www.csiro.au

Forest Fertilization and Environmental Effects
Trends Compared to Agriculture

Philip Smethurst

6th November 2009

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Aims of Presentation

- Overview of practice of forest fertilization and environmental effects
- Key research contributions
- Comparisons with agriculture
- Identify knowledge gaps

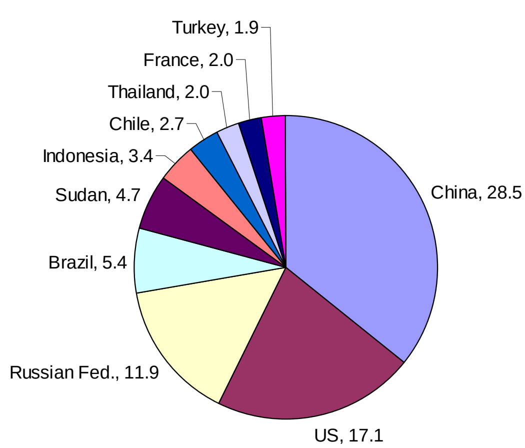
This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

World Food and Fibre Areas

Plantation area	140	Mha
Annual increase (2%)	2.8	Mha
Total food and fibre production area (3% forest plantations)	4700	Mha

(FAO 2006)

Top 10 Countries for Plantation Area (Mha)



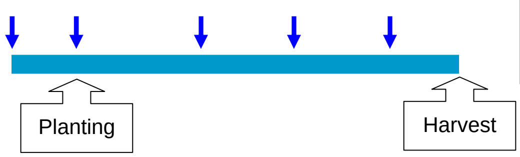
(FAO 2006)

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Where are the Eucalypt Plantations?

Fertilizer Timing vs Crop Cycle

Fertilizer Applications



- Later applications preferred in plantation forestry
- Otherwise similar to agriculture

Crop	Life Cycle (years)	Harvest Cycle (years)
Forest plantations	4-80	4-80
Agriculture:-		
Perennial horticulture	2-20	1
Annual crops	1	1

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Nitrogen Fertilizer Rates and Forms

Crop, Country	Nitrogen		
	Average rate applied (kg ha^{-1} $year^{-1}$)	**Common high rate** (kg ha^{-1} $application^{-1}$)	**Common forms***
Forest plantations			
Eucalyptus, Brazil	7	20	U, AS, MAP. DAP
Pinus, USA	6	224	U, DAP
Pinus, Australia	4	208	U, AS
Eucalyptus, Australia	10	104	AS, U
Agricultural systems, Australia			
Dairy	20	200	U
Sugarcane	160	300	U
Horticulture	100-800	8-64	U, DAP, MAP, KN
Cereals, oilseeds	30	200	U, AS

(May et al. 2009)

Potassium Fertilizer Rates and Forms

Crop, Country	Potassium
	Average rate applied (kg ha^{-1} $year^{-1}$)
Forest plantations	
Eucalyptus, Brazil	8
Pinus, USA	0.1
Pinus, Australia	0.5
Eucalyptus, Australia	2.8
Agricultural systems, Australia	
Dairy	2
Sugarcane	70
Horticulture	107
Cereals, oilseeds	2

(May et al. 2009)

Fertilizer Frequency

Frequency of application is the main difference between plantation forestry and agricultural fertilizer practices

Generally:

annual or sub-annual in agriculture and

2- to 20-yearly in forest plantations

Hence:

Average annual rates of fertilization are relatively low in in plantation forestry

Indicators of Fertilizer Requirements: Examples

Species, Country	N	P	K
Pinus, south-eastern USA	LAI	Soil: Bray2-P	
Eucalyptus, Australia	LAI		
	Soil: total-N	Soil: $CaCl_2$-P	
Pinus, Australia	LAI		Foliage: K
	Litter: total-N	Litter: total-P	
Eucalyptus, Brazil	Soil: OM	Soil : resin-P and clay	Soil: exch-K and clay

Indicators are generally poorly developed due to:
- Large plot size
- Long duration
- Low level of investment in R&D

Australian N and P Emissions by Landuse

Crop	Gaseous Losses (N_2O)	Water Losses N	Water Losses P
	(t/year)		
Forest plantations:-			
Eucalypt	140	170	40
Pine	70	80	20
Agriculture:-			
Pasture	500	103 900	7720
Sugarcane	1900	1100	200
Horticulture	2300	1500	340
Cereals, oilseeds	4410	52500	7190

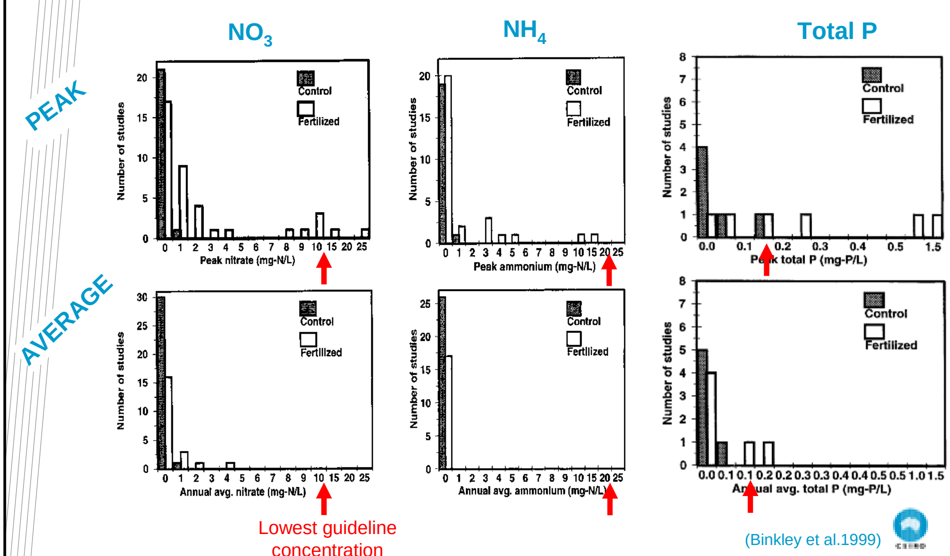
Lower forestry N and P emissions due to:
- Smaller area
- Low average annual rates of fertilization
- Low unit transfer to gas or water

(May et al. 2009)

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Stream Water N and P after Forest Fertilization (n = 40 studies)

Rarely are N or P concentrations a concern



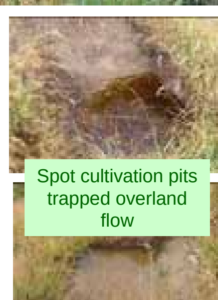
(Binkley et al.1999)

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Streamside Management Zone (SMZ) Paired-Catchment Experiment

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

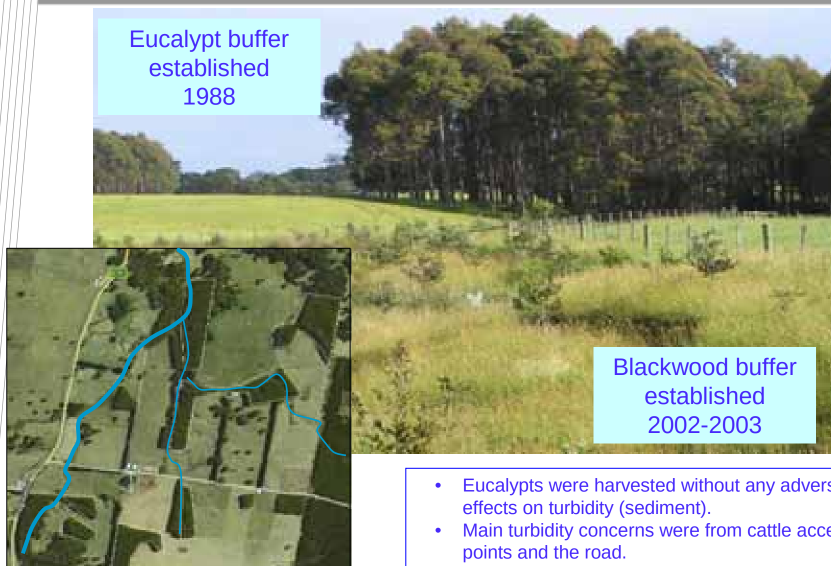
Turbidity was lower at the SMZ weir during base-flow and low-rainfall (Feb 25 mm storm)



Spot cultivation pits trapped overland flow

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

SMZ Harvesting Study



- Eucalypts were harvested without any adverse effects on turbidity (sediment).
- Main turbidity concerns were from cattle access points and the road.

Nitrogen Use Efficiency for Biomass (Biofuel)

Crop	Fertilized NUE (kg yield per kg N fertilizer)		Reference
	Minimum	Maximum	
Corn	1.2	2.6	Dobermann et al. 2002*
Cereals	124	488	Dobermann 2007*
Perennial pastures	32	144	Brouder et al. 2009
Pine plantations – high N	16	44	Albaugh et al. 2004
Eucalypt plantations – low N	2222	13,545	Stape et al. 2004

* Includes harvest i

Also need to consider:
- biomass-to-biofuel efficiencies
- other input efficiencies (energy, water etc.)
- costs

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Distinctive Aspects of Forest Soils for Consideration in Relation to Fertilization

- Nutrient cycling - external and internal
- Erosion
- Irrigation
- Soil temperature
- Utilized soil depth
- Stoniness
- Surface organic horizon

(Comerford 2002)

Nutrient Flux Density Approach for Hydroponic Culture

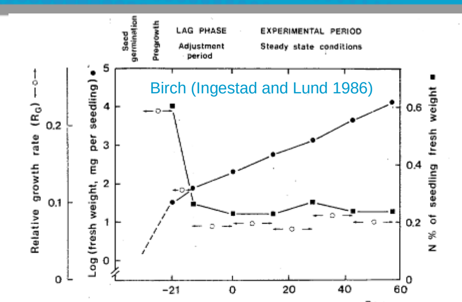
Method

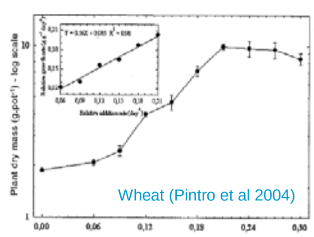
- Mist culture
- One limiting nutrient added at exponentially increasing rate
- Other nutrients non-limiting

Advantage

- Defined exponential growth rate (R_G=R_N)
- Constant internal nutrient concentrations

(Asher and Cowie 1970, Ingestad 1971)





This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

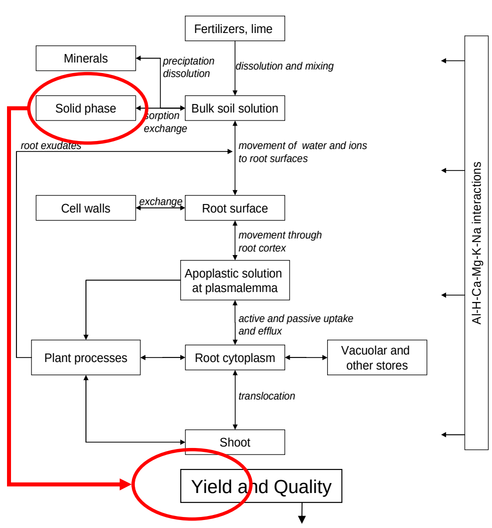
CEC and Base Cations

- Many forest soils: high OM, low pH
- pH not related to CEC
- Base saturation and CEC not related to cation availability
- Including H and Al assists, but many unknowns
- Soil solution versus exchangeable cations provide different interpretations for base cation availability
- Links needed between pH, H, Al, solution cations, availability, uptake and growth

Implications for agriculture as soils acidify and OM is sequestered

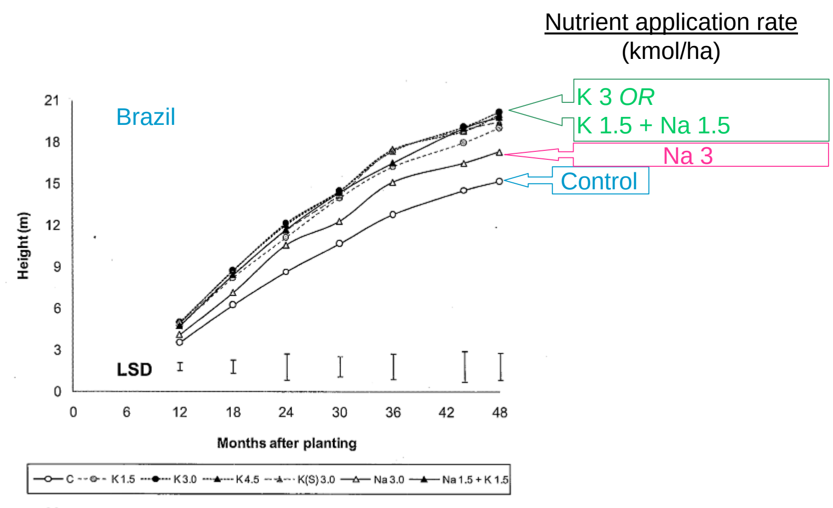
(Ross et al. 2008, Smethurst et al. 2008)

Base Cation Linkages Needed



This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Na partial substitution for K: *Eucalyptus* in Brazil and Congo



(Almeida et al 2009)

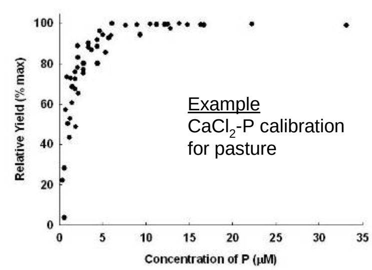
This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Indicator Concerns

- Few indicators are well-validated, i.e. lack replication in space and time
- User-pays philosophy has reduced resources available for traditional soil and foliar calibration research

⇒ old calibrations not up-dated;

⇒ new calibrations not developed.

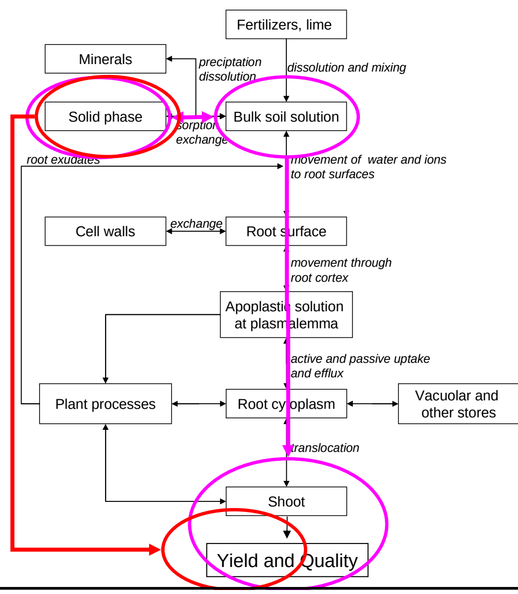


Example
$CaCl_2$-P calibration for pasture

Response: Rely less on empirical calibrations and more on generic, mechanistic indicators

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

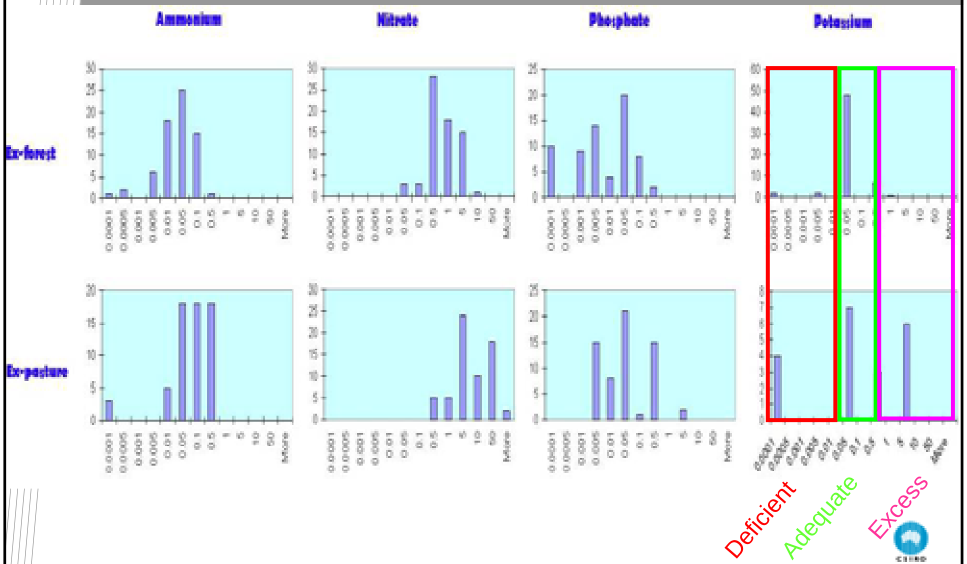
Soil Solution Method



Soils Solution Method

1. Water content measurement
2. Paste preparation c. 5:1 soil:water
3. Liquid sampling and analysis
4. Dilution and buffering considered
5. Potentially portable

Nutrient Concentrations in Soil Solution (mM): Frequency Distributions

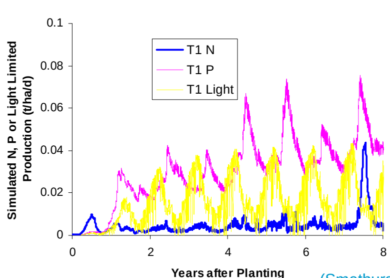


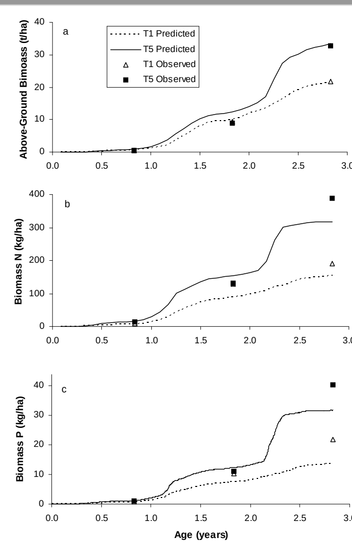
Nutrients Included in Productivity Modelling (CABALA-PCATS model)

Plant Growth (1D)
via light capture and
modifiers for water balance and temperature

N
CERES principles

P (or cations)
solute transport theory





(Smethurst et al. 2004)

Major Knowledge Gaps

1. New and up-dated soil analysis calibrations
2. Mechanistic knowledge that links Al, H, base cation availability, and growth
3. Plant growth models that mechanistically and simultaneously include major nutrients

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Sustainable Ecosystems Division
Sustainable Agriculture Flagship and
Water for a Healthy Country Flagship

Philip Smethurst
Soil and Water Scientist

Phone: 03 6237 5653
Email: Philip.Smethurst@csiro.au
Web: http://www.csiro.au/org/CSE.html

www.csiro.au

Thank you

Contact Us
Phone: 1300 363 400 or +61 3 9545 2176
Email: enquiries@csiro.au Web: www.csiro.au

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.