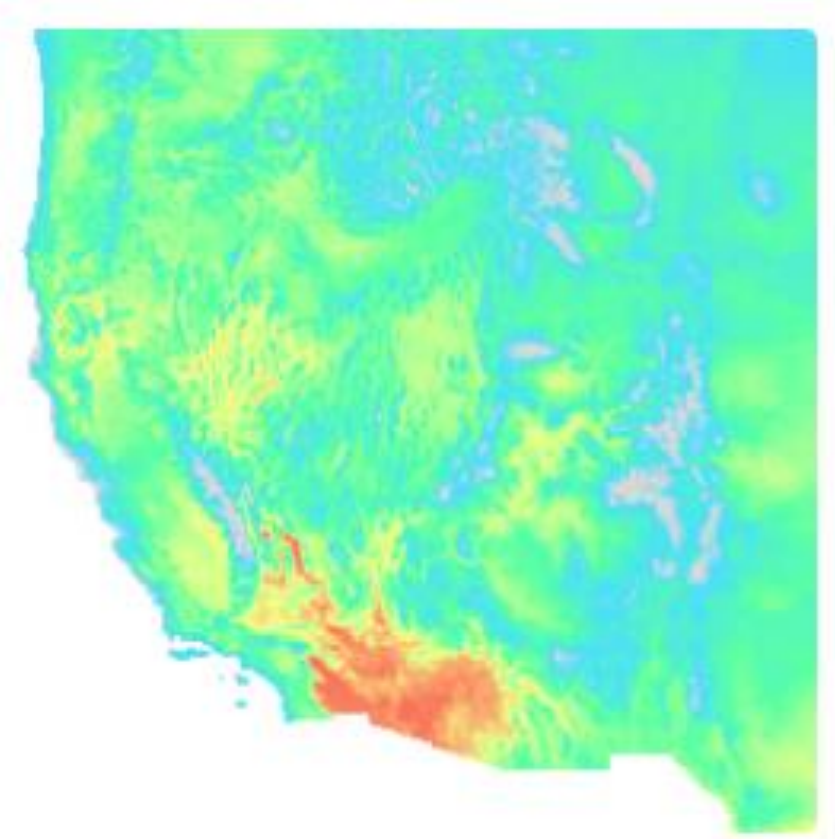
Energy

Pesticide


# Resource input 1: Water

# Water use depends on the area irrigated, climate (rainfall, evapotranspiration), soil, grass type

Climate data from GridMET



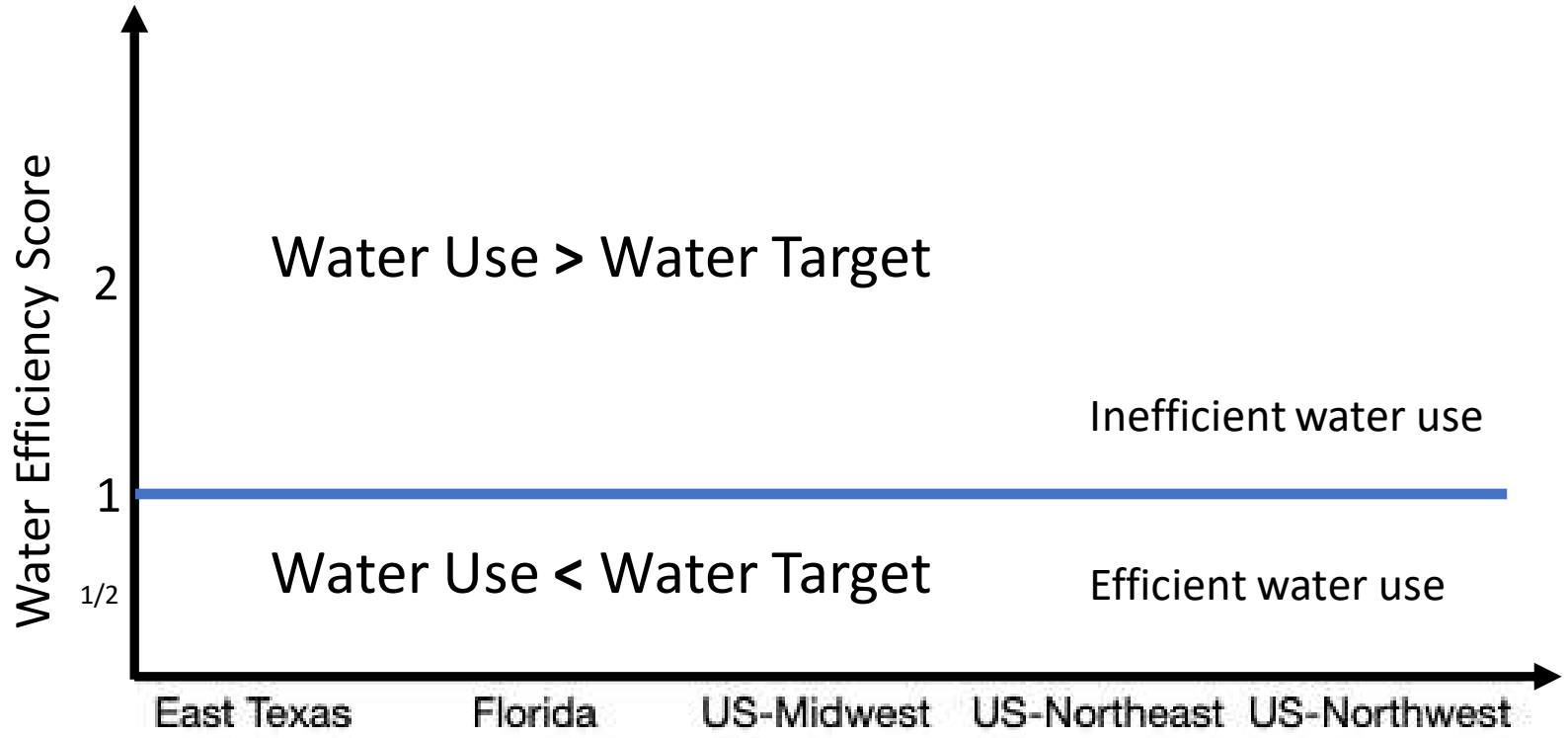
Soil data from Web Soil Survey

# We built a mathematical model that can simulate water use on golf courses and predict how much irrigation is needed based on the climate, soils, and grass type

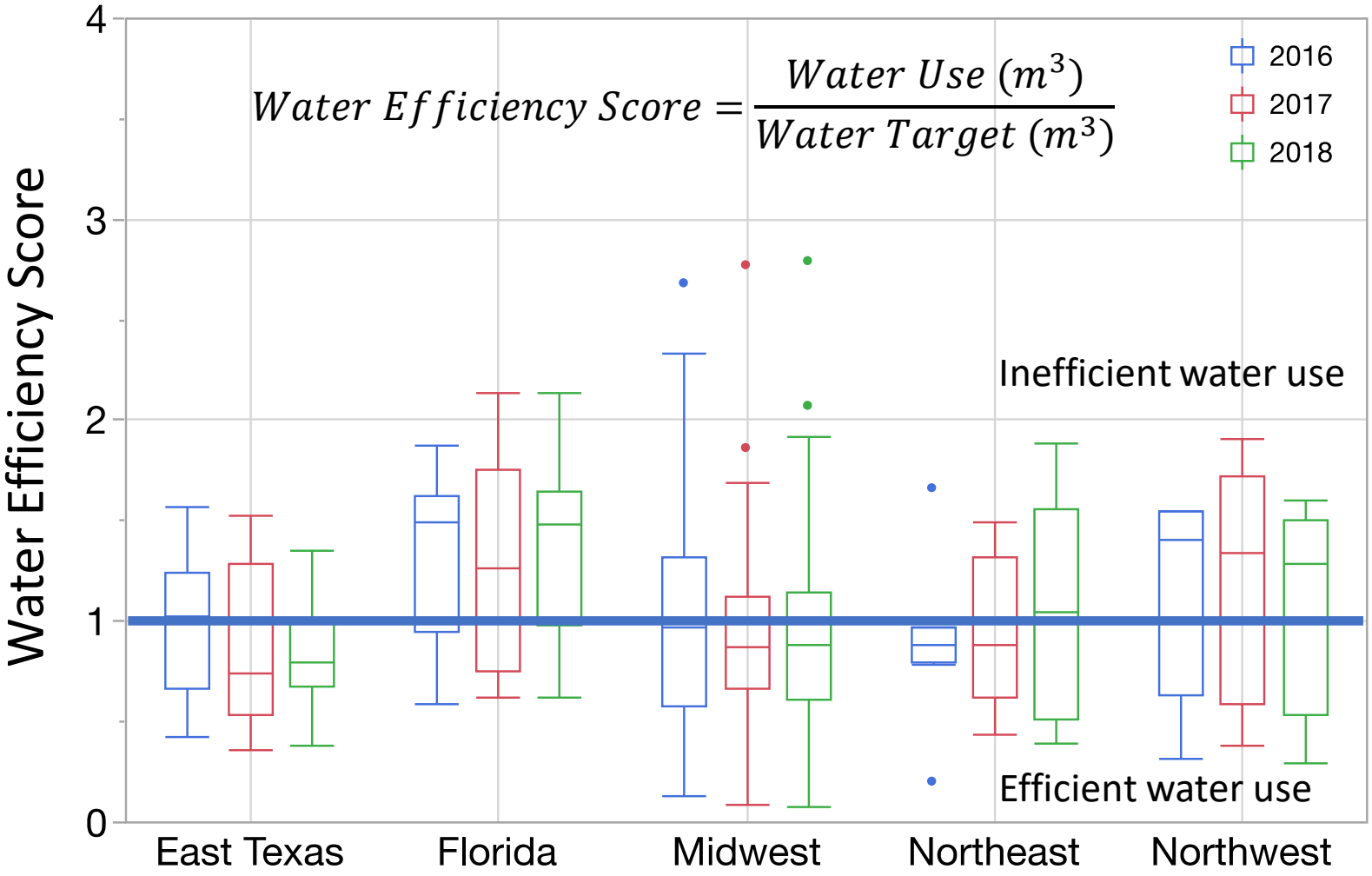
The Tipping Bucket Model

# Our goal with these models is to develop a water use efficiency score for individual golf courses

$$Water\ Use\ Efficiency\ Score = \frac{Water\ Use\ (m^3)}{Water\ Target\ (m^3)}$$

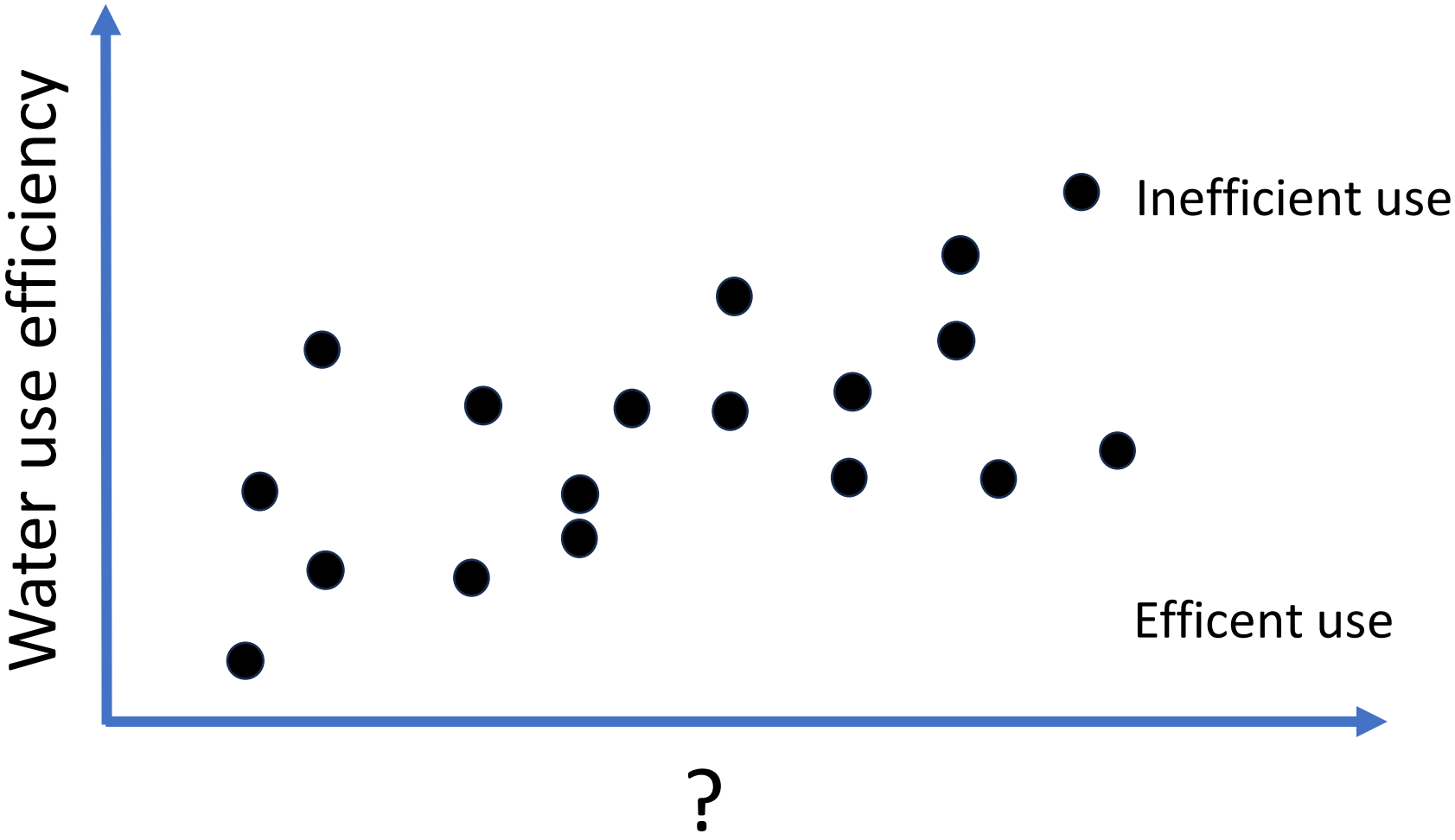


# The Tipping Bucket model predicts mean water use, but variance is high




*Finding: We can predict median use of water on golf courses in the study. Some golf courses use water much more efficiently than others.*

# What might cause some golf courses to use more water than others?

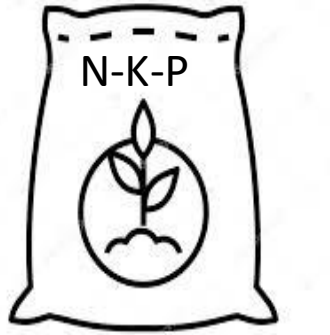



? = Maintenance budget ($r^2 = 0.11$)

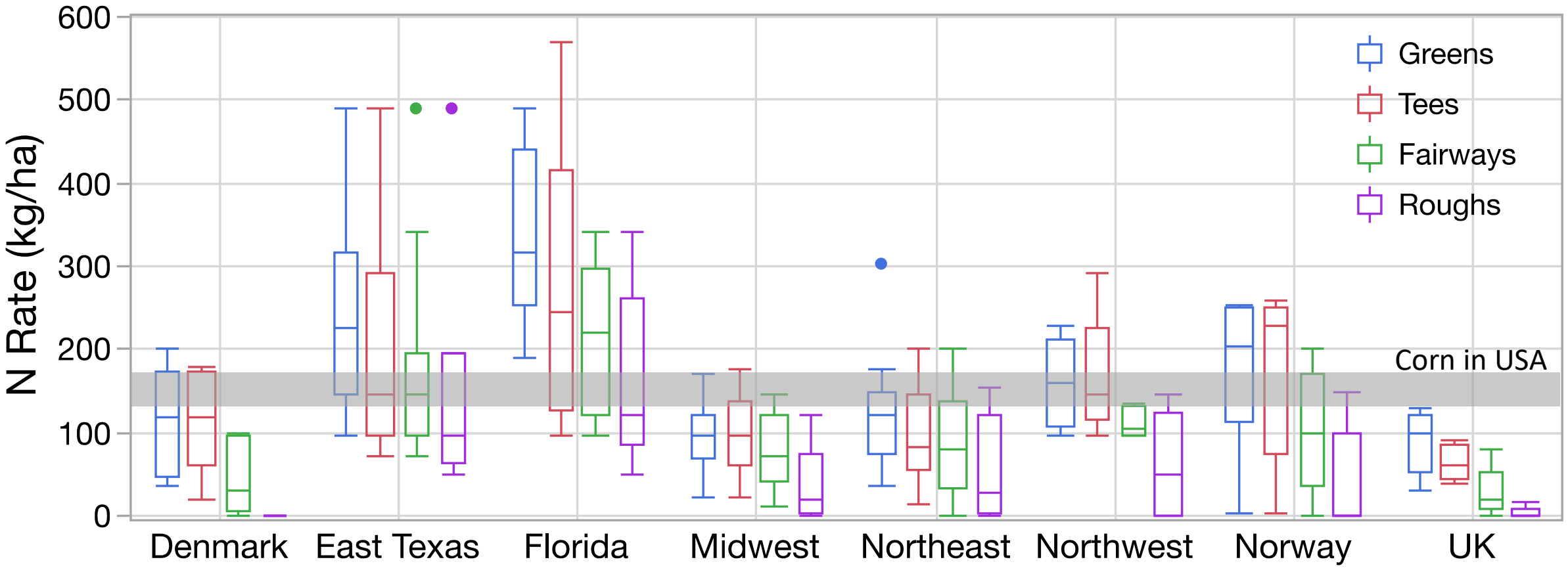
? = Irrigation budget
? = Green Fee
? = Revenue
? = Employees
? = Rounds
? = Grass type
? = Soil type

# Why is it important to use water more efficiently?

# Resource input 2: Fertilizer (Nitrogen)

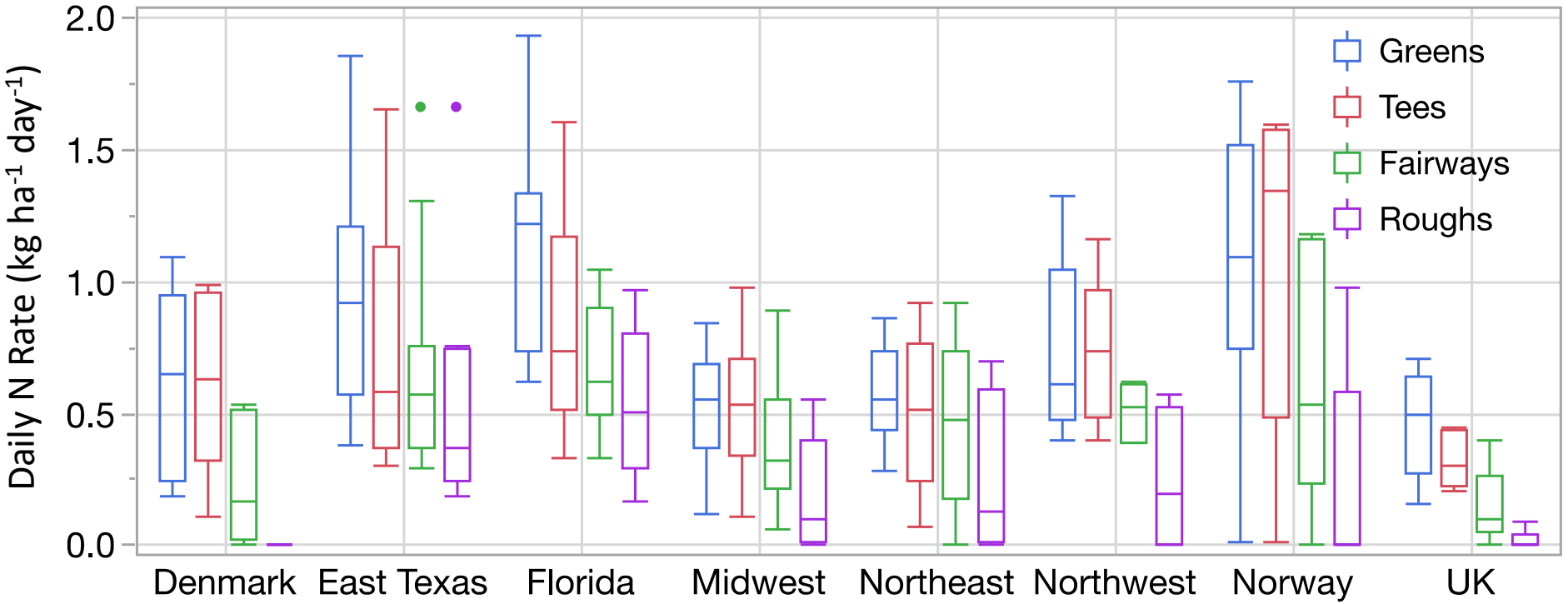


# Nitrogen rate by region and golf course component is highly variable



# Nitrogen rate (normalized by growing season length) by region and golf course component

$$Daily\ Nitrogen\ Rate\ (kg\ ha^{-1}) = \frac{Nitrogen\ Rate\ (kg\ ha^{-1})}{Growing\ Season\ Length\ (days)}$$

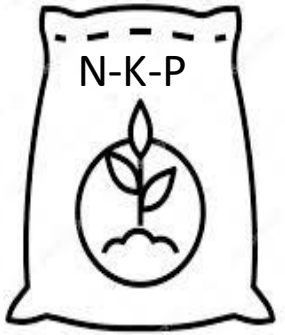



*Finding:*

N rate is highly variable even when you account for differences in growign season length.

Some golf course managers are more efficient with N than others.

# Estimating golf course N targets - GP N Requirement Model



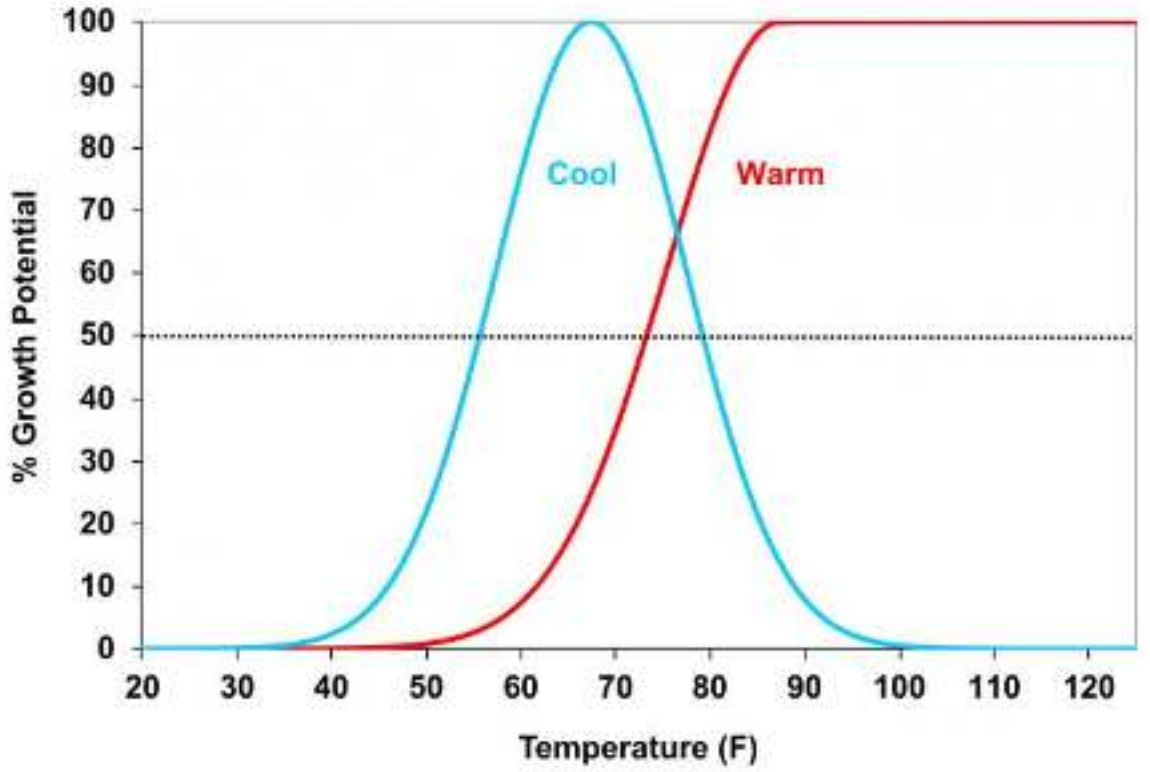

$$Nitrogen\ Efficiency\ Score\ (NES) = \frac{N\ Rate}{N\ target}$$

$$Nitrogen\ target = GP * N_{max}$$

$$GP = \frac{1}{e^{\frac{1}{2}\left(\frac{T_{obs} - T_{opt}}{var}\right)^2}}$$

$$\text{C3 } N_{max} = 35 \text{ kg N ha}^{-1}\text{mo}^{-1}$$

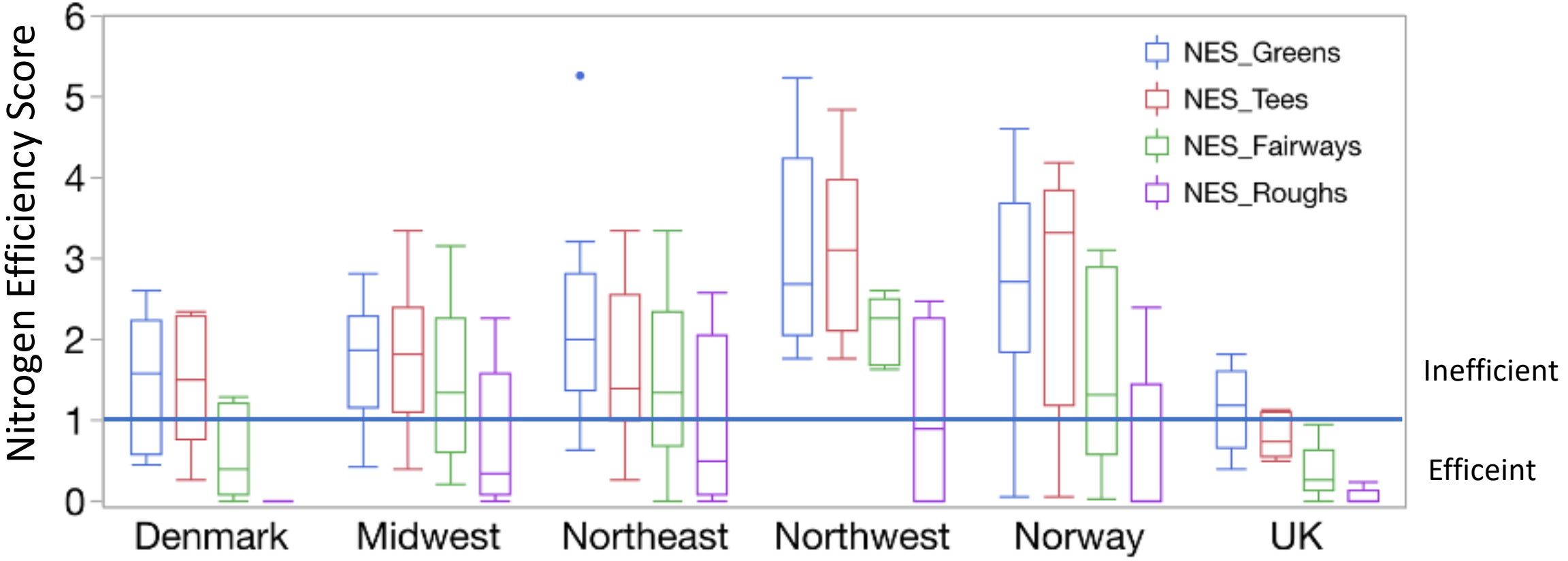
$$\text{C4 } N_{max} = 40 \text{ kg N ha}^{-1}\text{mo}^{-1}$$



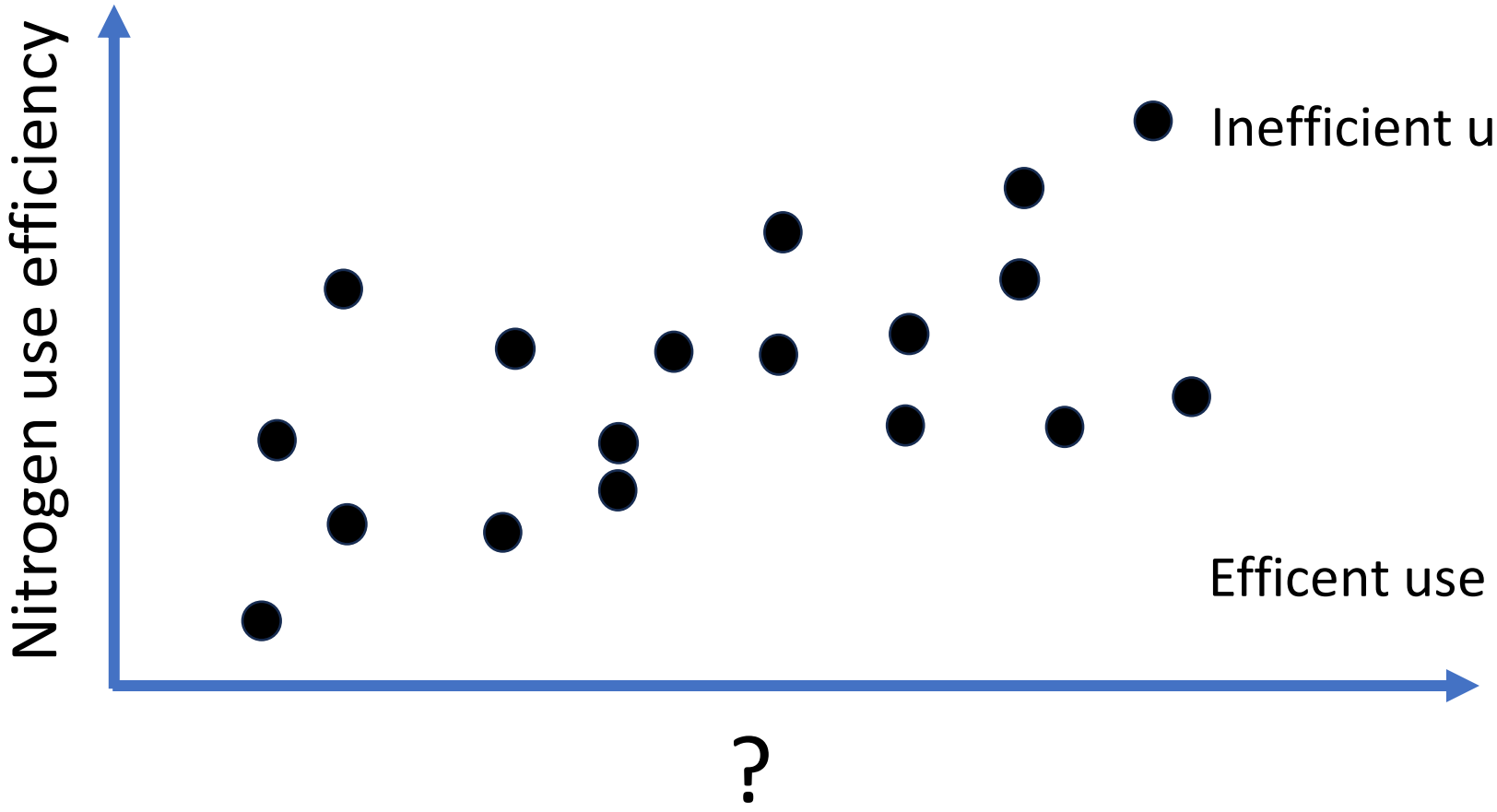

(Stowell & Gelernter 2005; Woods 2013)

# Nitrogen use efficiency is similarly variable

$$Nitrogen\ Efficiency\ Score\ (NES) = \frac{N\ rate}{N\ target}$$



# What might cause some golf courses to be more nitrogen use efficient than others?




? = Fertilizer Budget ($r^2 = 0.24$)

? = Maintenance budget ($r^2 = 0.15$)

? = Green Fee

? = Revenue

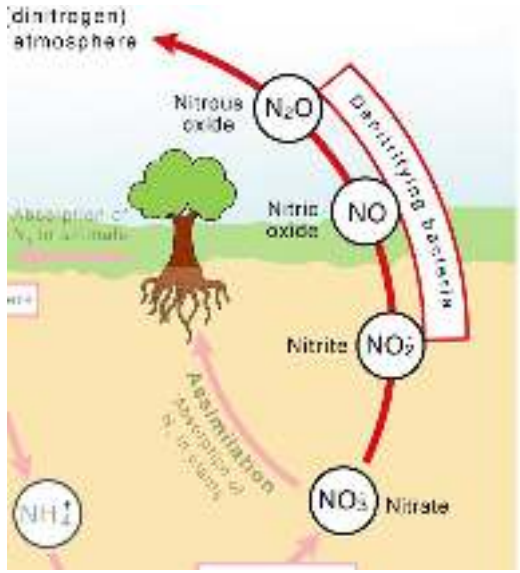
? = Employees

? = Rounds

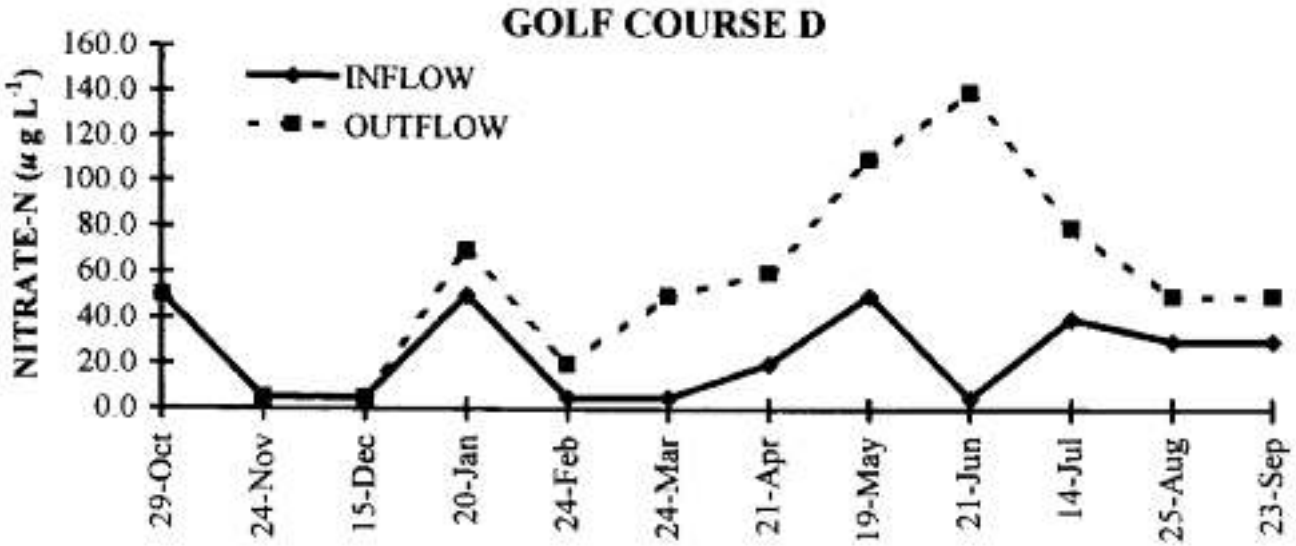
? = Grass type

? = Soil type

# Why is it important to use N efficiently?




Nitrate loss → Water quality decline



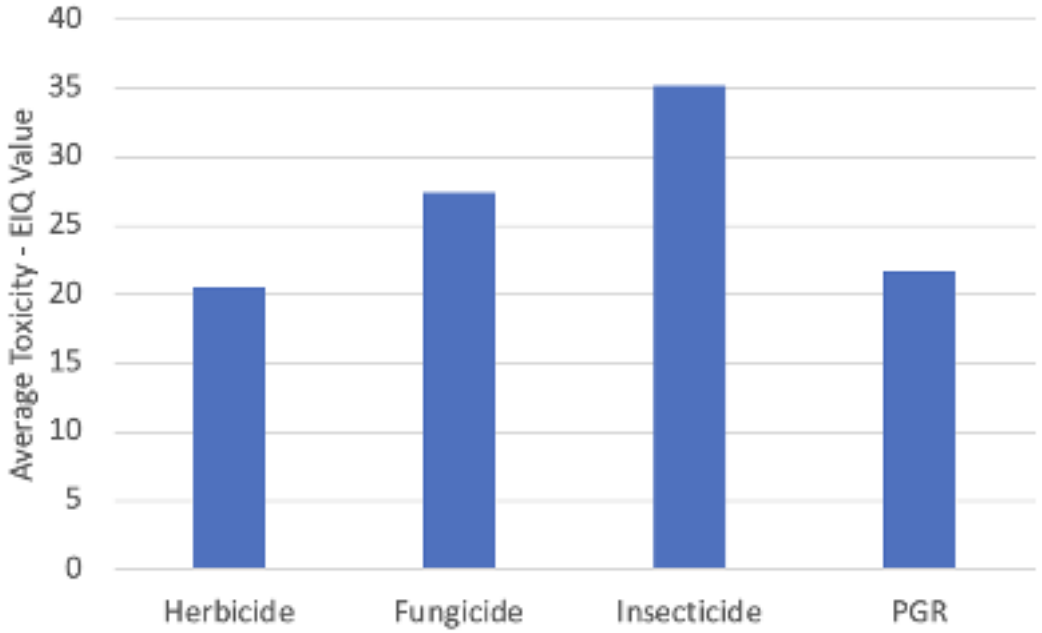

# Resource input 3: Energy use ($CO_2$ emissions)

# Resource input 4: Pesticide

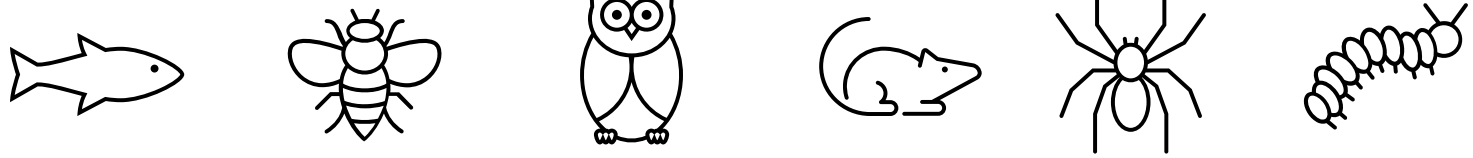
# Quantifying golf course ecological pesticide risk using the EIQ model


*Environmental Impact Quotient*

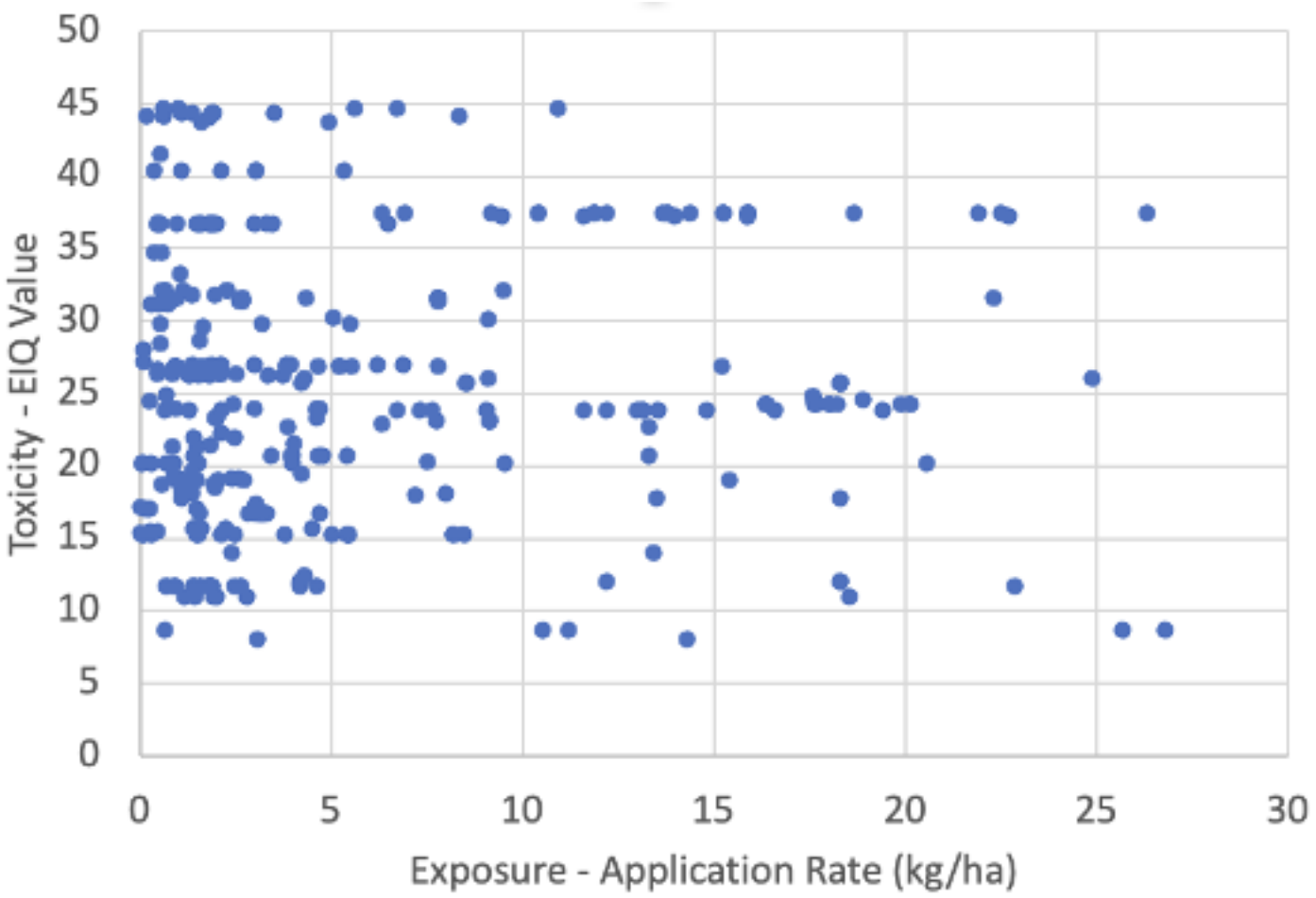
$$EIQ = ([C(DT * 5 + DT * P)] + \left[C * \left(\left(S + \frac{P}{2}\right) * SY\right) + (L)\right] + [F * R + (D\left(S + \frac{P}{2}\right) * 3 + (Z * P * 3) + (B * P * 3) + (B * P * 5)])/3$$



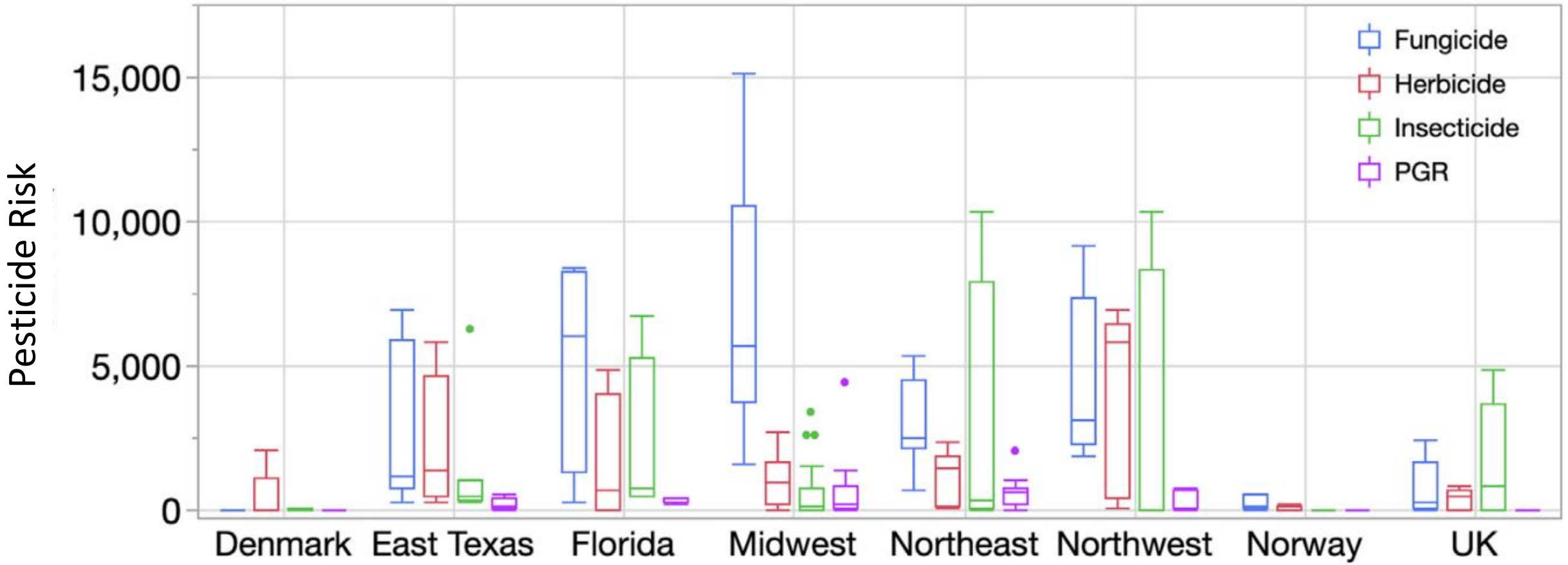

Risk with respect to:



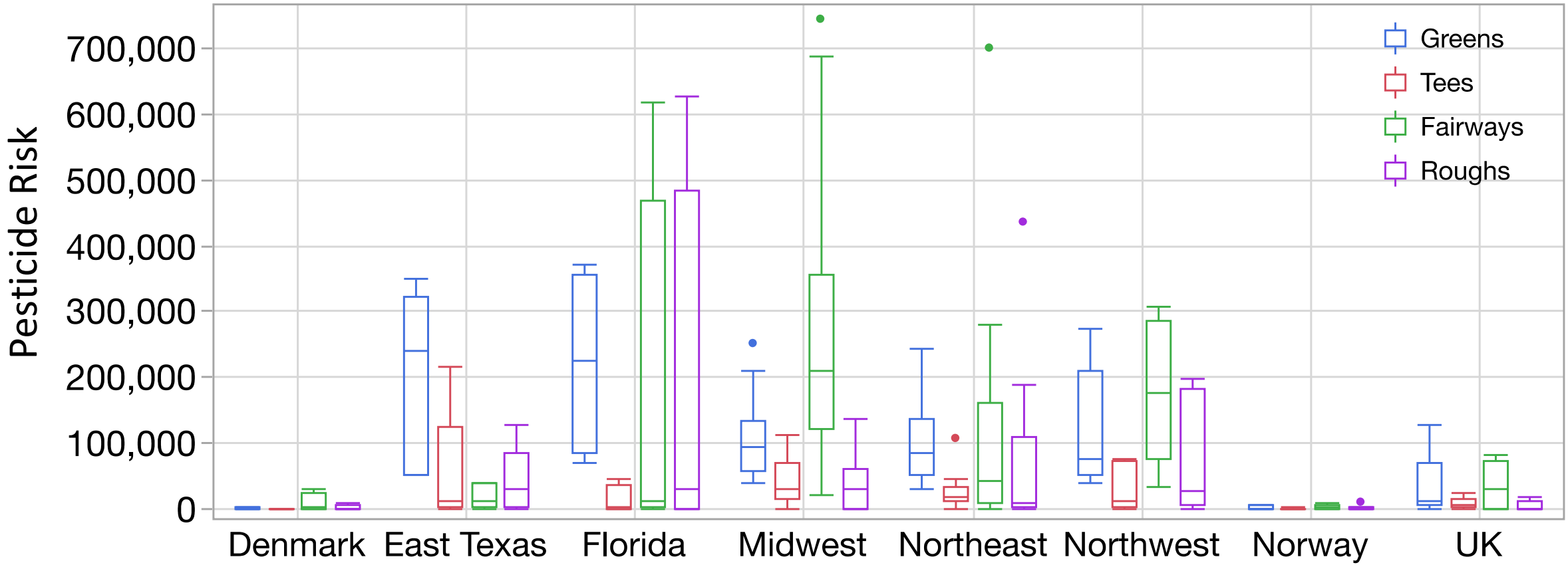
# Some pesticides have higher pesticide risk than others – risk is composed of both toxocity and explosure



# Pesticide risk by pesticide type – fungicides and herbicides have the highest risk in most regions

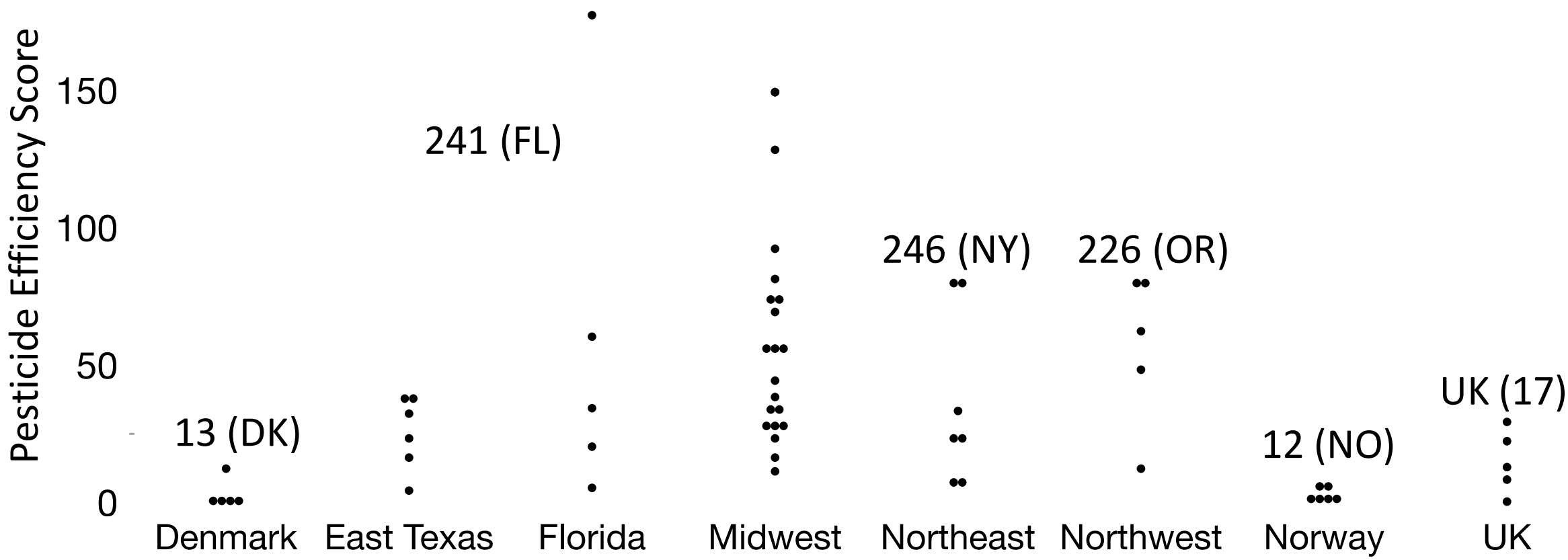


# Pesticide risk by golf course components – depends on the region – greens or fairways have the highest risk

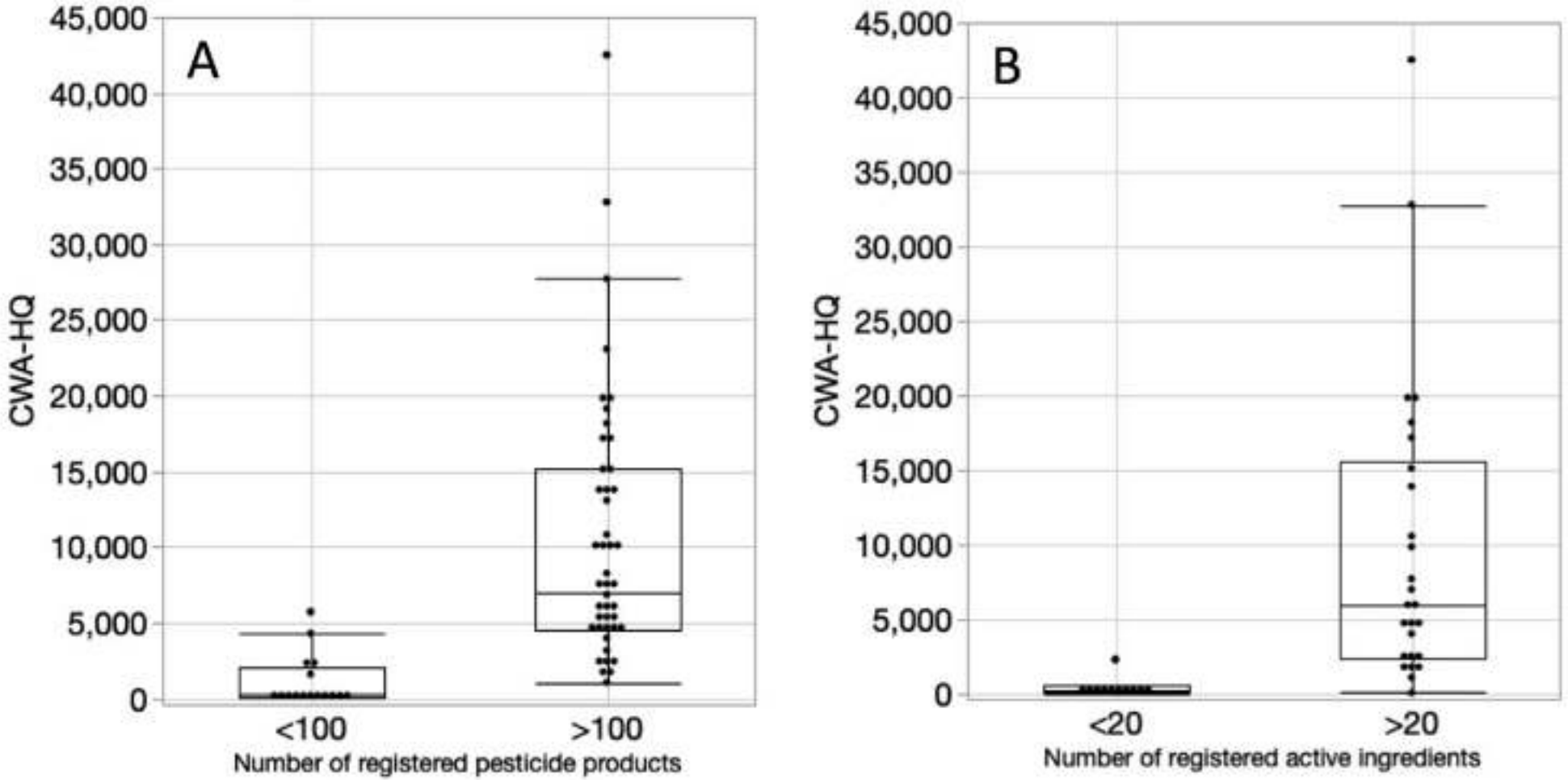


# Regulatory environment seems to greatly influence pesticide efficiency score

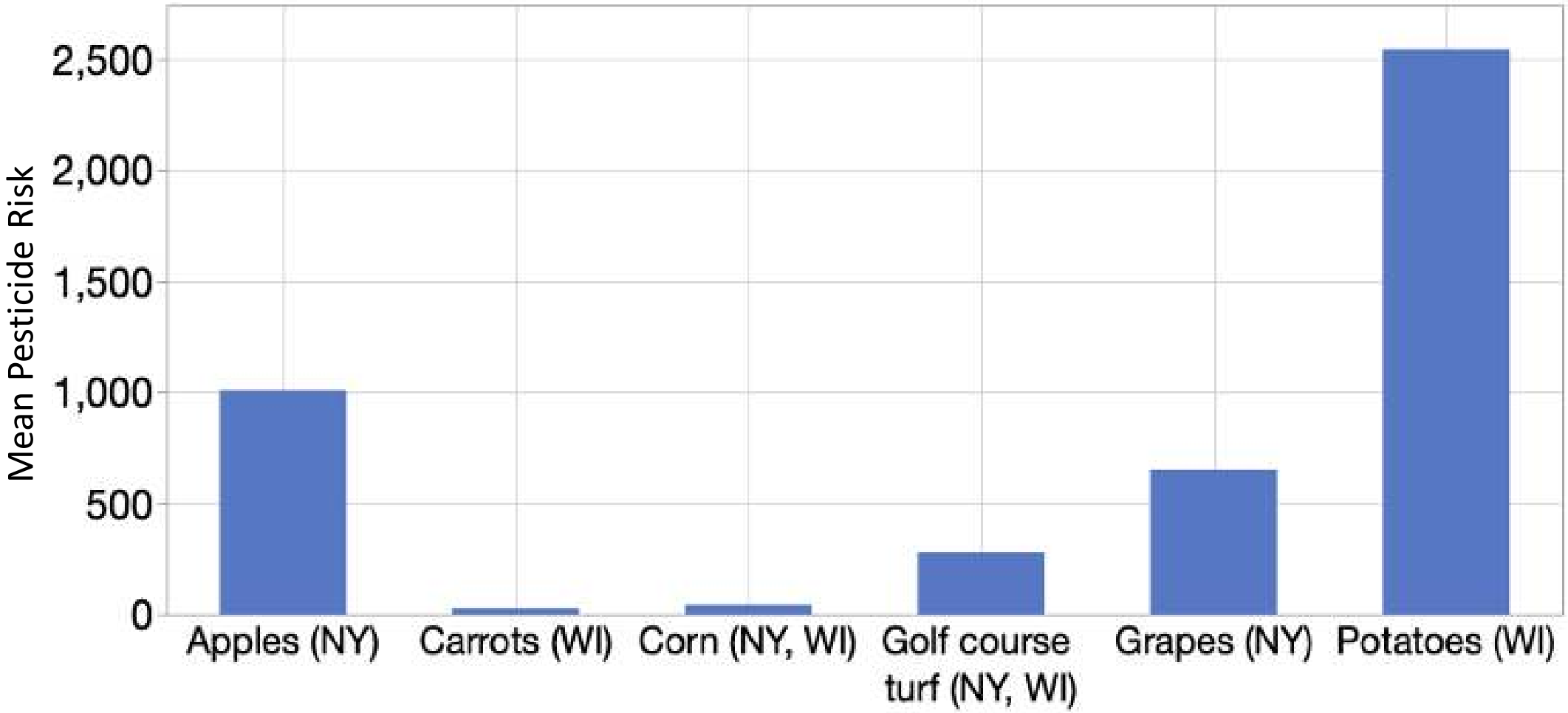

$$Pesticide\ Efficiency\ Score\ (PES) = \frac{Pesticide\ Risk}{Growing\ season\ length}$$



# What might cause some golf courses to use more pesticide than others?



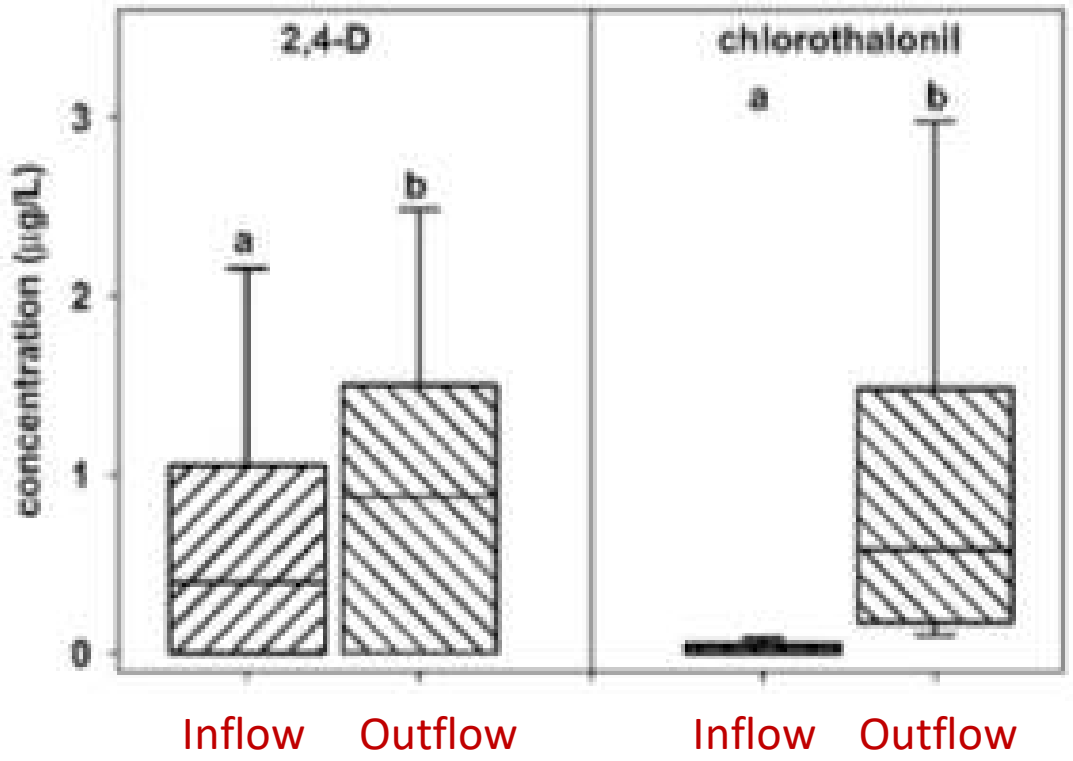
# Comparing pesticide risk on WI and NY golf courses to agriculture in both states




*Finding: Pesticide risk on golf courses is lower than for grapes, potatoes and apples, but higher than corn and carrots.*

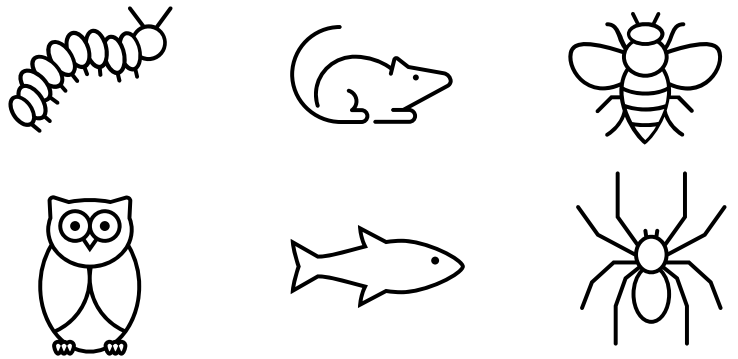
# Why is it important to use fewer pesticides?

Pesticide Loss → Water quality decline

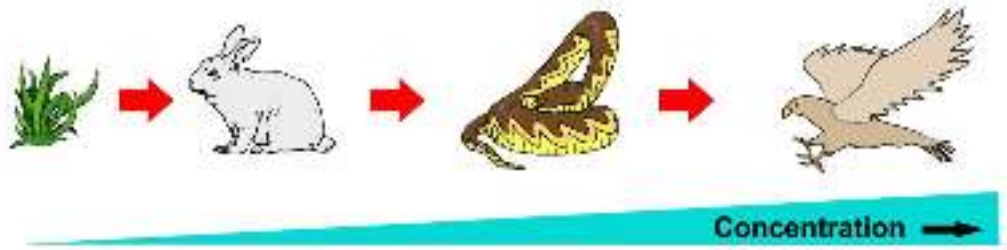



King and Balogh, 2010

Non-target effects

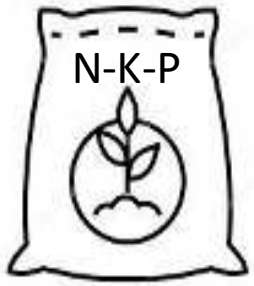


Bioaccumulation

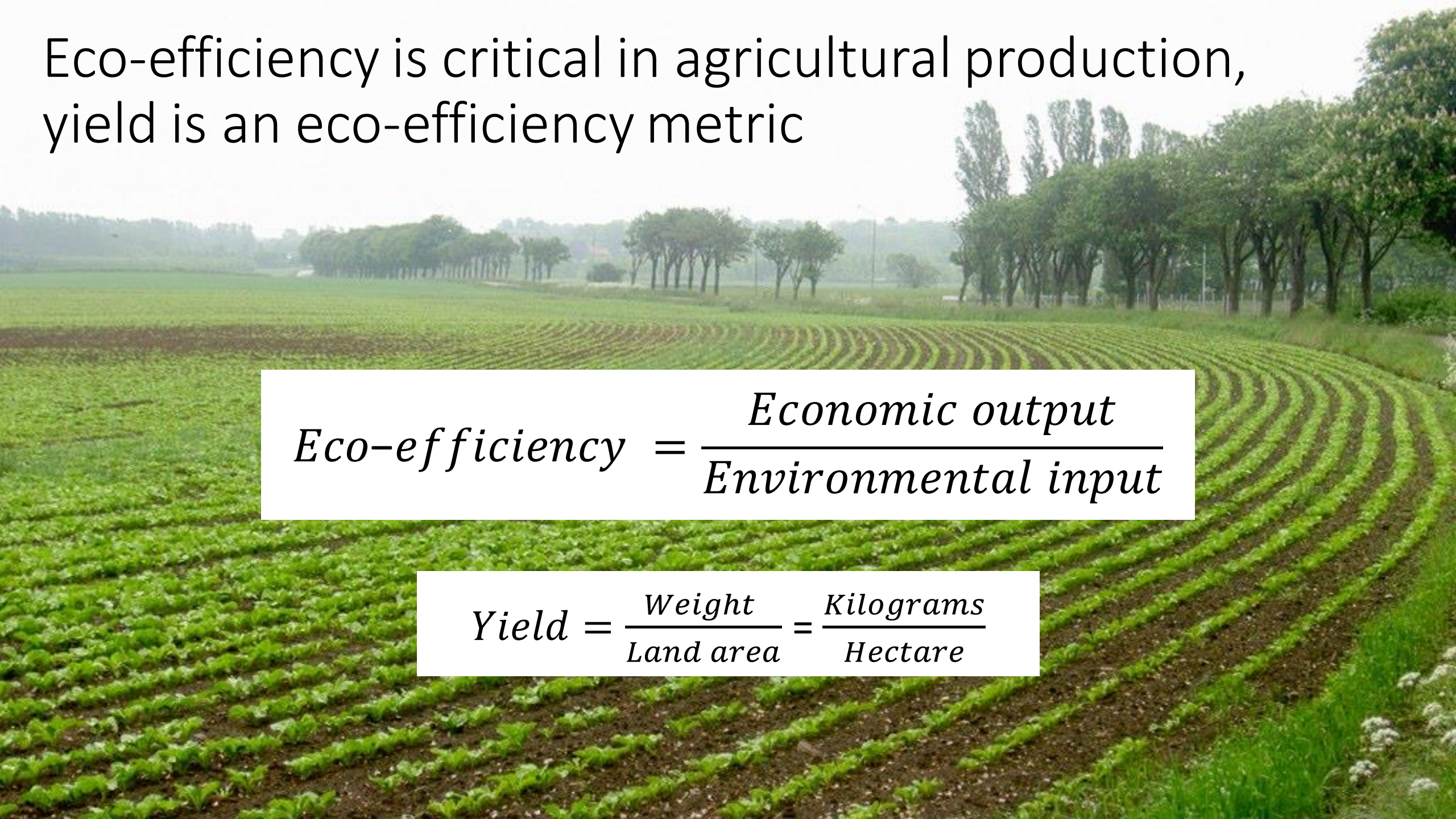


# 3. How to create a single score to represent golf course resource use efficiency?

# Eco-efficiency – creating a single score to optimize resource use




# Eco-efficiency is critical in agricultural production, yield is an eco-efficiency metric



$$Eco\text{-}efficiency = \frac{Economic\ output}{Environmental\ input}$$

$$Yield = \frac{Weight}{Land\ area} = \frac{Kilograms}{Hectare}$$

# Eco-efficiency metrics are important because they help define resource input levels

?

$$CV = \frac{Standard\ deviation}{Mean}$$

Fertilizer rate

Farmers use yields to calibrate resource input levels, the CV of N rate in northern US corn production is 25%

But what if you don't know your yield (i.e. golf courses), the CV of N rate in golf is often over 80%

# We want to build an eco-efficiency model for golf

$$Eco\text{–}efficiency = \frac{Economic\ output}{Environmental\ input}$$

$$An\ Eco\text{–}efficiency\ model\ for\ golf = \frac{?}{?}$$

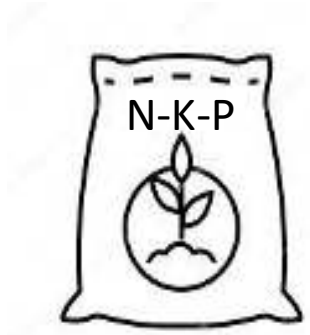
# What are the environmental inputs to a golf course?

Water

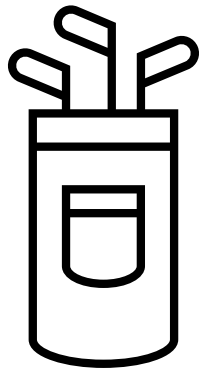
Fertilizer (Nitrogen)

Energy

Pesticide




# What is the yield of a golf course?

| Public | Resort | Private |
| --- | --- | --- |
|  |  |  |
| Rounds of golf | Profit | Member satisfaction |

# If golf course yield is measured as rounds of golf, then the ratio of rounds to resource use is…

$$EE_W = \frac{Rounds}{Water\ use}$$

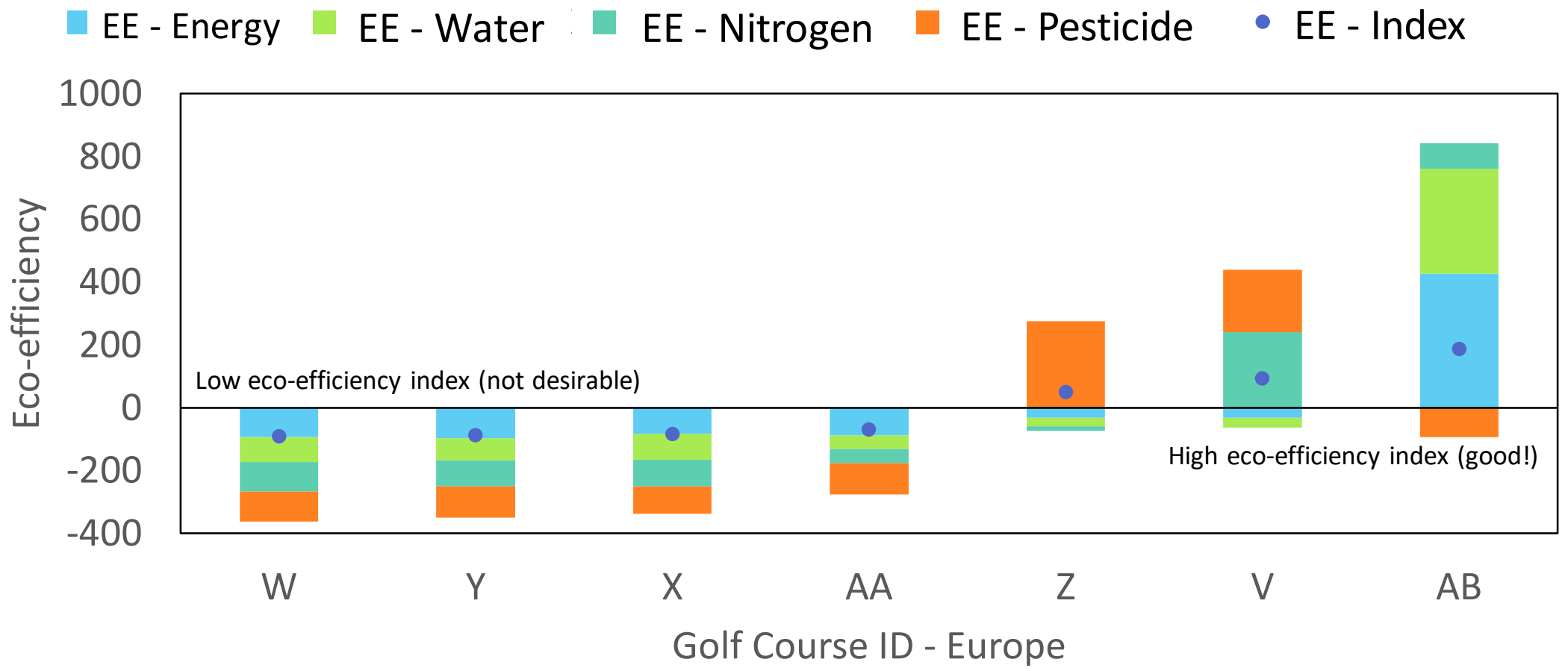
$$EE_N = \frac{Rounds}{Nitrogen\ use}$$

$$EE_F = \frac{Rounds}{Energy\ use}$$

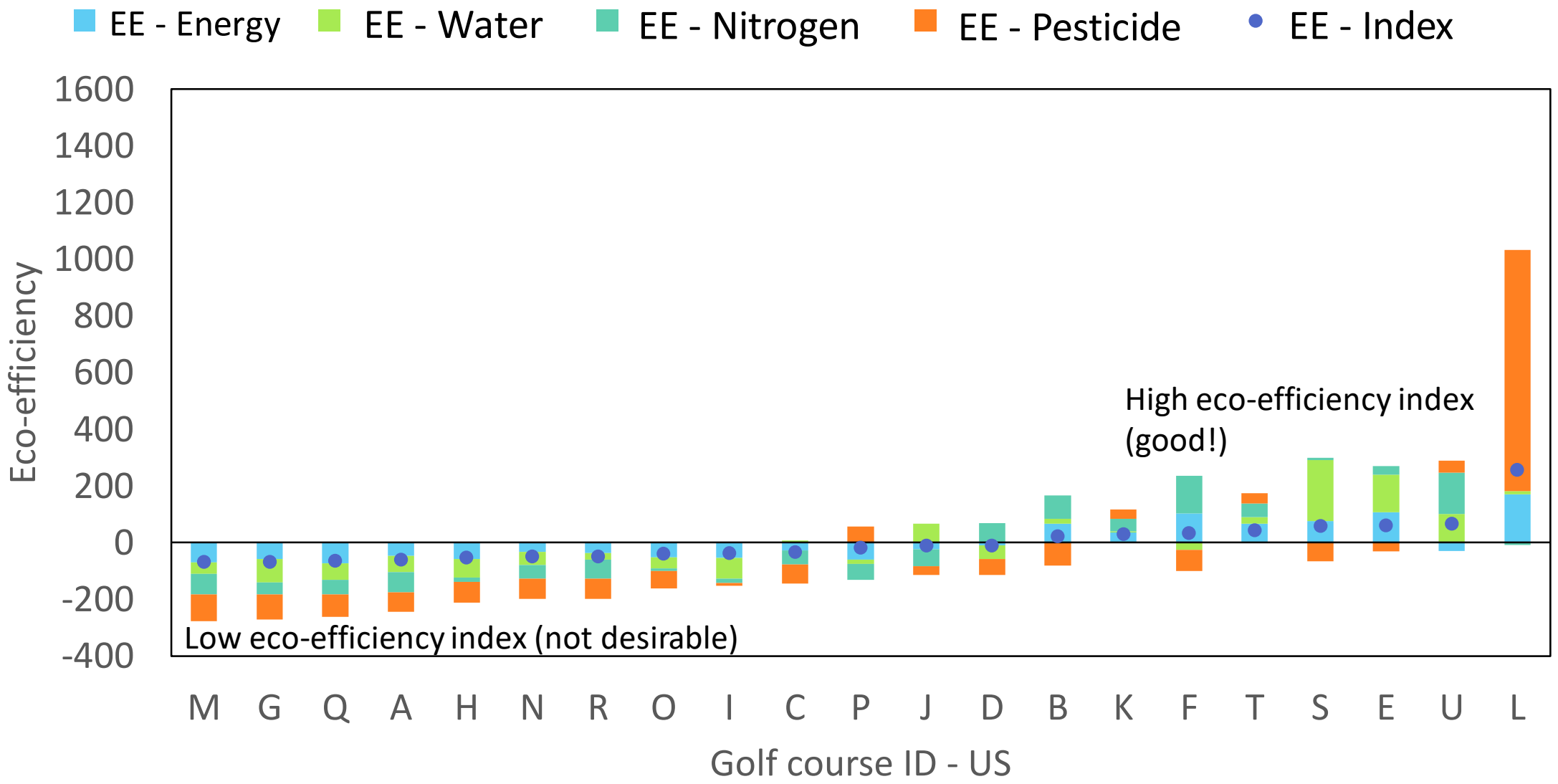
$$EE_P = \frac{Rounds}{Pesticide\ use}$$

Weigh each 25% = Eco-efficiency index

# The eco-efficiency index of 7 European golf courses



# The eco-efficiency index of 21 US golf courses



# What a does high eco-efficiency golf course look like? An example from a European golf course

**Environmental inputs: very low**

- Near zero pesticide use (strict gov regulation)
- Very low fuel use (electric mowers)
- Moderate fertilizer inputs
- Efficient irrigation use

**Economic output (rounds): medium high**

- 54,000 annually

$$Eco\text{–}efficiency = \frac{Economic\ output}{Environmental\ input}$$

**Eco-efficiency: very high**

# Conclusions

1. Golf course water, fertilizer, and pesticide use efficiency is highly variable
2. That variation itself is an indication that we can be more efficient as an industry
3. Using less resource is often best both agronomically and environmentally!
4. Eco-efficiency is a framework we can use to become more efficient

# Becoming a data driven greenkeeper: example of some useful annual metrics

## Track (annually)

- Fertilizer: kg N $ha^{-1}$ $yr^{-1}$ on greens, tees, fairways, roughs
- Pesticide: kg ai $ha^{-1}$ $yr^{-1}$ on greens, tees, fairways, roughs
- Water: $m^3$ irrigation applied and $m^2$ of irrigated area, determine average irrigation rate in mm
- Energy: KWh electricity, liters diesel, liters petrol

## Analyze

- Trends from year to year
- Compare your resource use with golf courses nearby

## Ask

- Could you use fewer resources?
- Could you be more efficient? How?
- Collecting data on resoure use is a critical place to start

# Thank you!

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