# INTER-ROTATIONAL MANAGEMENT AND PRODUCTIVITY OF RADIATA PINE

John Turner and Marcia Lambert
Forsci Pty Ltd
July 2013

# QUESTIONS

## In forest plantations:

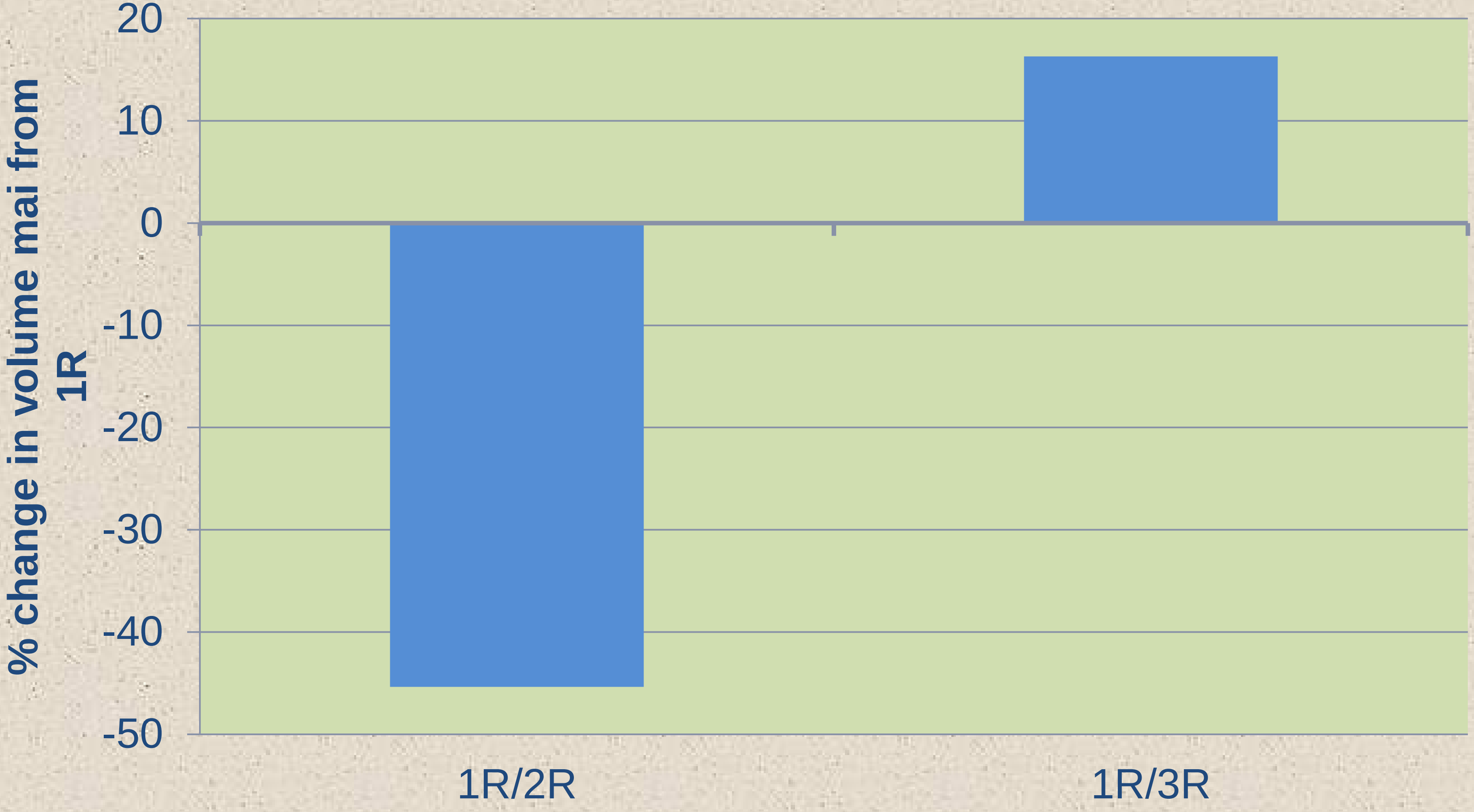
Is the production of subsequent rotations the same as in the first rotation?

If there are differences, what are the causes?

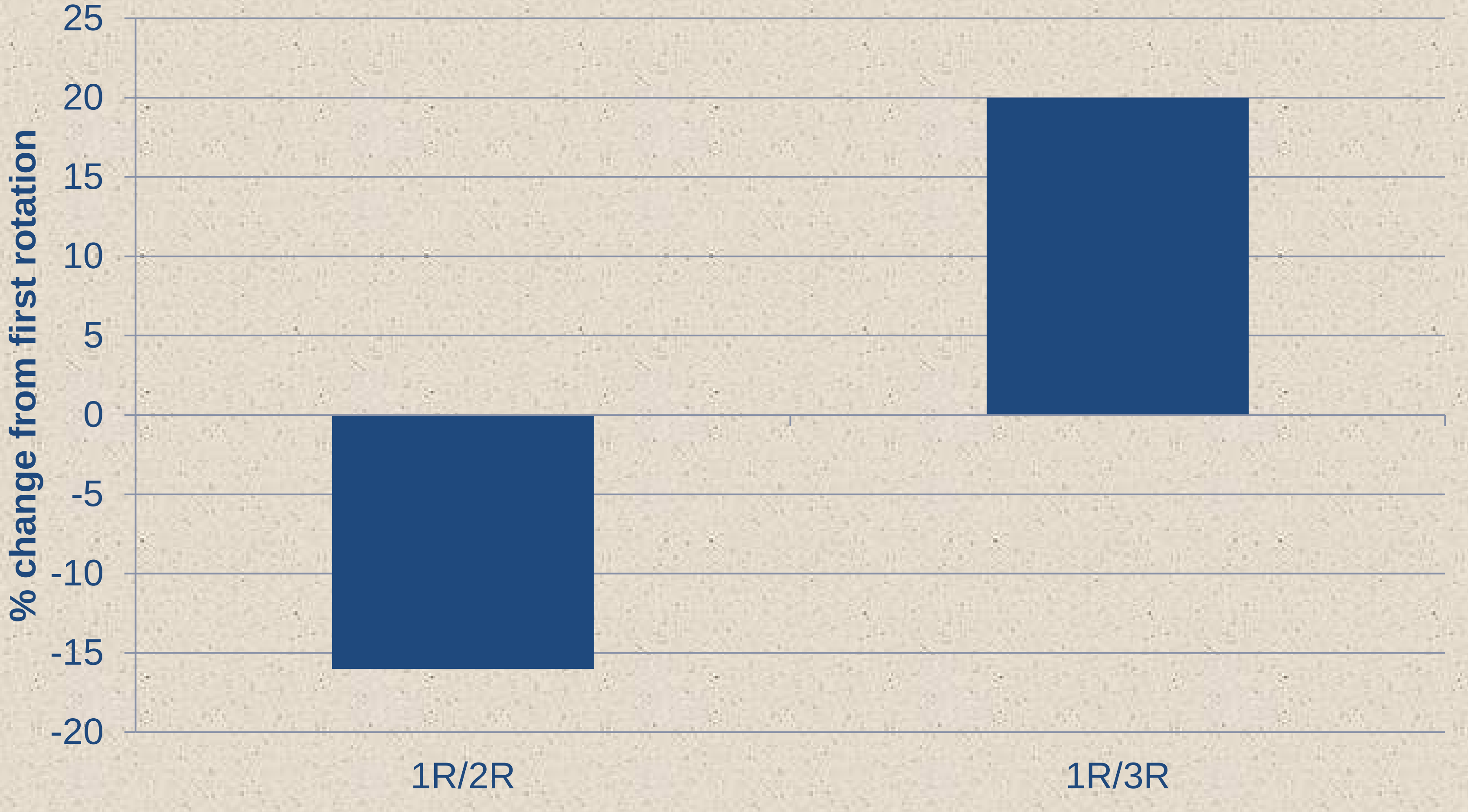
Are the results as expected?

Why raise the issue in the first place?

# Keeves (1966) productivity decline of radiata on fine sands, further analysis by O'Herir and Nambiar (2010)



# Jorge Toro in Chile on soils from metamorphic rocks



# INTEGRATED ANALYSES OF PRODUCTION FORESTS

- Relationships in forest plantations of:
  - Wood production
  - Water yield
  - Carbon accretion
  - Nutrient utilization
- Plantation sustainability
- Site Specific Management
- Integration with other land use

# STUDY SITE: LIDSDALE STATE FOREST

- Early pine plantation (1920) on old farm site.
- After 1936 plantation quality assessment recommended for termination at end of rotation.
- Early 1960’s research commenced on soils, nutrition, growth and hydrology.
- Moving into third rotation.

# LIDSDALE PROJECT

Research project aimed to address:

- Changes in productivity between rotations.
- Causes of any change.
- Impacts of nutrition (evaluate long term fertilizer  trials).
- Forest management and long term hydrology.
- Carbon and nutrient changes in plantations.
- Are these changes what we expected?

# RESEARCH ISSUES

- How do we measure long term changes?
- Maintenance of long term data and information (growth, hydrology, soils, compartment histories).
- How do we interpret results (baselines)?
- What is relevance to other plantation site types?
- How to relate changes in productivity to changes in soil properties and/or plantation management?

  [Recognise: finding a change in soil properties and in productivity does not mean they are related].
- Are short term and long term changes related?
- Should we be concerned about any changes?

# Lidsdale Plantation

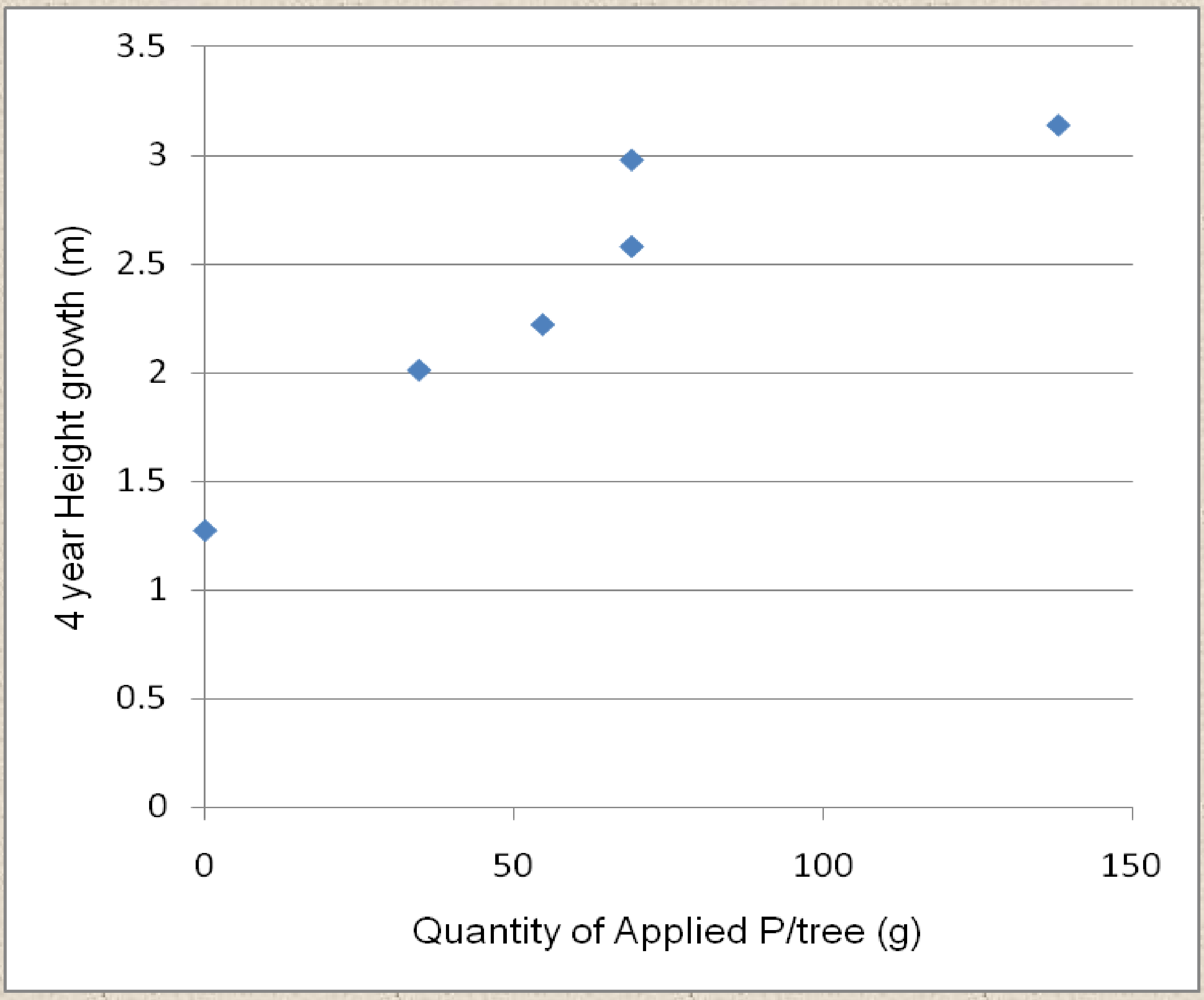
Soil developed from conglomerate, Lidsdale SF

# Nutrition Research

- Commenced in early 1960's by Wal Gentle and Reg Humphreys.
- Rainfall adequate but growth poor with some nutritional symptoms.
- Nutrition surveys identified low P and Ca and high Al.
- Established fertilizer trials, results used here to identify base lines  (early and later age trials).

# Phosphorus and calcium deficiency in 30 year old radiata pine

# Establishment fertilizer



# Layout of ripping x fertilizer trial

30 M 20 M

240 M

**BLOCK I**
**RIPPED**

| | | | |
|---|---|---|---|
| 1 CAN | 8 MAP | 9 Super P | 16 Control |
| 2 MAP | 7 Super P | 10 Control | 15 CAN |
| 3 Super P | 6 Control | 11 CAN | 14 MAP |
| 4 Control | 5 CAN | 12 MAP | 13 Super P |
| 17 CAN | 24 MAP | 25 Super P | 32 Control |
| 18 MAP | 23 Super P | 26 Control | 31 CAN |
| 19 Super P | 22 Control | 27 CAN | 30 MAP |
| 20 Control | 21 CAN | 28 MAP | 29 Super P |

**BLOCK II**
**RIPPED PLUS GYPSUM**

| | | | |
|---|---|---|---|
| 1 CAN | 8 MAP | 9 Super P | 16 Control |
| 2 MAP | 7 Super P | 10 Control | 15 CAN |
| 3 Super P | 6 Control | 11 CAN | 14 MAP |
| 4 Control | 5 CAN | 12 MAP | 13 Super P |
| 17 CAN | 24 MAP | 25 Super P | 32 Control |
| 18 MAP | 23 Super P | 26 Control | 31 CAN |
| 19 Super P | 22 Control | 27 CAN | 30 MAP |
| 20 Control | 21 CAN | 28 MAP | 29 Super P |

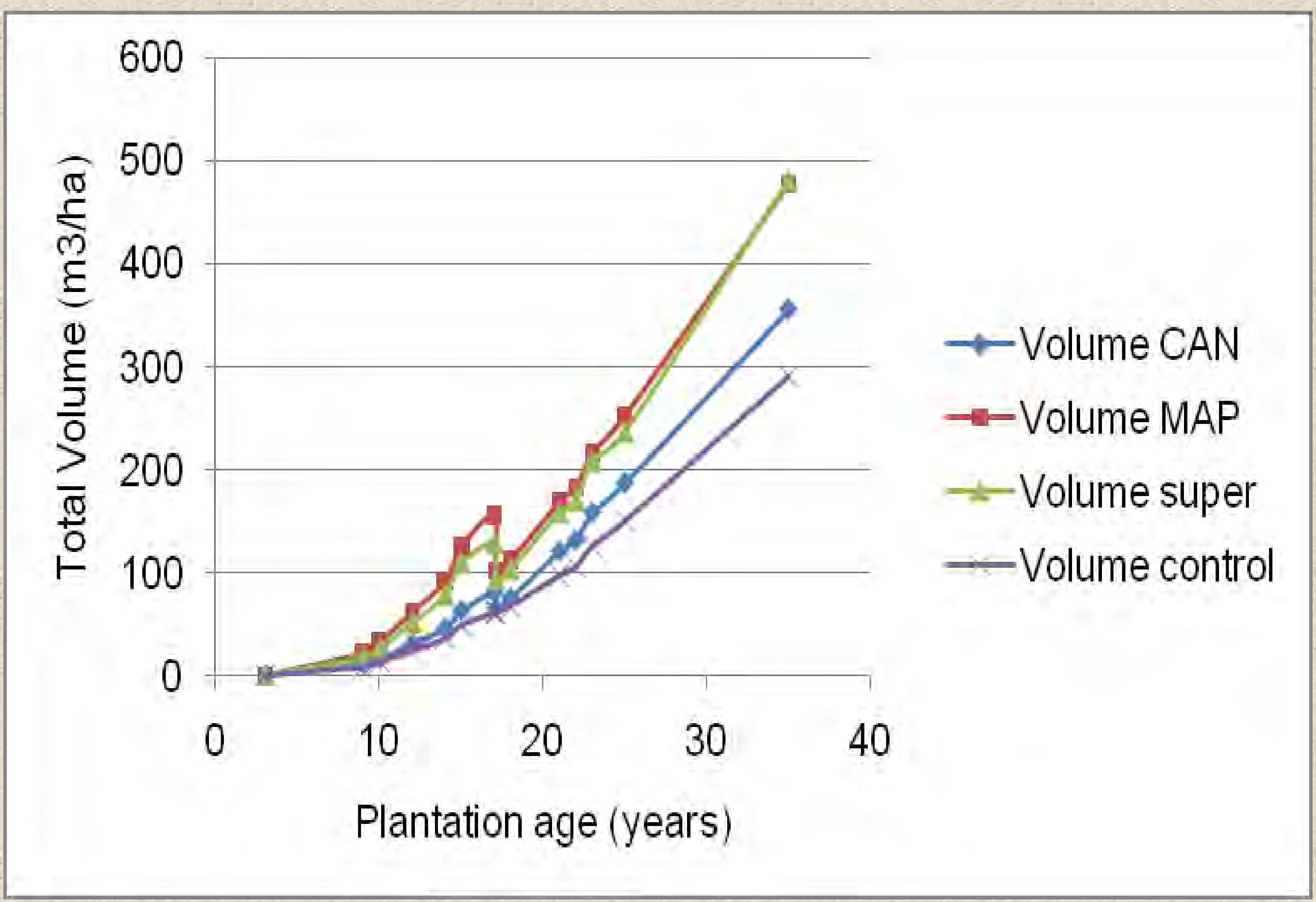
**BLOCK III**
**SHALLOW RIP**
**treated again with fertilizer at age 17**

| | | | |
|---|---|---|---|
| 1 CAN | 8 MAP | 9 Super P | 16 Control |
| 2 MAP | 7 Super P | 10 Control | 15 CAN |
| 3 Super P | 6 Control | 11 CAN | 14 MAP |
| 4 Control | 5 CAN | 12 MAP | 13 Super P |
| 17 CAN | 24 MAP | 25 Super P | 32 Control |
| 18 MAP | 23 Super P | 26 Control | 31 CAN |
| 19 Super P | 22 Control | 27 CAN | 30 MAP |
| 20 Control | 21 CAN | 28 MAP | 29 Super P |

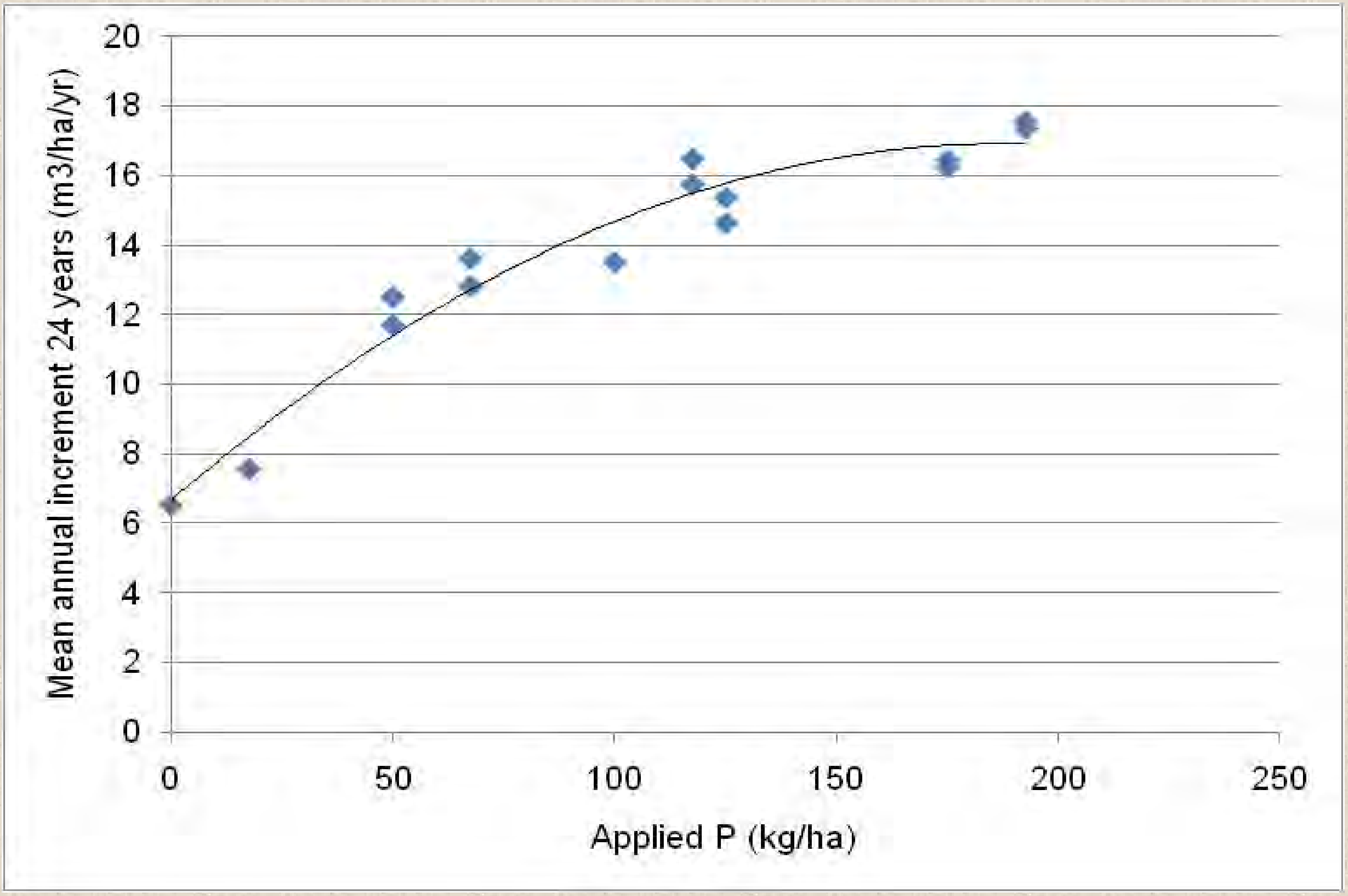
**BLOCK IV**
**CONTROL**

| | | | |
|---|---|---|---|
| 1 CAN | 8 MAP | 9 Super P | 16 Control |
| 2 MAP | 7 Super P | 10 Control | 15 CAN |
| 3 Super P | 6 Control | 11 CAN | 14 MAP |
| 4 Control | 5 CAN | 12 MAP | 13 Super P |
| 17 CAN | 24 MAP | 25 Super P | 32 Control |
| 18 MAP | 23 Super P | 26 Control | 31 CAN |
| 19 Super P | 22 Control | 27 CAN | 30 MAP |
| 20 Control | 21 CAN | 28 MAP | 29 Super P |

# Long term effects of single application at planting



# Phosphorus applications



# Inter-rotational Productivity

» Yield

» Productivity

» Productive Capacity

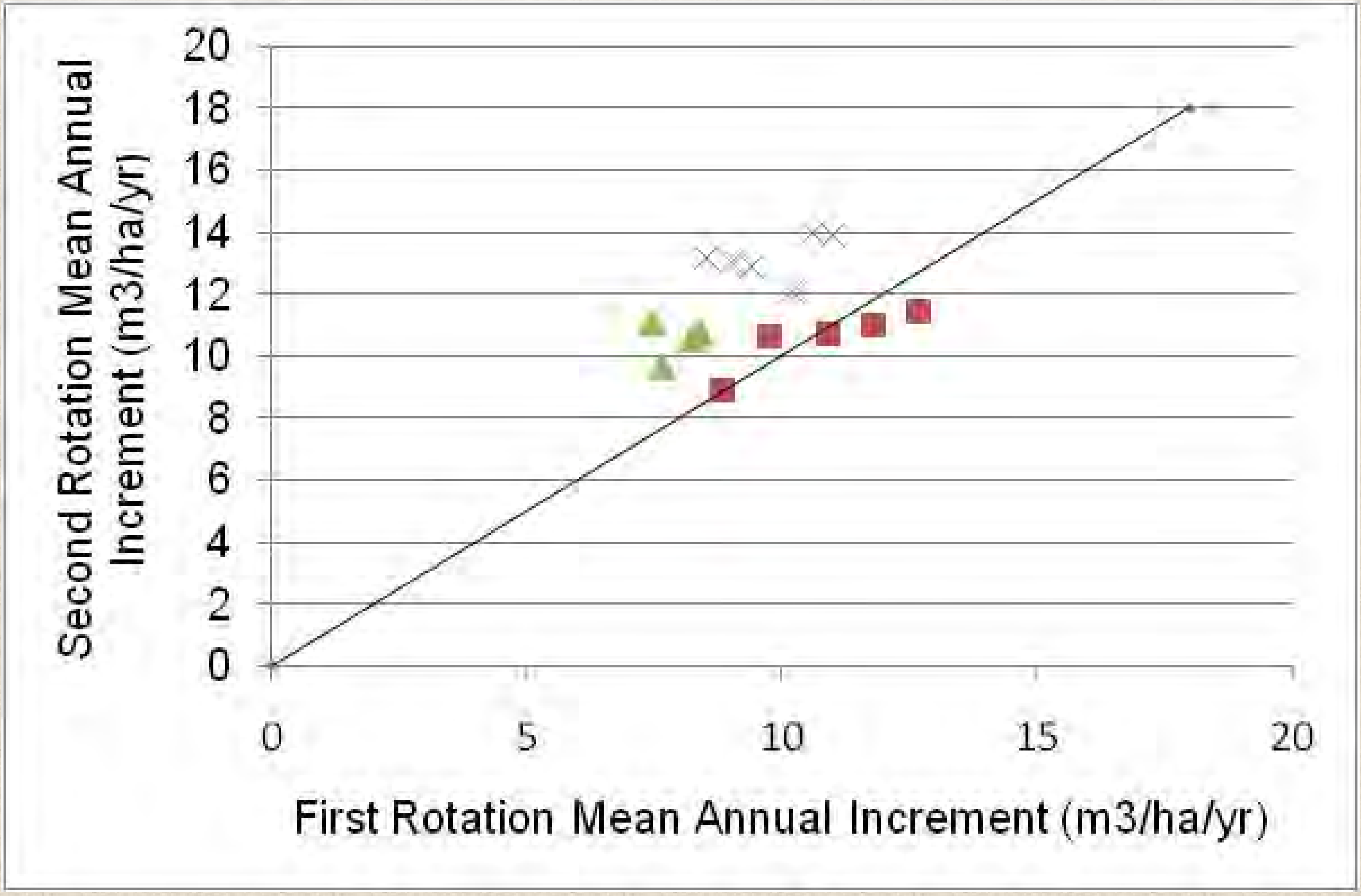
» Baselines

# Comparison of first and second rotation yield (Compartment level)

Yield is merchantable timber expressed as mean annual volume increment ($m^3$/ha/yr)

Yield = (total volume of timber removed at final harvest ($m^3$) plus removals in thinning ($m^3$))
divided by compartment area (ha)
divided by rotation length (years)

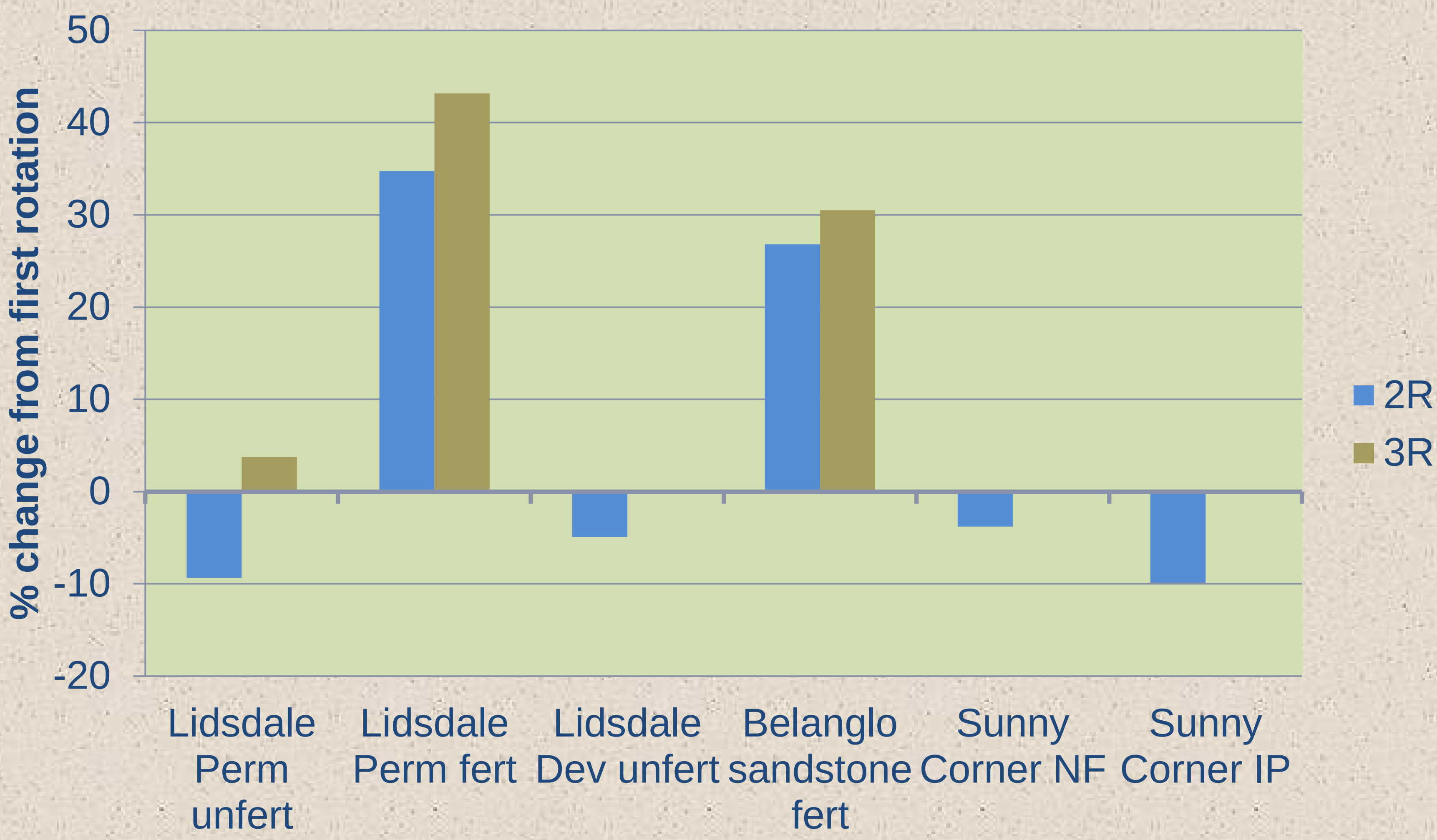
# Compartment yields for first and second rotations



# Comparison of first and second rotation productivity

- Productivity estimation plot based.
- Plots on same location in 1R and 2R.
- Re-measurement of diameters and height.
- Application of same volume equations.
- Productivity calculated as volume mean annual increment ($m^3$/ha/yr) and includes thinnings.

# Plot based productivity changes from first, second and third rotations



# Second rotation productivity related to first rotation and age

# Productivity Conclusion

- Yield and productivity declines occurred on 2R sites where no major change in nutrients status.
- 3R generally higher than 1R.
- Yield and productivity of fertilized 2R sites higher. Residual effect into 3R.
- High nutrient sites 2R productivity lower but yield higher than 1R (deformity factor).
- Early growth may not reflect long term growth.

# Soil Analyses

- Repeat sampling of soils at same points using same analyses or paired site sampling.
- Compared concentrations and quantities (kg/ha) [Earlier models used concentration data only].
- Used in soil-productivity models developed from first rotation and applied soil data from second rotation.

# Relationship of soil factors to productivity

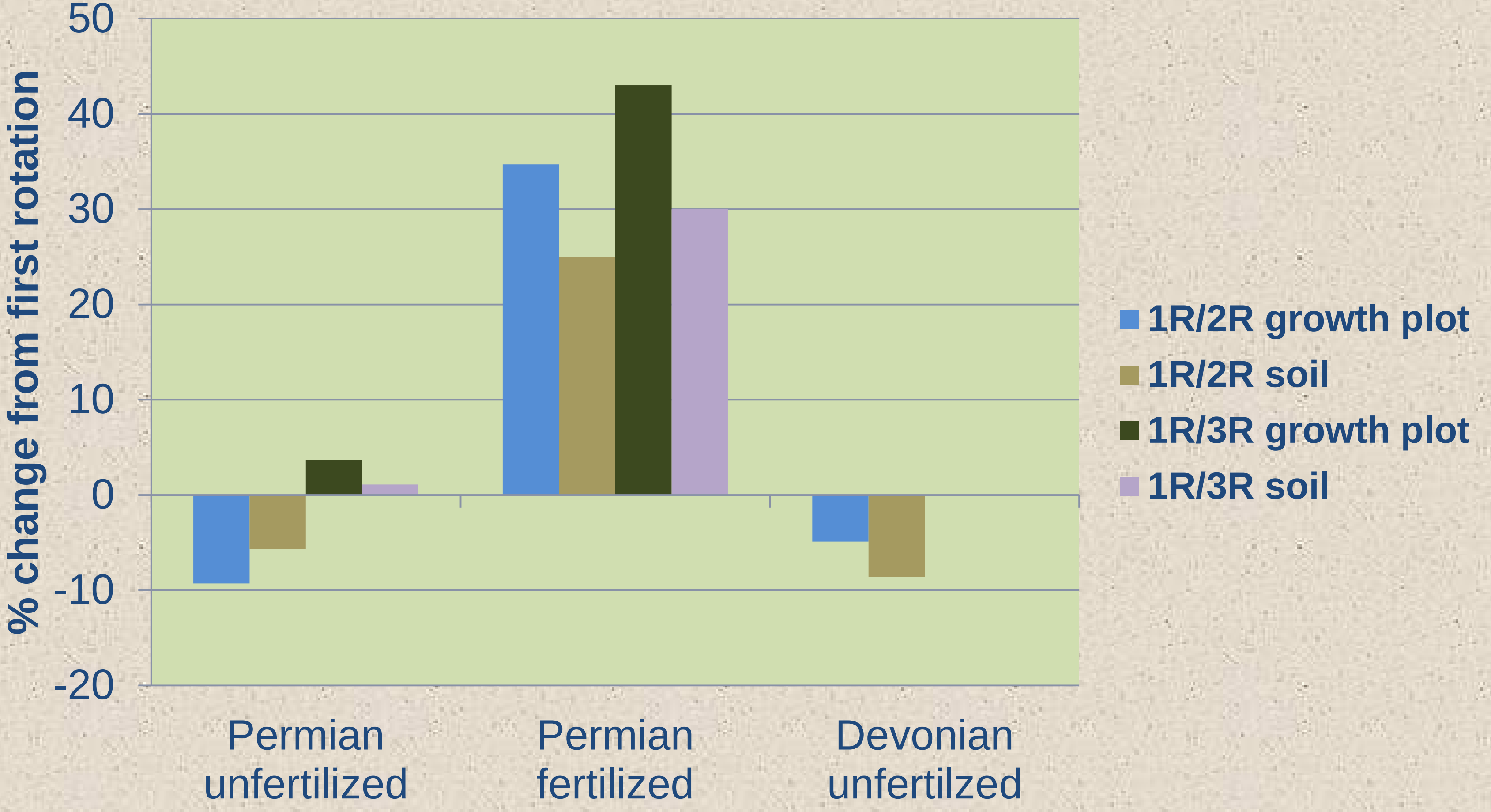
- Functions of productivity and soils based on 1R soils.
- Applied to 2R soils to evaluate change.
- Used quantity (kg/ha) to integrate soil depth data and allow assessment of losses or additions.
- **Lidsdale nutrient quantities (50 cm soil depth) - example**

MAI ($m^3$/ha/yr) =

5.093 +
0.00305*P(kg/ha) +
0.0146*ex Ca(kg/ha) +
0.107*ex K (kg/ha)

$R^2$=0.763
SE=1.803

# Measured growth plot comparisons and estimated from soil changes



# Conclusions on Soil Analyses

- Soil changes over rotations
  - P changes due to fertilizer application.
  - N declines at establishment but then accumulates.
  - Cations decline.
  - Others change depending on site.
- Soil/productivity relationships
  - Changes in productivity can be related to soil nutrient change.
  - Early productivity appears related to N and P.
  - Rotation length changes largely result of cation shift.

# Theoretical Productivity of Second Rotation

Second Rotation Productivity =

Productivity of first (prior) rotation x

f [environment: productive capacity: genetics: management]

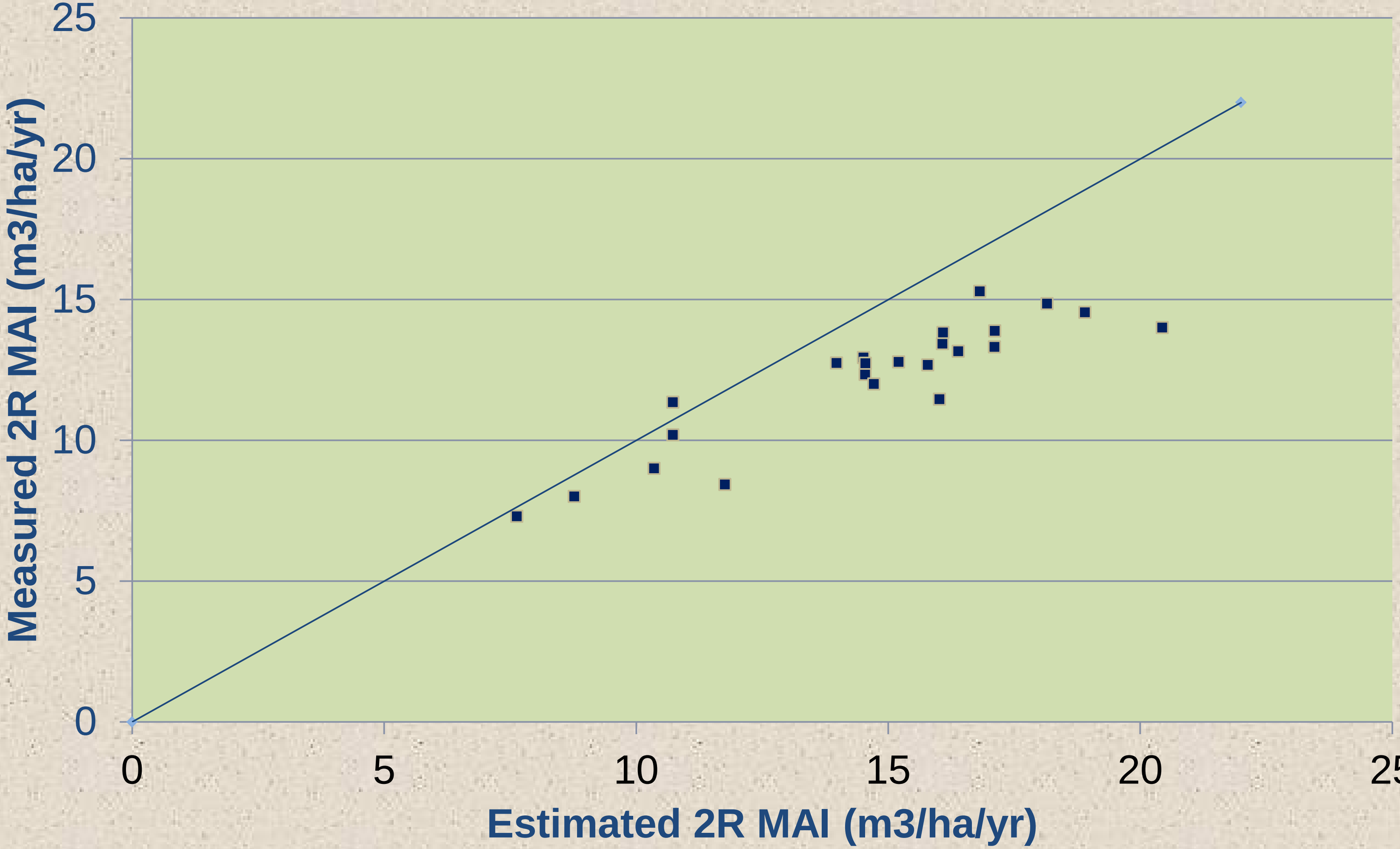
Environment = rainfall, rainfall regime, temperature, other.

Productive capacity = primarily nutrient availability, compaction.

Genetics = tree breeding programs improvements.

Management = site preparation, weed control, fertilizers, other.

# Predicted and measured 2R productivity




**Assume environment +3%, Genetics +9%, Management +9%. 2R measured productivity 12.2 $m^3$/ha/yr, predicted 14.6 $m^3$/ha/yr, 16.6% difference).**

# CONCLUSIONS

- Changes occur in productive capacity between rotations.
- Studies require multiple approaches.
- Type and magnitude of change is related to site.
- Early measured differences (1R/2R) not necessarily maintained through rotation.
- Site differences indicate potential for classification into risk and identify risk factors for change.

# CONCLUSIONS (2)

- Nitrogen and phosphorus availability are major factors in early stand development.

- Calcium, potassium, magnesium and boron impact later even though not at apparently limiting levels.

- Pool sizes based on site type major factors in long term productivity (proportional change).

# MANAGEMENT IMPLICATIONS

## Rotation Length Nutrient Management Systems

Early treatments affect later treatments

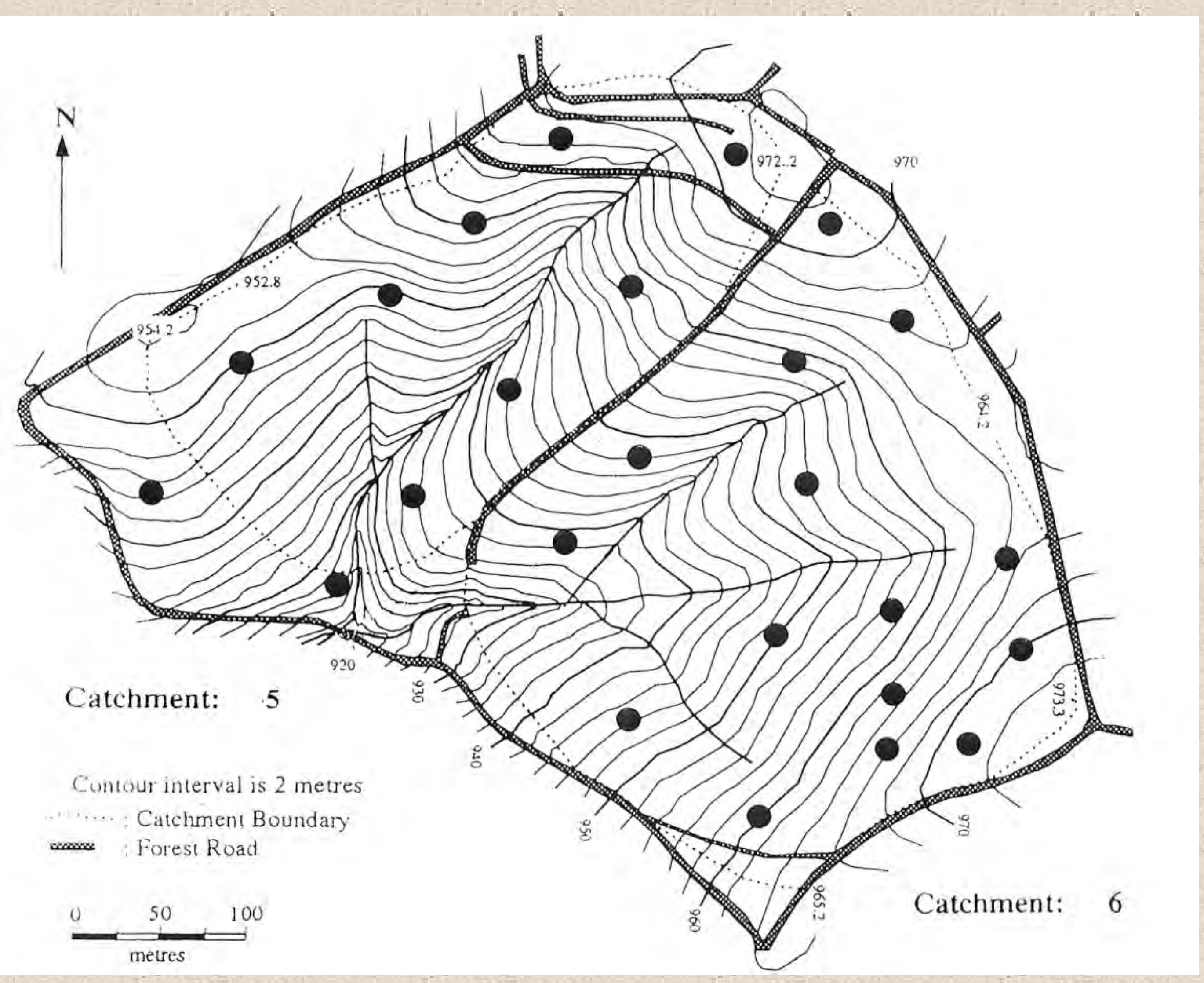
- Site Classification (nutrient status).
- Residue management (including burning).
- Nutrient monitoring.
- Establishment and early fertilization (N & P early).
- Later age fertilization.
- Harvesting removals.
- Soil losses.
- Residual Effects.

# Hydrology Research

- Eleven research catchments established in 1961 by Univ of NSW.
- Monitoring maintained for 25-30 years partially funded by FCNSW.
- Five catchments used for nutrient cycling commencing in 1978 and used in this study.

# Eucalypt stand catchment 5

# Layout of Catchments 5 and 6



# Catchment 3 V-notch weir

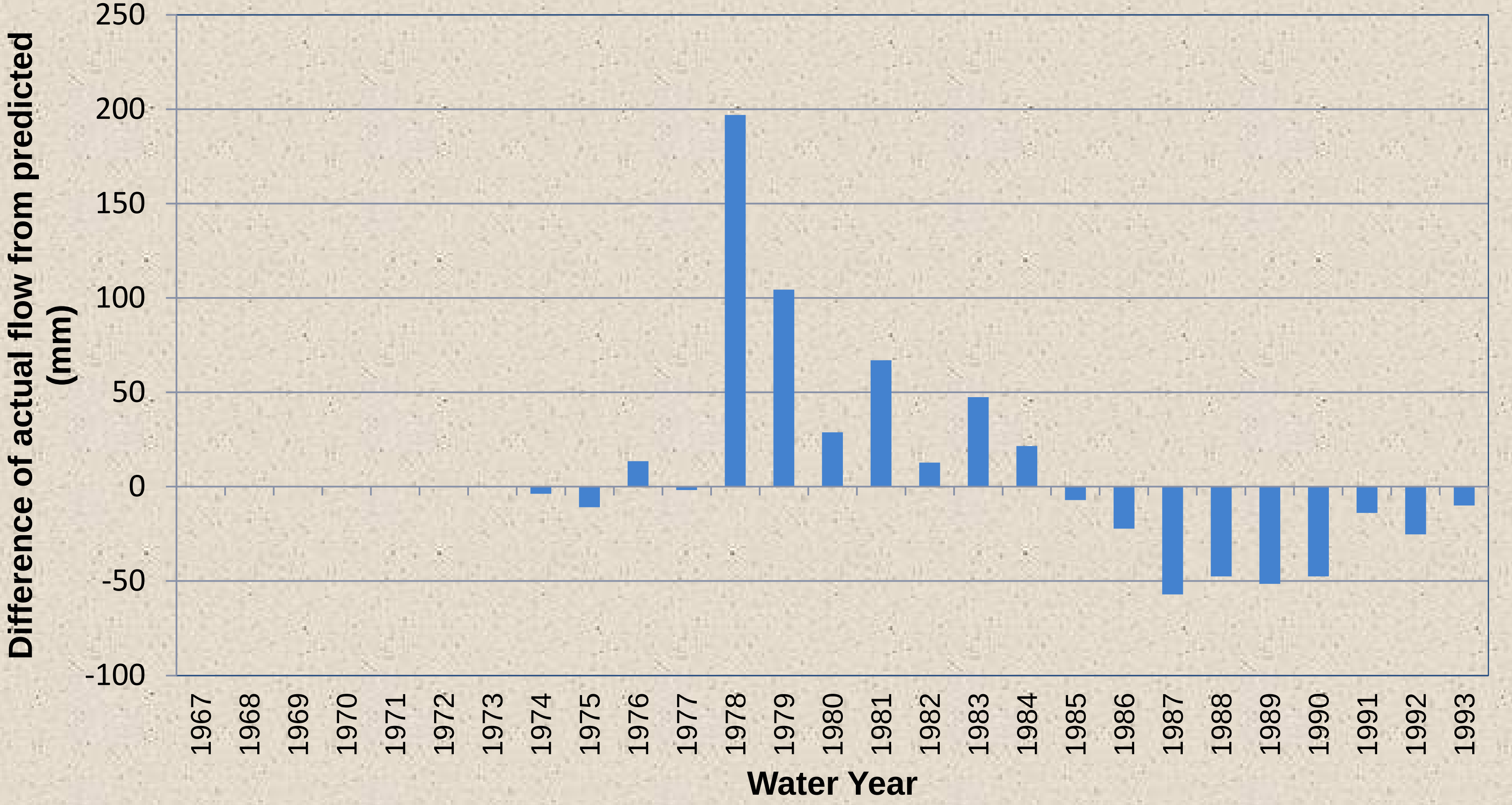
# Water Balance (mm/yr)

Precipitation (P) = Interception (I) +
Evapotranspiration (Et) +
Soil moisture change (ΔS) +
Runoff (R) +
(Deep seepage (Dg))

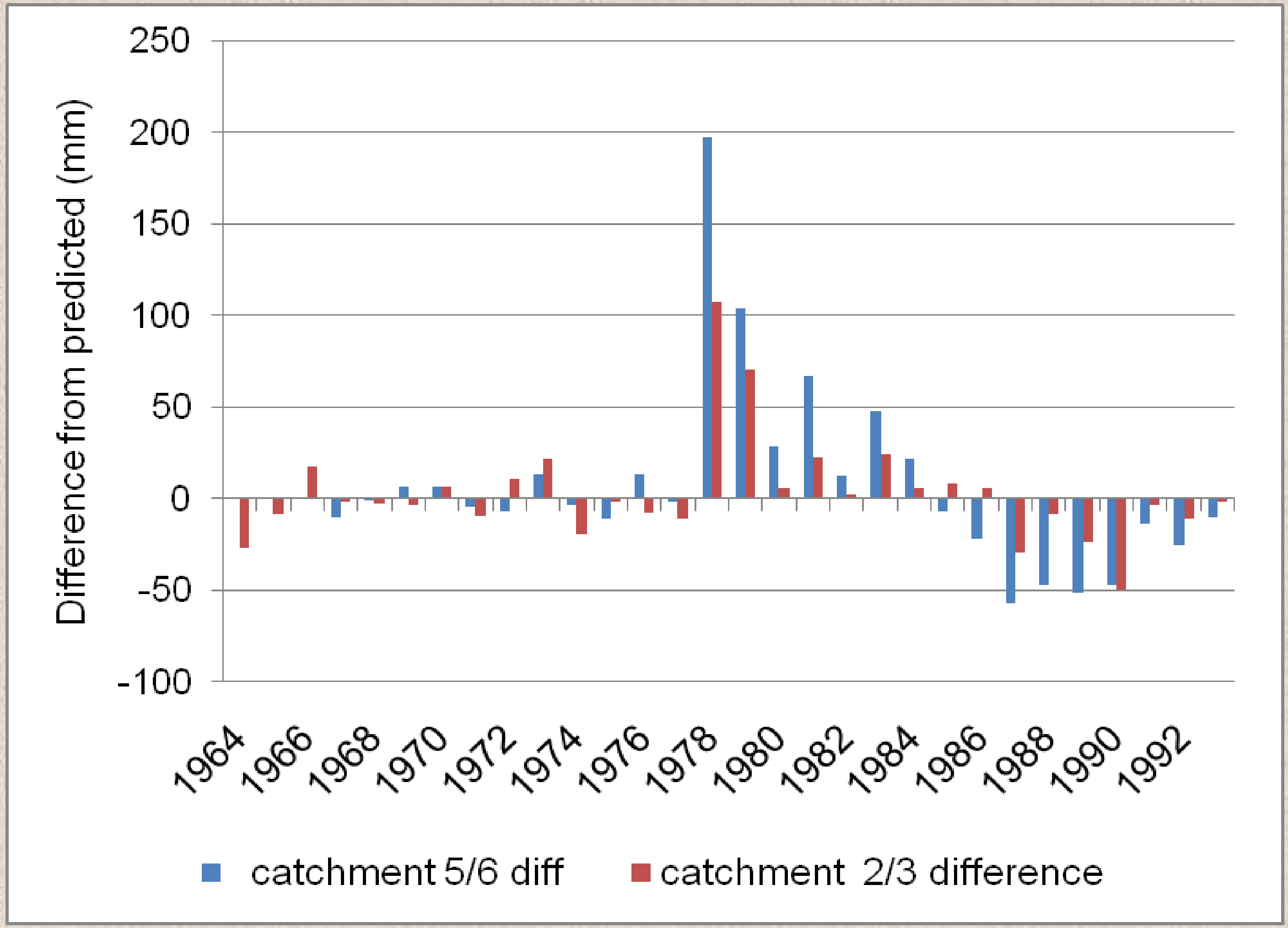
Interception (I) = Precipitation (P) –
Throughfall (Tf) –
Stemflow (Sf)

Stand Level Water Use Efficiency = NPP /Et

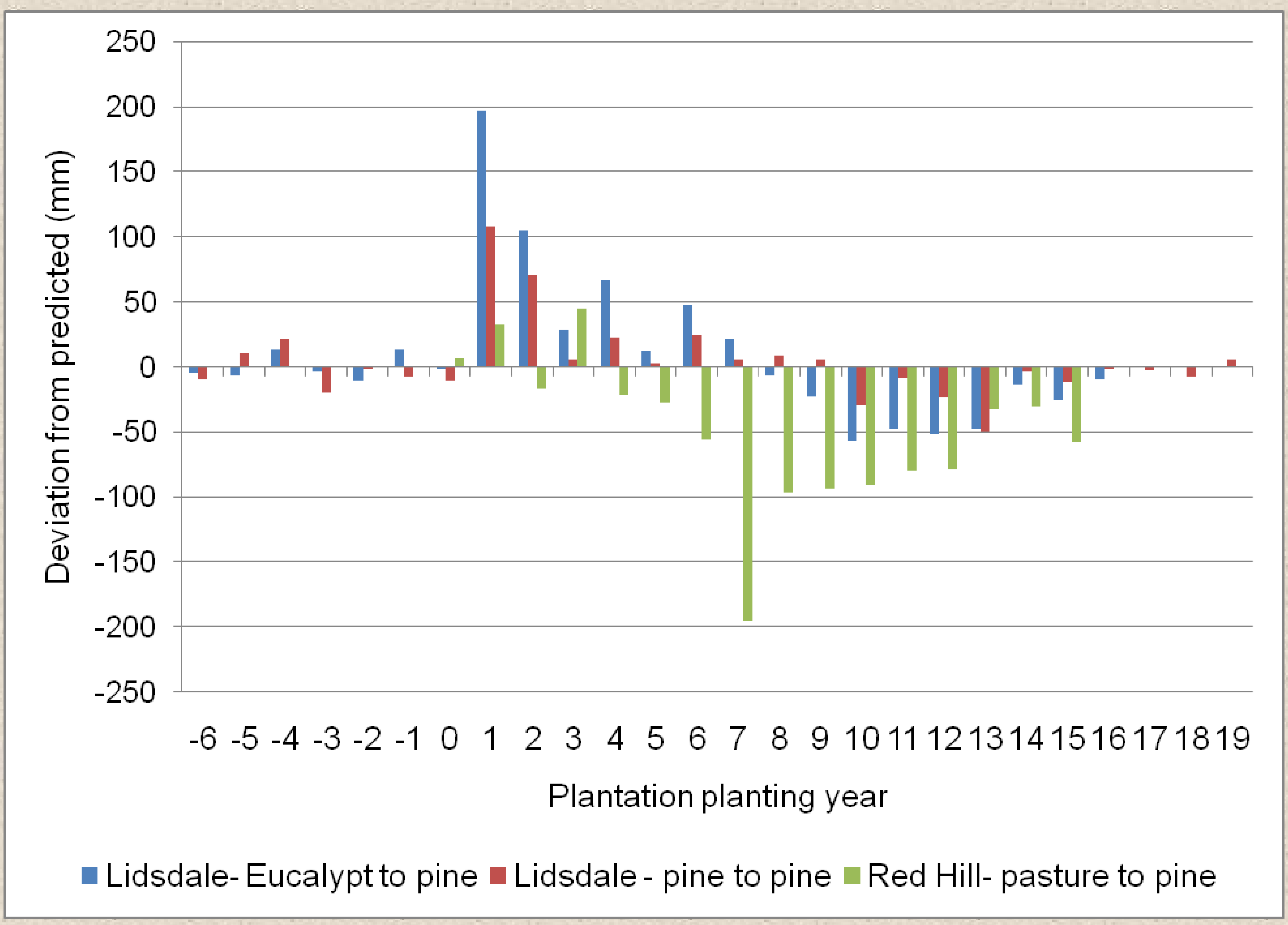
# Effect of first rotation pine establishment on water yield (eucalypt to pine)



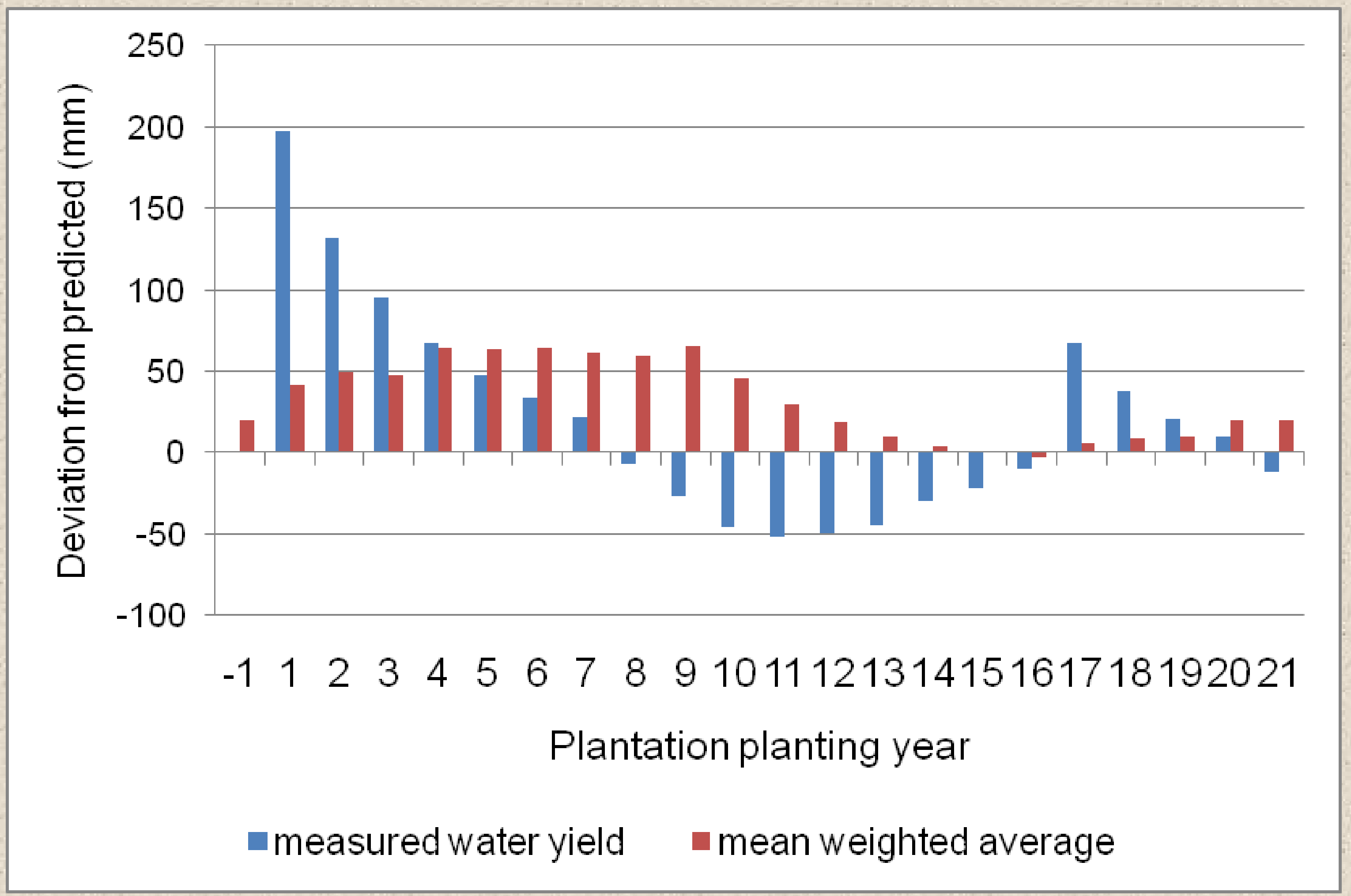
# Runoff deviations after plantation establishment eucalypt to pine and pine to pine



# Effects of pine establishment on water yield (three comparisons)



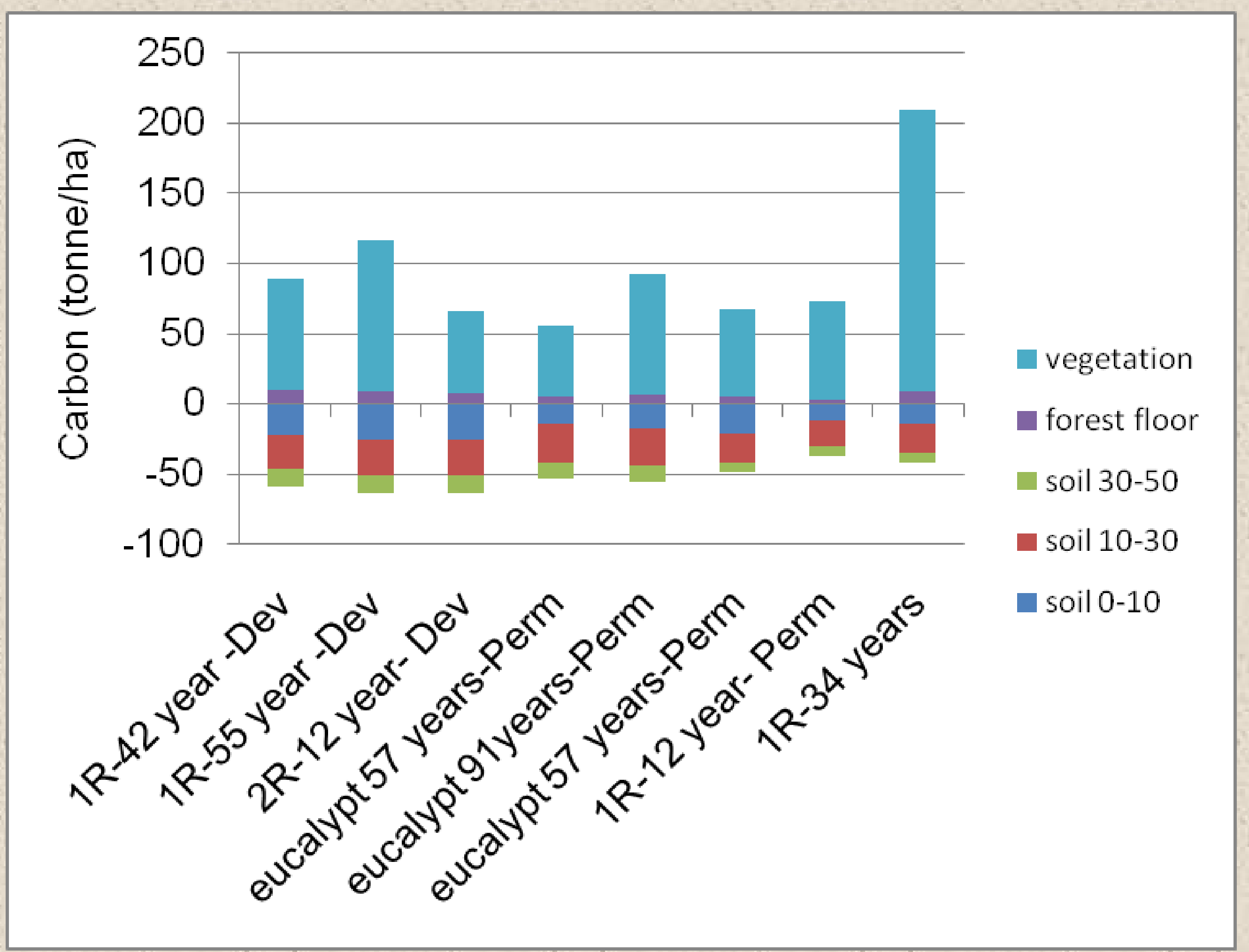
# Larger catchment (nine age classes) compared with single planting.  Thinnings included.



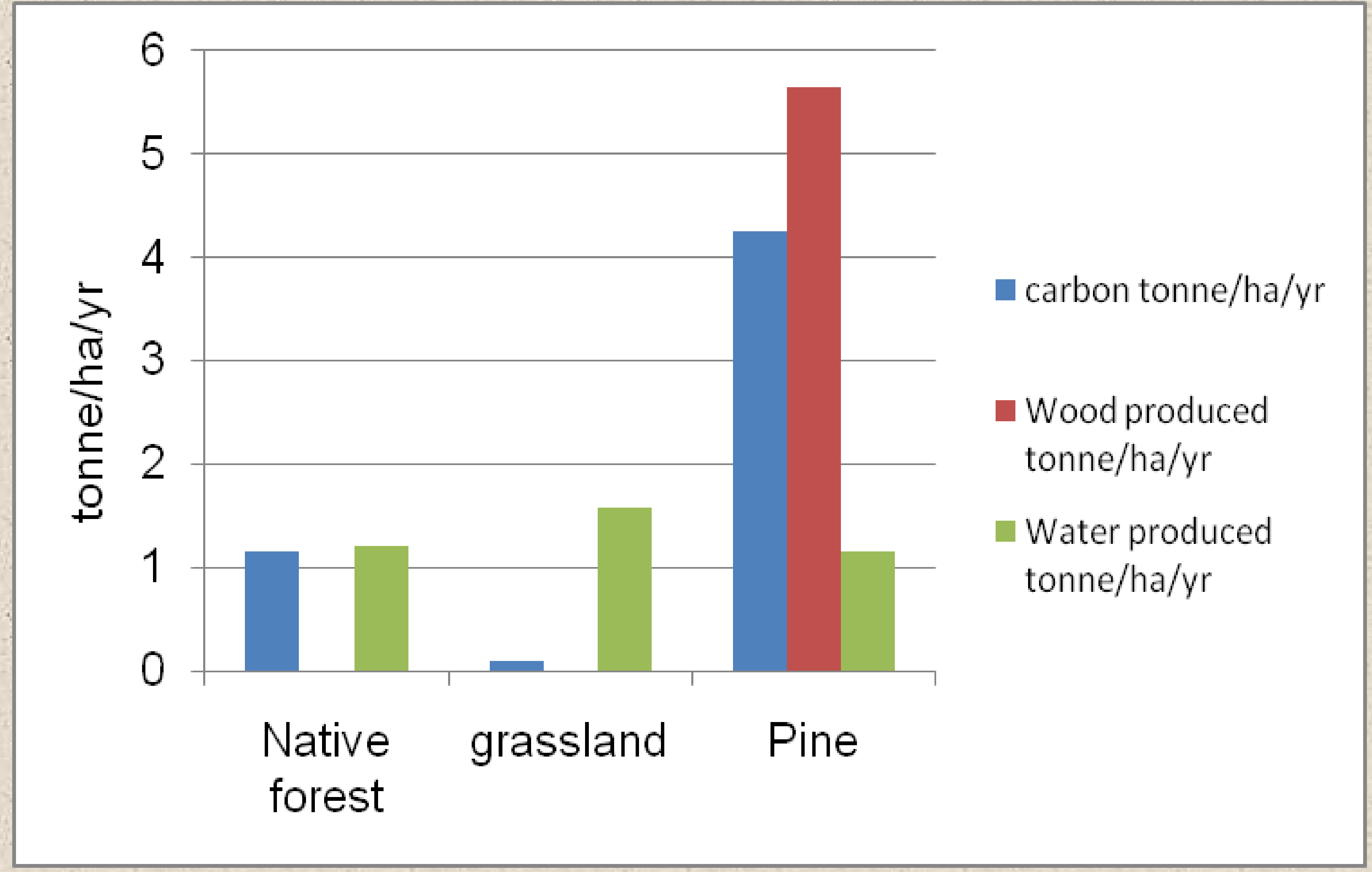
# Hydrology Research

- Hydrology research in plantations is limited in extent.
- Integrated hydrology research (integrated with forest productivity and site types) is more limited.
- Scaling-up of research data to plantation scale is difficult.
- Require cooperative research.

# Carbon distribution in catchments at different times



# How do we analyse and compare different values?



# GENERAL CONCLUSIONS

- Integrated long term research is both valuable and important for forest management.  Greatest impediment is loss of data.
- Short term analyses may not be indicative of rotation length results.
- Inter-rotational changes in productivity occur but reasons are site specific.  Build as risk factor into site classification.
- Fertilizers to be part of whole of rotation nutritional management.
- Hydrology research critical but needs cooperative and multi-disciplinary approach.
- Carbon (and nutrient) budgets related to land use.  Carbon accretion function of productivity and high water demand.