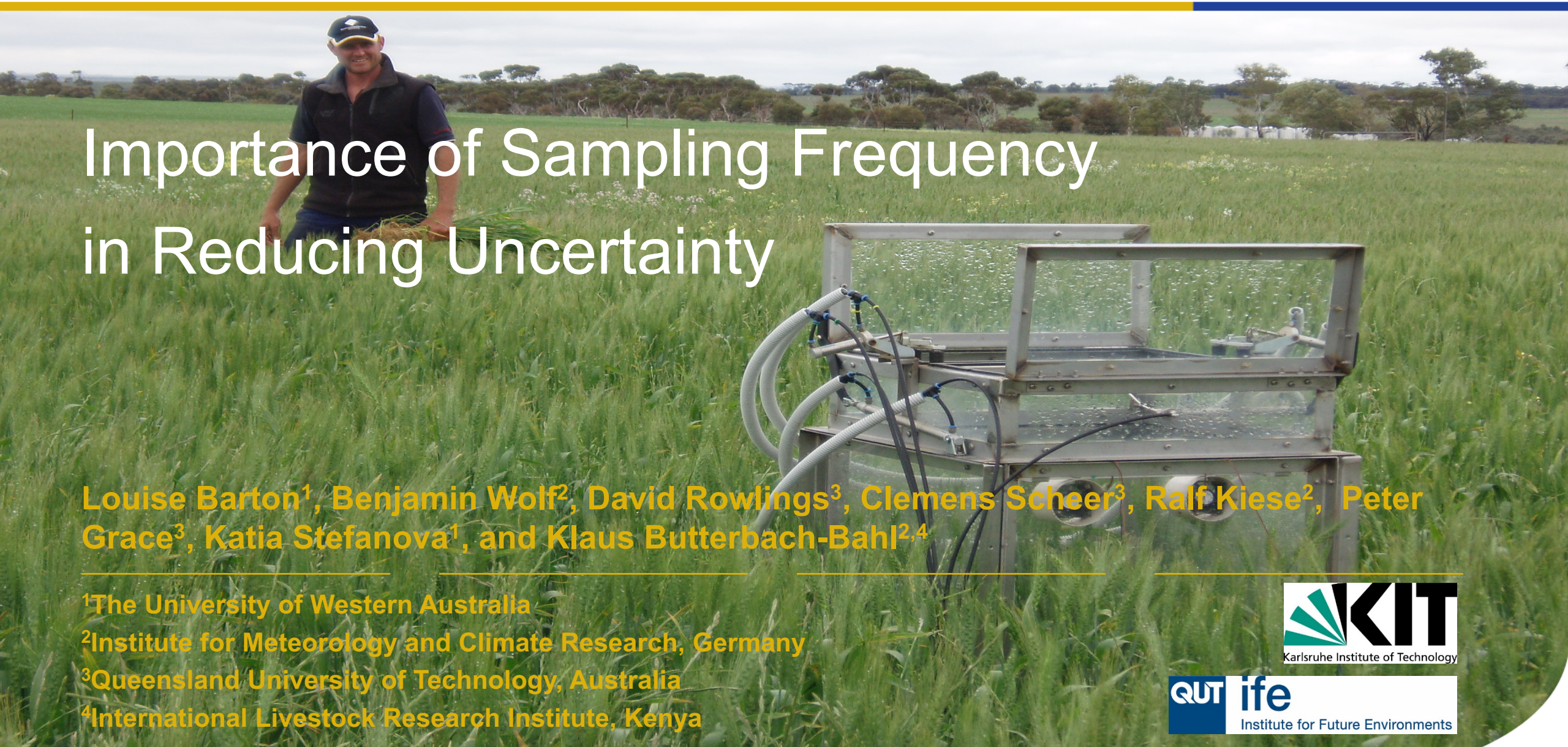
# Importance of Sampling Frequency in Reducing Uncertainty

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- Grains & Research Development Corporation
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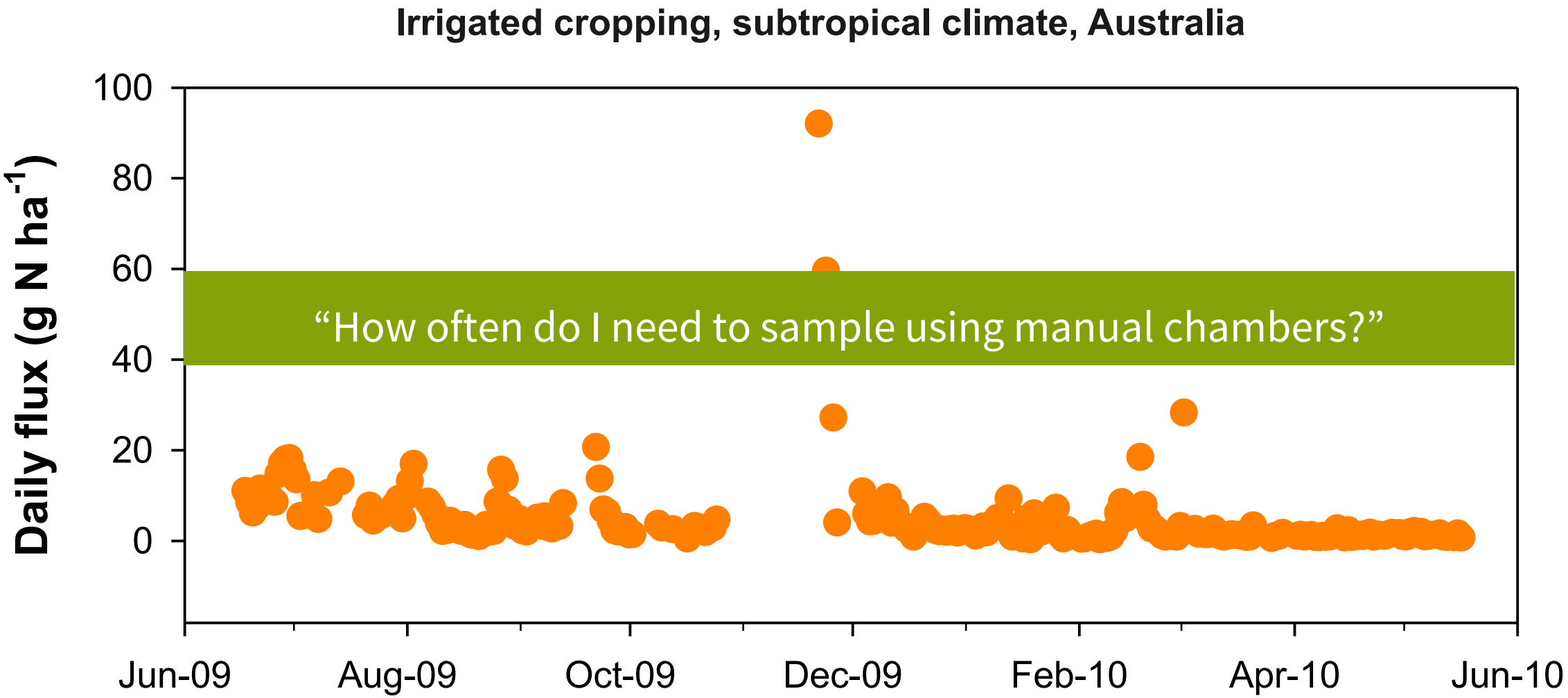
# NITROUS OXIDE FLUXES AND TEMPORAL VARIABILITY




Source: Scheer *et. al.* 2013. *Nutrient Cycling in Agroecosystems* **95**: 43–56.

Rain-fed cropping, Wongan Hills, south-western Australia

# OVERALL OBJECTIVE

Investigate the effect of sample frequency on estimates of **annual** $N_2O$ fluxes by using data collected:

- On a sub-daily basis using automated chamber systems
- From a variety of climates and land-uses

Semi-arid

Sub-tropical

Tropical

# TWENTY EIGHT DATASETS: RANGE IN ANNUAL FLUXES

THE UNIVERSITY OF WESTERN AUSTRALIA

| LOCATION | DATASETS (Yrs,Treat) | CLIMATE | LANDUSE | ANNUAL $N_2O$ FLUX (kg N $ha^{-1}$) |
|---|---|---|---|---|
| Bellenden Kerr, Australia | One (1, 1) | Tropical | Forest | **1.16** |
| Cunderdin, Australia | Eight (4, 2) | Semi-arid | Cereal cropping | **0.08–0.16** |
| Höglwald, Germany | Two (1, 1) | Temperate | Plantation forest | **0.58–2.46** |
| Kingsthorpe, Australia | Three (1, 3) | Sub-tropical | Irrigated cereal-cotton cropping | **2.61–2.93** |
| Mooloolah Valley, Australia | Five (3, 2) | Sub-tropical | Forest, Pasture, Orchard | **0.48–8.12** |
| Wongan Hills, Australia | Eight (2, 4) | Semi-arid | Cereal cropping | **0.03–0.07** |
| Xilin, Inner Mongolia | One (1) | Semi-arid | Steppe grassland | **0.21** |

# TWENTY EIGHT DATASETS: RANGE IN 'EPISODICITY'

| LOCATION | DATASETS (Yrs,Treat) | CLIMATE | LANDUSE | ANNUAL $N_2O$ FLUX (kg N $ha^{-1}$) | DAILY FLUX CV (%) | EPISODICITY |
|---|---|---|---|---|---|---|
| Bellenden Kerr, Australia | One (1, 1) | Tropical | Forest | 1.16 | 98 | Moderate |
| Cunderdin, Australia | Eight (4, 2) | Semi-arid | Cereal cropping | 0.08–0.16 | 173–428 | High to Extreme |
| Höglwald, Germany | Two (1, 1) | Temperate | Plantation forest | 0.58–2.46 | 169–179 | High |
| Kingsthorpe, Australia | Three (1, 3) | Sub-tropical | Irrigated cereal-cotton cropping | 2.61–2.93 | 181–235 | High to Extreme |
| Mooloolah Valley, Australia | Five (3, 2) | Sub-tropical | Forest, Pasture, Orchard | 0.48–8.12 | 78–172 | Moderate to High |
| Wongan Hills, Australia | Eight (2, 4) | Semi-arid | Cereal cropping | 0.03–0.07 | 380–913 | Extreme |
| Xilin, Inner Mongolia | One (1) | Semi-arid | Steppe grassland | 0.21 | 260 | Extreme |

CV, coefficient of variation

# APPROACH

*For each data set, we calculated:*

Daily fluxes by averaging sub-daily fluxes (**removed diurnal variation**)

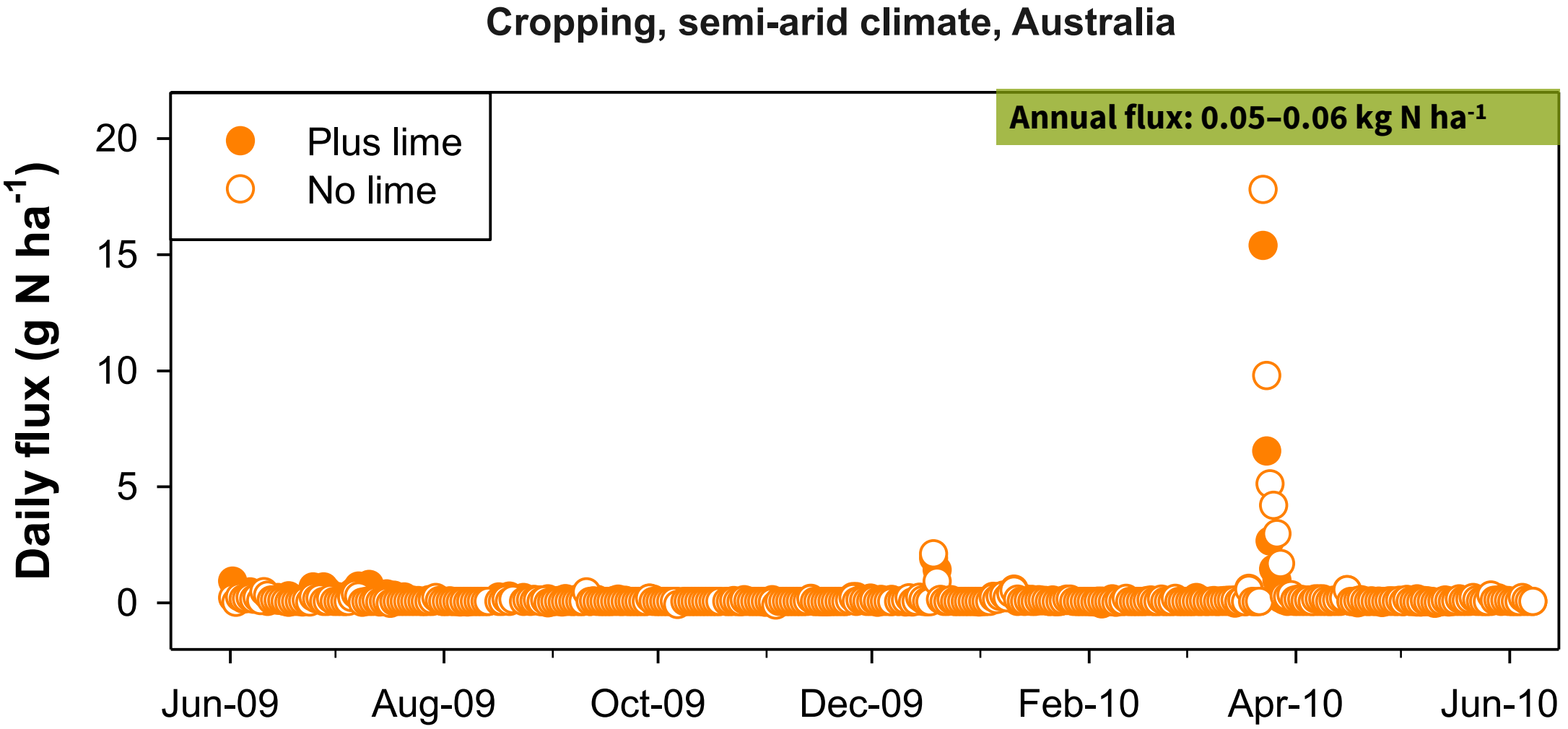
Annual fluxes calculated for different sampling frequencies (**5 intervals**) using 'Jack-Knife' analysis

| Frequency (day) | Permutations | Example |
|---|---|---|
| **Daily (0)** | **1** | **All sample days** |
| 3-days/week (2) | 7 | Sun-Tue-Thu; Mon-Wed-Fri; Tue-Thu-Sat *etc* |
| Weekly (7) | 7 | Sun, Mon, Tue, Wed, Thu, Fri, Sat |
| Every 2$^{nd}$ week (14) | 14 | Sun (Week 1, 2), Mon (Week 1, 2) *etc* |
| Every 4$^{th}$ week (28) | 28 | Sun (Weeks 1–4), Mon (Week 1–4) *etc* |

For each sampling frequency, annual flux compared with **'best' estimate (daily)**

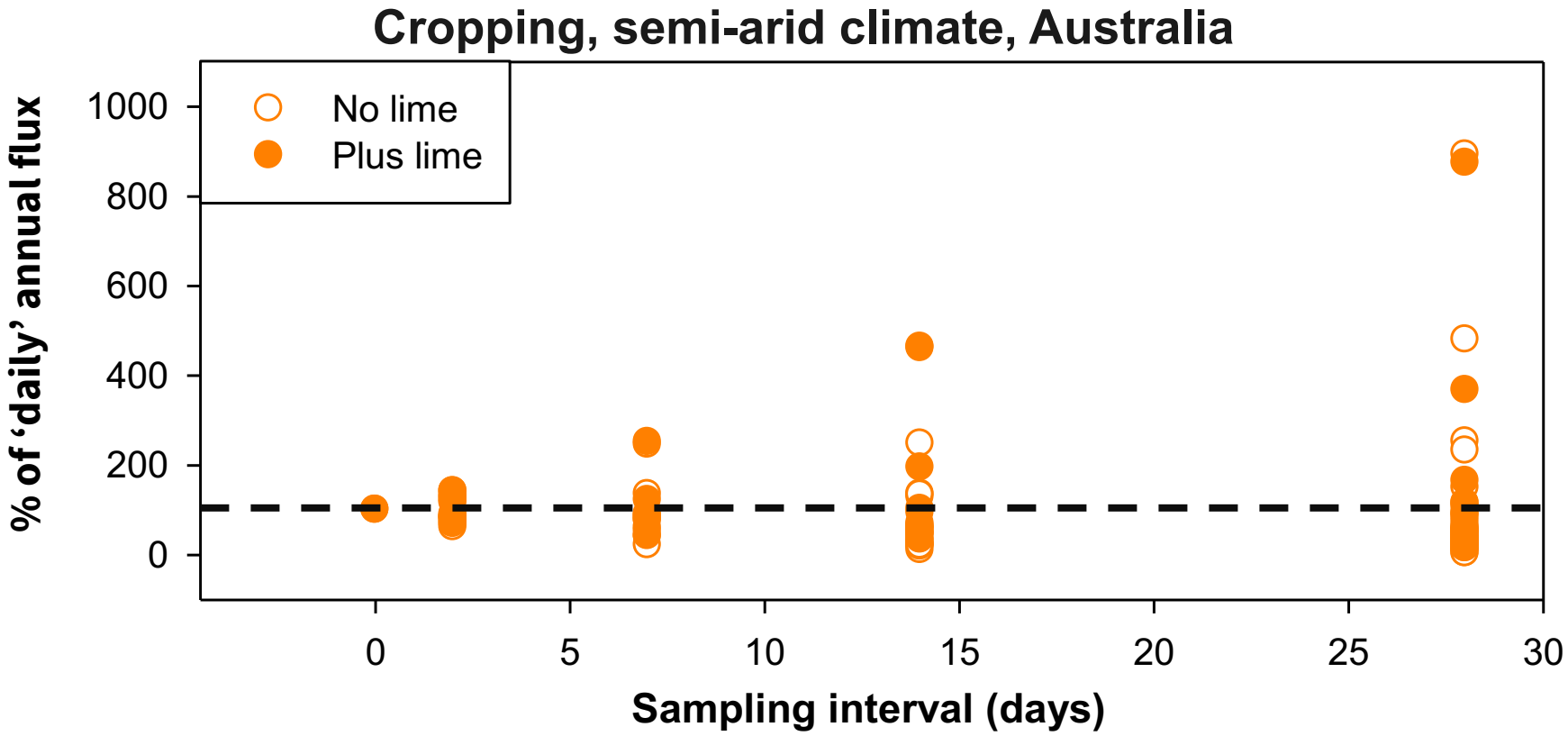
Result expressed as **% of 'daily' annual flux**

# DAILY NITROUS OXIDE FLUX PROFILE: ‘Extremely’ episodic

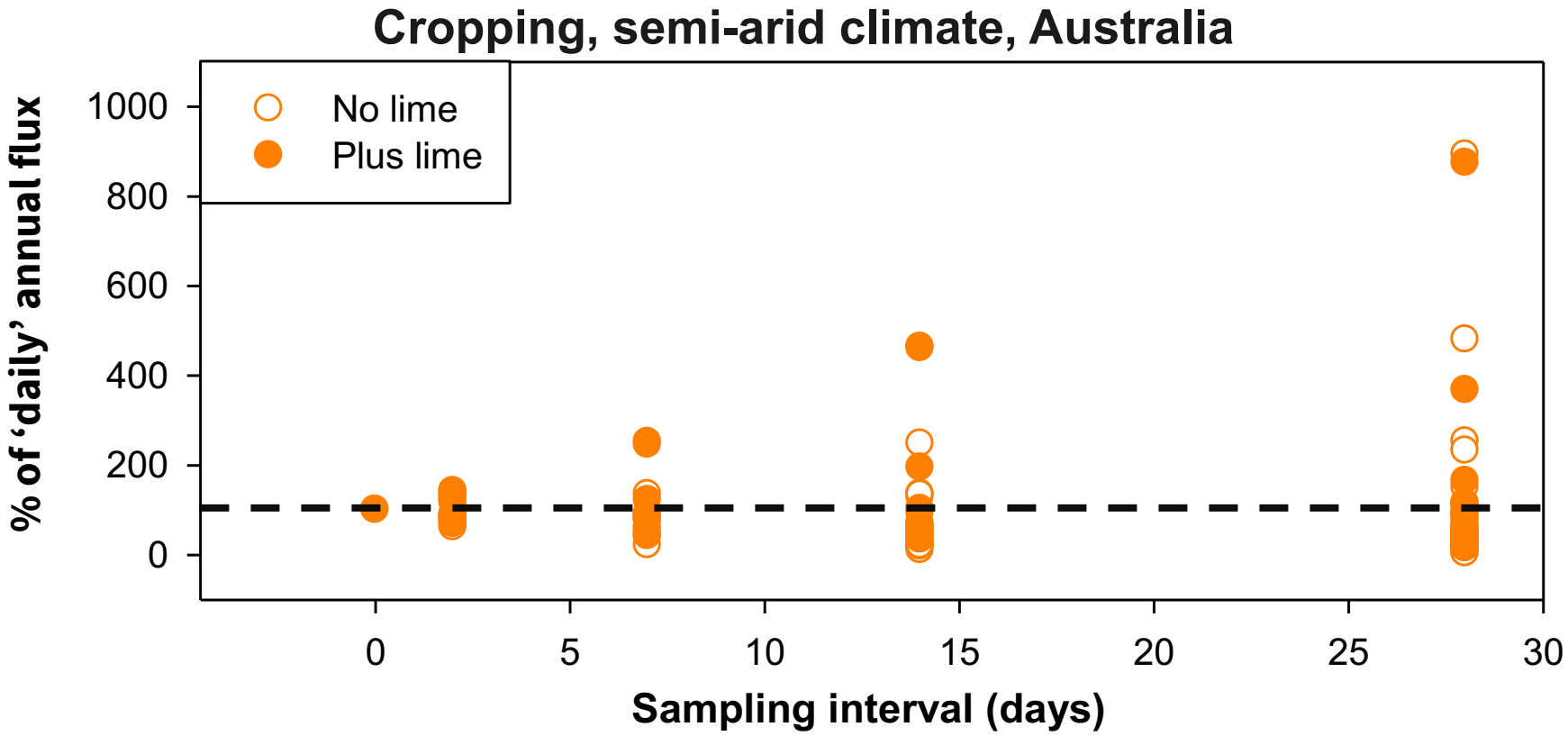



Source: Barton *et. al.* 2013. *Agriculture, Ecosystems and Environment* **167**: 23–32.

# SAMPLING FREQUENCY & ANNUAL FLUX : ‘Extremely’ episodic

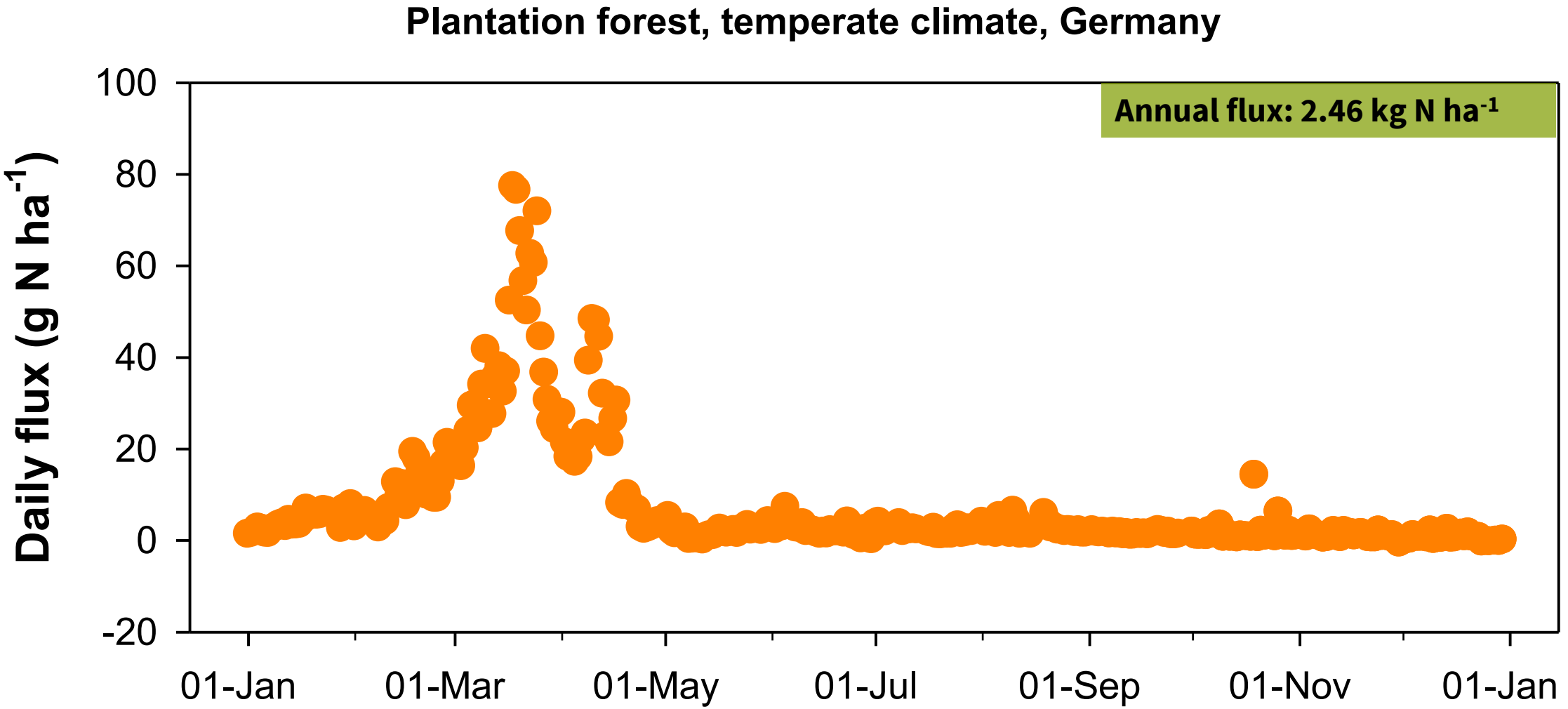


# SAMPLING FREQUENCY & ANNUAL FLUX : ‘Extremely’ episodic



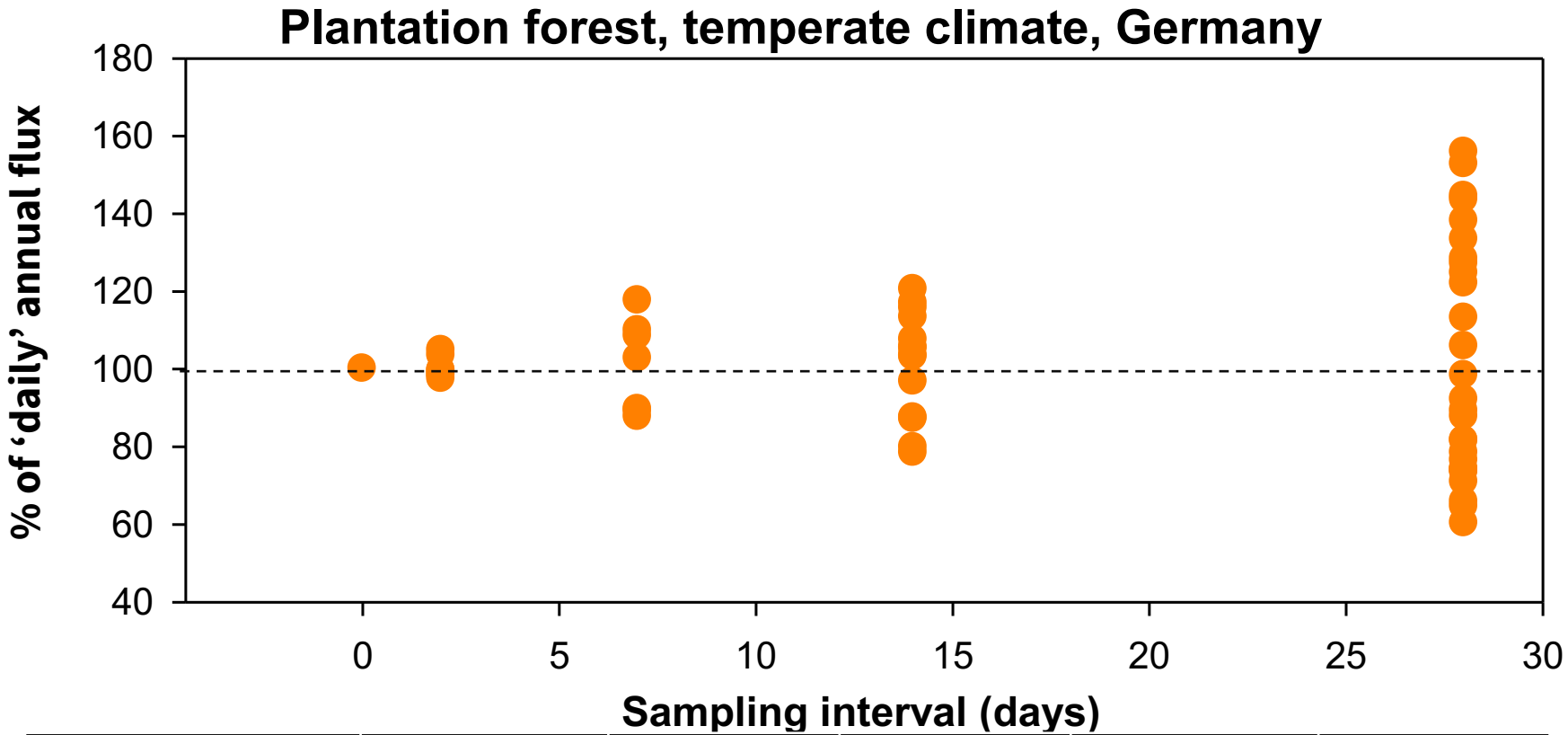

| | 0 (Daily) | 2 | 7 | 14 | 28 |
|---|---|---|---|---|---|
| % Best estimate | 100 | 61–141 | 21–251 | 10–464 | 3–893 |
| Annual Flux (kg N $ha^{-1}$) | 0.05–0.06 | 0.03–0.08 | 0.01–0.14 | 0.01–0.5 | 0–0.5 |

# DAILY NITROUS OXIDE FLUX PROFILE: 'Highly' episodic



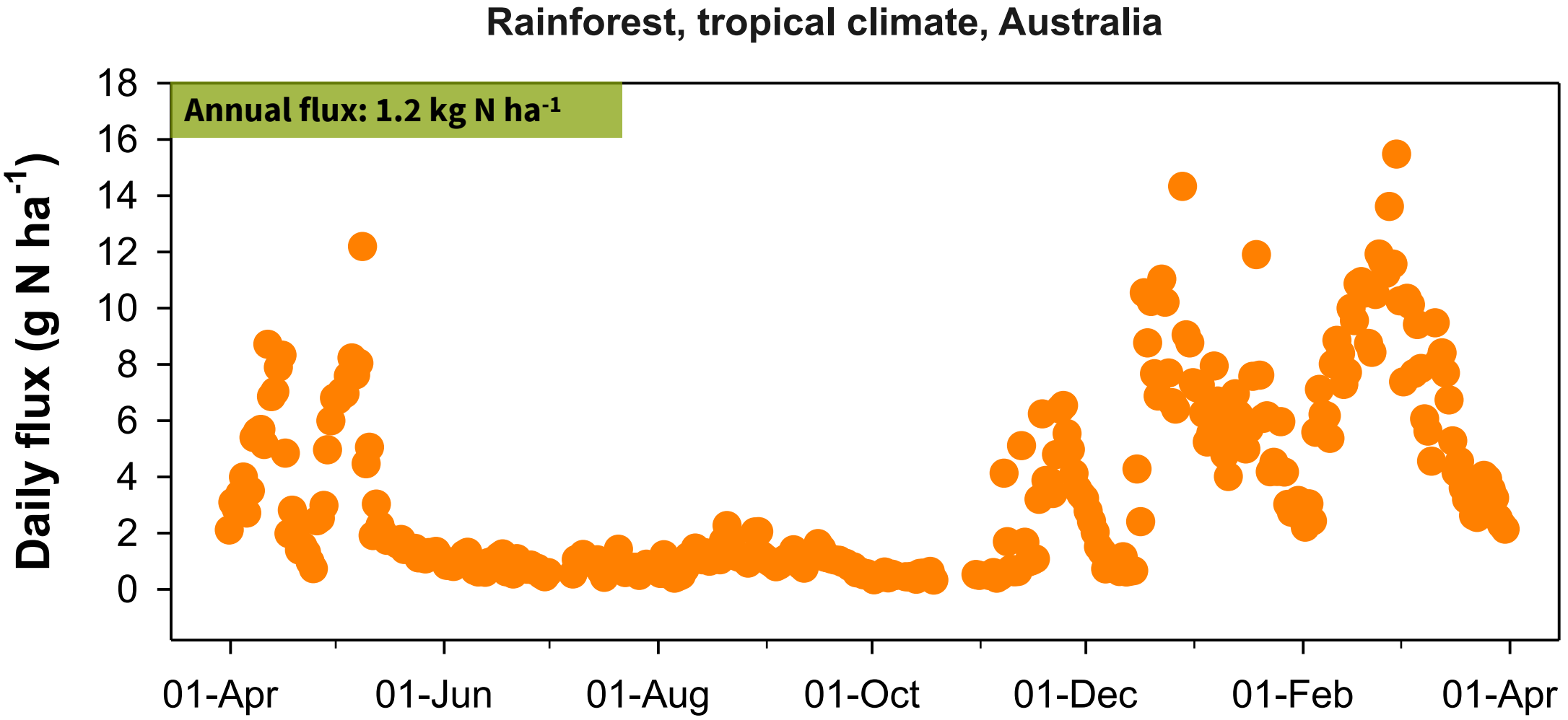

Source: Butterbach-Bahl *et. al.* 2002. *Plant and Soil* **240**: 117–123.

# SAMPLING FREQUENCY & ANNUAL FLUX : ‘Highly’ episodic



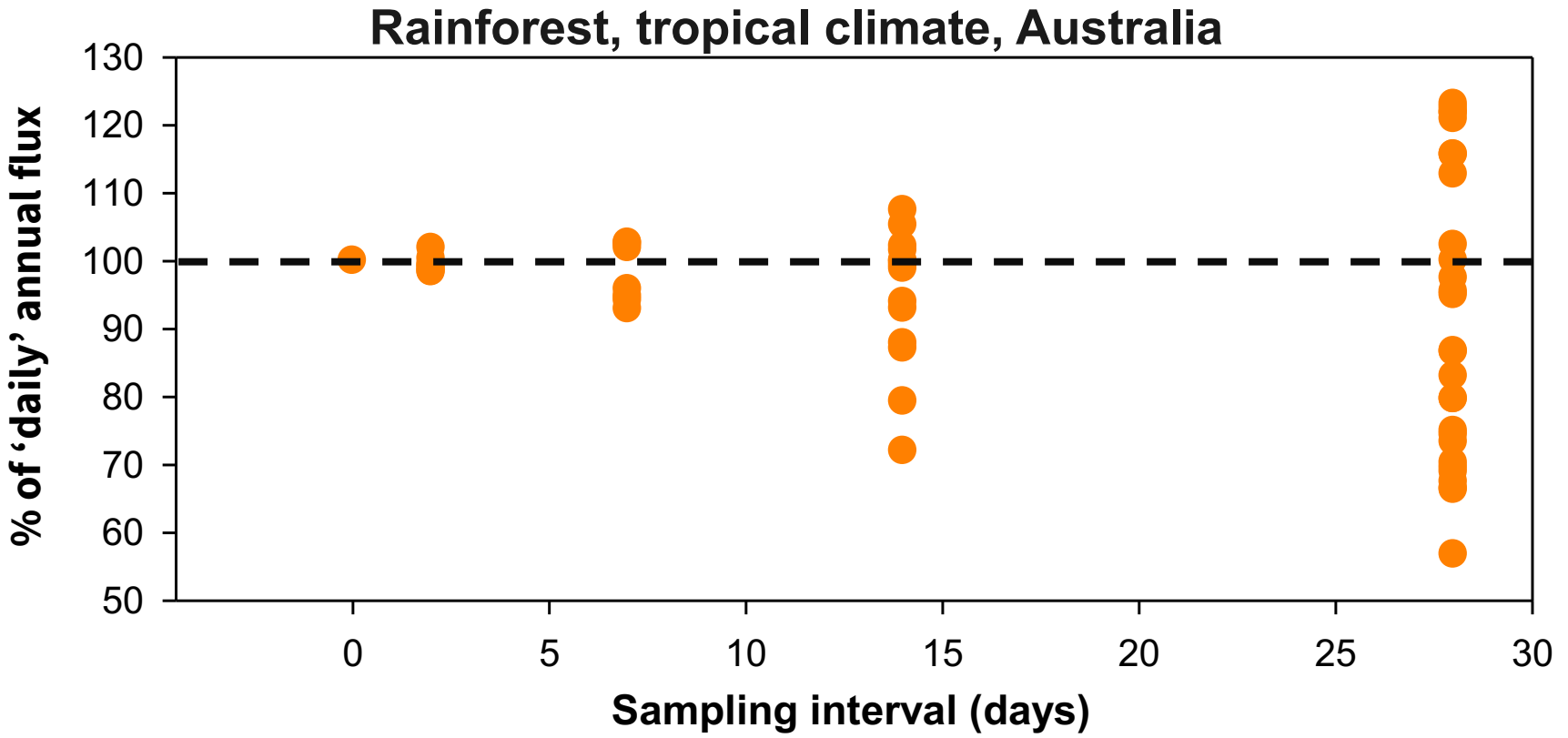

| | 0 (Daily) | 2 | 7 | 14 | 28 |
|---|---|---|---|---|---|
| % Best estimate | 100 | 97–105 | 88–118 | 78–120 | 60–156 |
| Annual Flux (kg N $ha^{-1}$) | 2.46 | 2.40–2.58 | 2.16–2.90 | 1.93–2.97 | 1.49–3.85 |

# DAILY NITROUS OXIDE FLUX PROFILE: 'Moderately' episodic



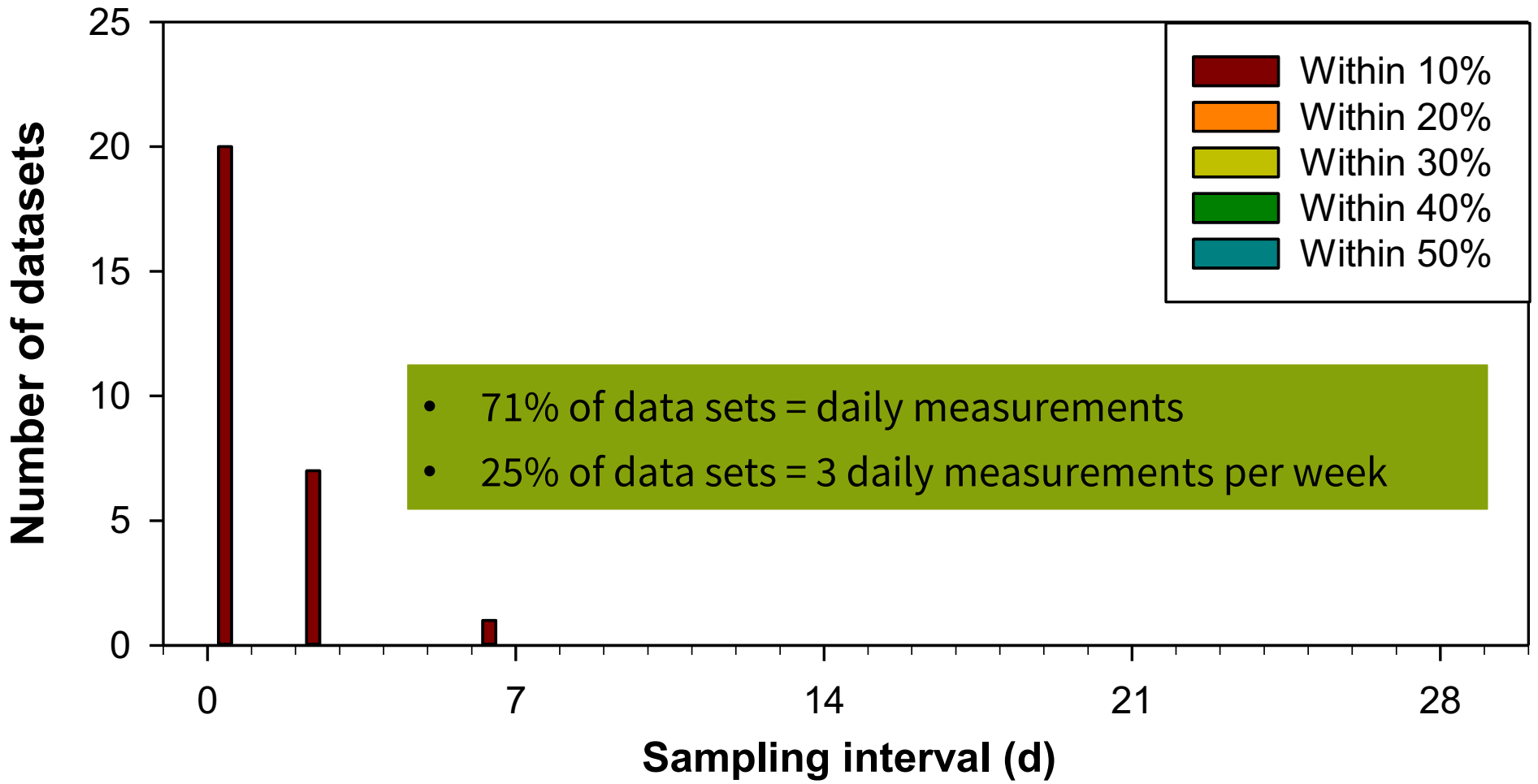

Source: Kiese *et. al.* 2003. *Global Biogeochemical Cycles* **17**: 1043

# SAMPLING FREQUENCY & ANNUAL FLUX: ‘Moderately’ episodic



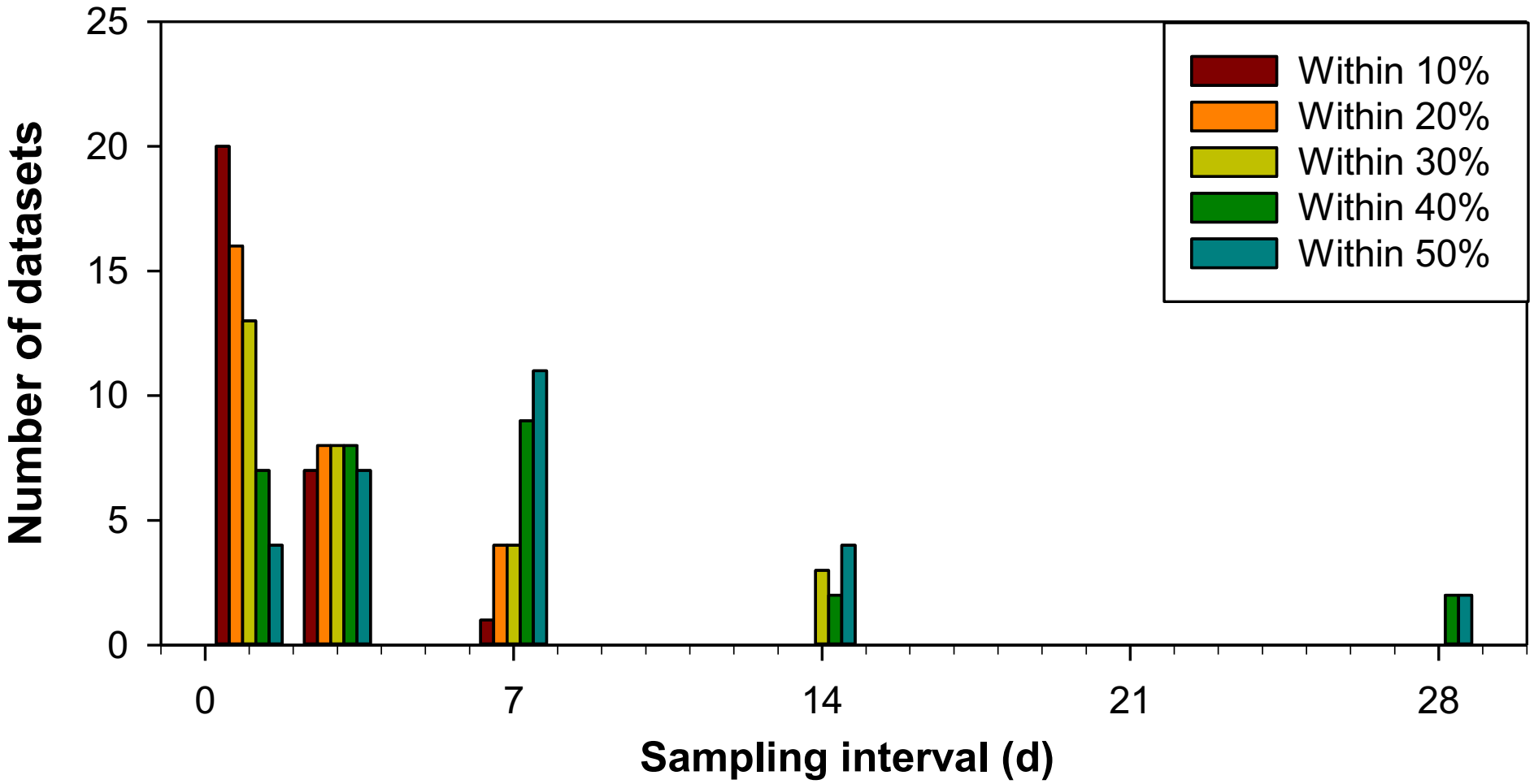

| | 0 (Daily) | 2 | 7 | 14 | 28 |
|---|---|---|---|---|---|
| % Best estimate | 100 | 100–102 | 98–103 | 72–107 | 57–123 |
| Annual Flux (kg N $ha^{-1}$) | 1.2 | 1.1–1.2 | 1.1–1.2 | 0.8–1.2 | 0.7–1.4 |

# RECOMMENDED SAMPLING FREQUENCY




Source: Barton *et. al.* 2015. *Sci. Rep.* 5:15912 | DOI: 10.1038/srep15912

# RECOMMENDED SAMPLING FREQUENCY




Source: Barton *et. al.* 2015. *Sci. Rep.* 5:15912 | DOI: 10.1038/srep15912

# OTHER STUDIES

*Corn-soybean, Iowa, USA*

**“**At relatively frequent sampling intensities (i.e., **once every 3d**) $N_2O$–N flux estimates were within **±10%** of the expected value”

Parkin (2008)

*Cotton, Shanxi Province, China*

“Sampling daily (at 9am) to **every two days** caused a deviation of up to **7.3%** from annual flux estimated from sub-daily measurements.”

Lui *et al.* (2010)

Pasture, Otago, New Zealand

“… gas samples collected **three times a week** between 10:00-12:00h provided **zero bias** in calculating cumulative emissions when compared with those based on frequent, 2-hourly, flux measurements.”

Van der Weeden et al. 2013

*Sugar Cane, Queensland, Australia*

“**Weekly sampling with biweekly sampling for one week after >20 mm of rainfall** was the recommended sampling regime. It resulted in no extreme (>20%) deviations from the ‘actuals’, had a high probability of estimating the annual cumulative emissions within **10% precision** …”

Reeves *et al.* (2016)

# RECOMMENDED SAMPLING STRATEGY:

## 'Jackknife' and 'Informed'

THE UNIVERSITY OF WESTERN AUSTRALIA

| LOCATION | DATASETS (Yrs,Treat) | CLIMATE | LANDUSE | ANNUAL $N_2O$ FLUX (kg N $ha^{-1}$) | EPISODICITY | JACKNIFE (sampling days) | INFORMED (sampling days) |
|---|---|---|---|---|---|---|---|
| Bellenden Kerr, Australia | One (1, 1) | Tropical | Forest | 1.16 | Moderate | 52 | 156 |
| Mooloolah Valley, Australia | Five (3, 2) | Sub-tropical | Forest, Pasture, Orchard | 0.48–8.12 | Moderate to High | 156–365 | Not determined |
| Höglwald, Germany | Two (1, 1) | Temperate | Plantation forest | 0.58–2.46 | High | 156 | 83 |
| Xilin, Inner Mongolia | One (1) | Semi-arid | Steppe grassland | 0.21 | Extreme | 156 | Not determined |
| Cunderdin, Australia | Eight (4, 2) | Semi-arid | Cereal cropping | 0.08–0.16 | High to Extreme | 156–365 | Not determined |
| Kingsthorpe, Australia | Three (1, 3) | Sub-tropical | Irrigated cereal-cotton cropping | 2.61–2.93 | High to Extreme | 365 | Not determined |
| Wongan Hills, Australia | Eight (2, 4) | Semi-arid | Cereal cropping | 0.03–0.07 | Extreme | 365 | 60 |

# CONCLUSIONS

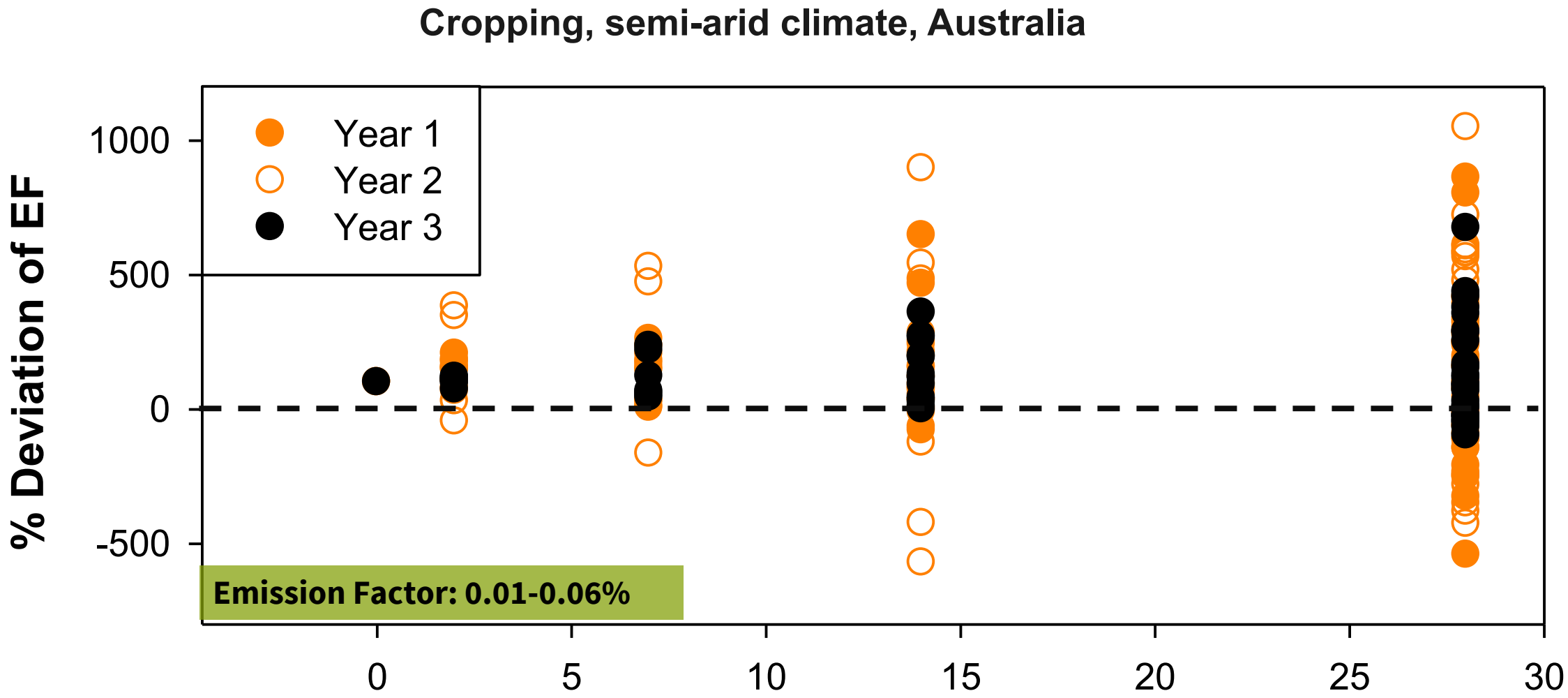
- **Nitrous oxide emissions generally need to be measured daily to accurately estimate (within 10%) annual fluxes in a variety of land-uses and climates**
  - 71% of data sets = daily measurements
  - 25% of data sets = 3 daily measurements per week

- **For study sites where temporal variability has not previously been characterised (or when variability is expected to change from year-to-year) recommend daily sampling with manual chambers**

- **Recommended sampling frequency increases with increasing "episodicity"**

- **Data from automated chambers should be continuously used to develop guidelines for manual chamber sampling frequency**

# SAMPLING FREQUENCY & EMISSION FACTOR



# Relationship between coefficient of variation of the daily $N_2O$ flux and the deviation (range) from the 'best estimate' annual $N_2O$ flux: 4-weekly sampling interval