Soil carbon and nutrient pools, microbial properties and gross nitrogen transformations in adjacent natural forest and hoop pine plantations of subtropical Australia

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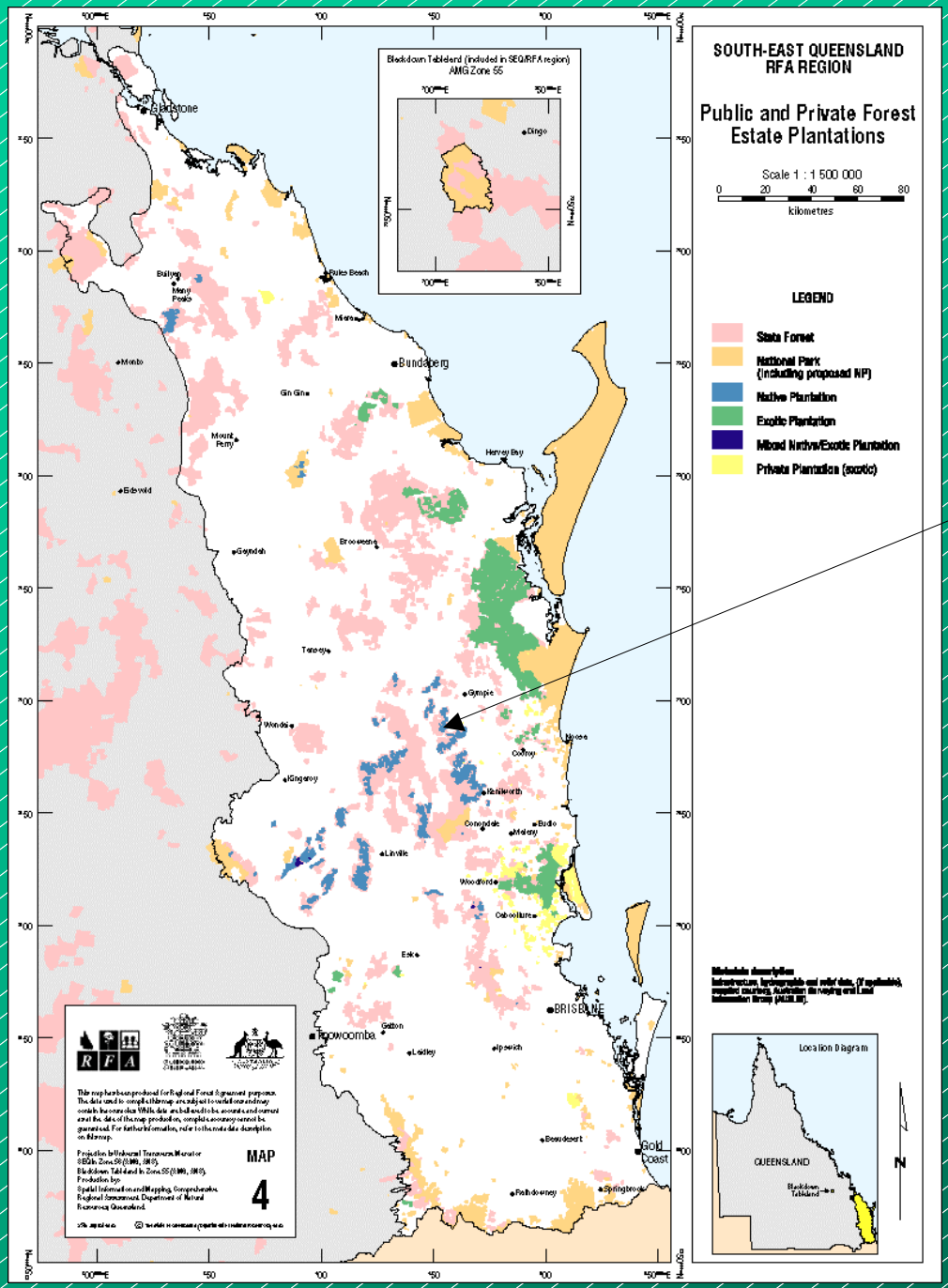

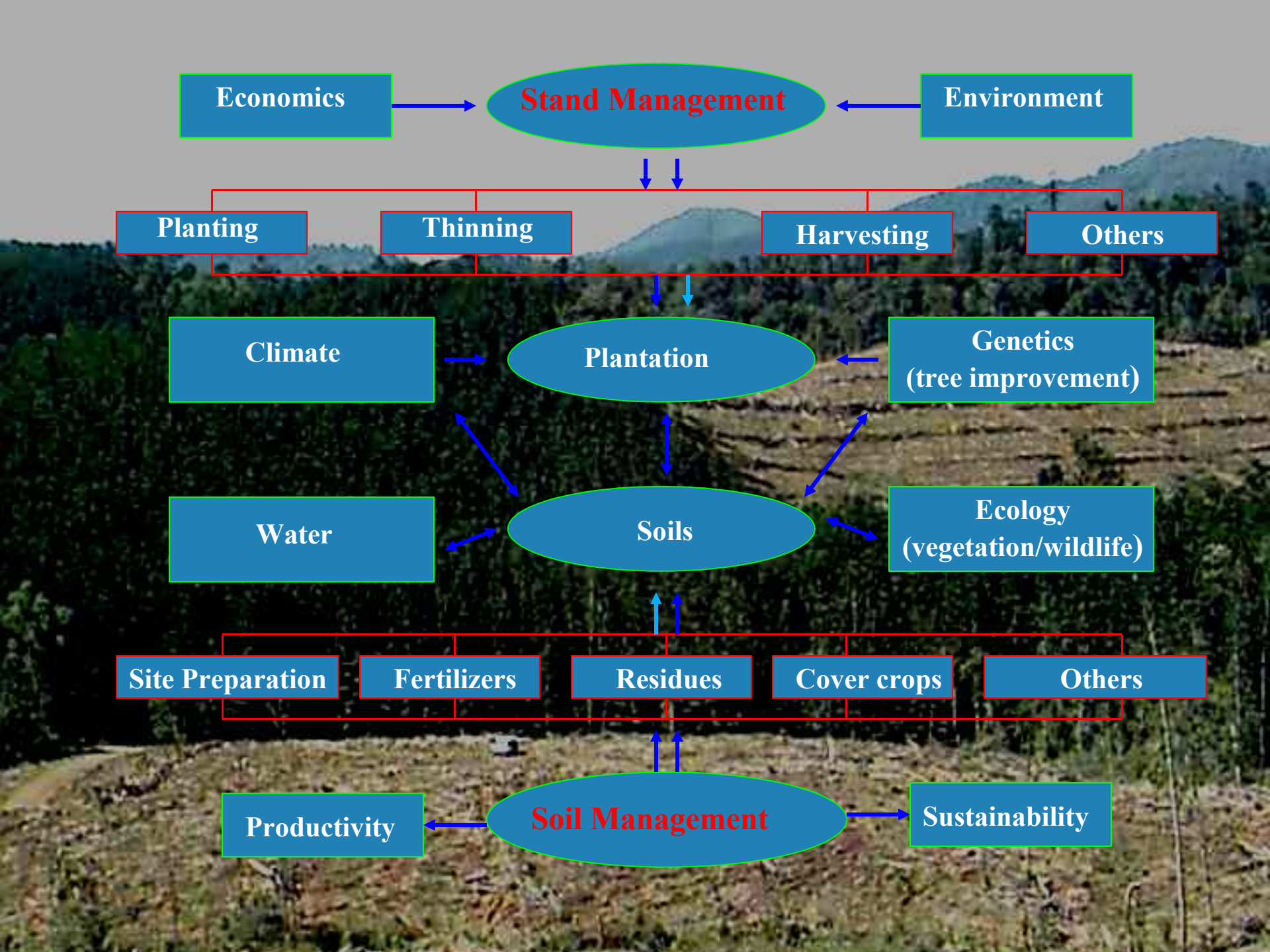
Economics
Stand Management
Environment
Planting
Thinning
Harvesting
Others
Climate
Plantation
Genetics
(tree improvement)
Water
Soils
Ecology
(vegetation/wildlife)
Site Preparation
Fertilizers
Residues
Cover crops
Others
Productivity
Soil Management
Sustainability

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- Introduction;
- Objectives;
- Materials and methods;
- Results and discussion;
- Conclusions
- Acknowledgement

Introduction

- An improved understanding of soil carbon (C) and nutrient pools as well as microbially-mediated processes under different forest types and management is required for improving forest productivity and sustainability;
- Spatial and temporal variations in these soil chemical and biological properties can be influenced by forest types and management, but information on such variations is lacking.

Objectives

- To quantify the impacts of forest types and management practices on soil C and nutrient pools in adjacent natural forest (NF) and hoop pine plantations of ca. 50-year-old first rotation (1R) and 1-year-old second rotation (2R) in southeast Queensland, Australia;
- To assess microbial properties and gross nitrogen (N) transformations in top 10 cm soil under the adjacent natural forest, 1R and 2R hoop pine plantations.

Materials and methods

- Experimental sites and soil collections
- The three adjacent forest sites are located at Yarraman State Forest (26°52′ S, 151°51′ E);
- Subtropical climate: mean annual rainfall – 791 mm (ranging from 433 to 1110 mm);
- Five transects spaced 3 m apart with 9 sampling points along each transect (1.2 m between 2 adjacent sampling points) were selected for each of the 3 forest plots (9.6 m x 12.0 m), with 45 20-cm soil cores (ca. 7.5 cm in diameter) taken in August 2000 and separated into 0-10 and 10-20 cm soil depths.

Materials and methods (continued)

- Each (about 30 by 100 m) of the three research areas, near the first grid-sampling areas under NF, and 1R and 2R hoop pine plantations, was divided into 5 subplots;
- A total of 25 soil cores (0-10 cm) were randomly collected in October 2001 with an auger (ca. 7.5 cm diameter) from each subplot and bulked (well mixed);
- The soil samples (0-10 and 10-20 cm) via the grid-sampling were analysed for total C, total N, $\delta^{13}C$ and $\delta^{15}N$ on mass spectrometer at Griffith University;

Materials and methods (continued)

- Soil chemical and physical properties were determined on the top 10 cm soil samples collected in October 2001; these include: soil pH, CEC, exchangeable cations (K, Ca, Mg, Mn), total P, total K, bulk density, particle sizes, and conductivity at DPI&F Chemistry Laboratory at Indooroopilly, Brisbane;
- Soil microbial C and N, respiration, and gross N transformations (assayed by anaerobic incubation with ^{5}N-labelled solution) were determined at Griffith University.

Results and discussion

- Soil total C and N, $\delta^{13}C$ and $\delta^{15}N$;
- Estimated sampling sizes for soil total C and N, $\delta^{13}C$ and $\delta^{15}N$;
- Other soil chemical and physical properties;
- Soil microbial properties;
- Soil gross N transformations;
- Relationships among the soil microbial properties and chemical properties.

Table 1 Soil total carbon (C) and nitrogen (N), and stable C and N isotope composition ($\delta^{13}C$ and $\delta^{15}N$) in 3 adjacent forest ecosystems (NF - natural forest, 1R and 2R – first and second rotation hoop plantations)

Forest type	TC (%)	TN (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
	0-10 cm			
NF	6.3ab[a]	0.55a	-25.89b	10.02a
1R	6.4a	0.58a	-25.36a	8.32b
2R	5.8b	0.49b	-25.53a	8.03b
	10-20 cm			
NF	4.7a	0.42a	-25.32b	10.20a
1R	3.7b	0.37b	-24.54a	9.04b
2R	3.0c	0.29c	-24.67a	8.72b

[a]Means within a column for a given soil depth followed by the same letter are not different from each other at 5% level of significance.

Table 2 Sample size required for estimation of mean soil total C and N with the sample mean relative error at 10% (RE10%) and 20% (RE20%) with 95% confidence

Forest type	Total C (%)		Total N (%)	
	RE10%	RE20%	RE10%	RE20%
	0-10 cm			
NF	13	6	12	5
1R	24	9	16	7
2R	39	13	20	7
	10-20 cm			
NF	13	6	11	5
1R	48	15	31	10
2R	30	10	20	7

Table 3 Sample size required for estimation of mean stable C and N isotope composition ($\delta^{13}C$ and $\delta^{15}N$) with the sample mean relative error at 10% (RE10%) and 20% (RE20%) with 95% confidence

Forest type	$\delta^{13}C$ (‰)		$\delta^{15}N$ (‰)	
	RE10%	RE20%	RE10%	RE20%
	0-10 cm			
NF	3	3	23	8
1R	3	3	17	7
2R	3	3	8	4
	10-20 cm			
NF	3	2	9	5
1R	3	3	10	5
2R	3	2	6	4

Table 4 Soil (0-10 cm) pH, cation exchange capacity (CEC), total P and total K in 3 adjacent forest ecosystems (NF - natural forest, 1R and 2R – first and second rotation hoop plantations)

Forest type	pH	CEC	Total P	Total K
	(1:5 H_2O)	(cmol kg^{-1})	(mg kg^{-1})	(mg kg^{-1})
NF	5.0a[a]	35.7a	1477a	701b
1R	6.0a	38.7a	1116b	1191b
2R	5.4a	28.5a	748c	5588a

[a]Means within a column followed by the same letter are not different from each other at 5% level of significance.

Table 5 Soil (0-10 cm) microbial biomass C (MBC) and N (MBN), CO_2 respiration (CO_2-C, mg kg^{-1} h^{-1}) and metabolic quotient (qCO_2-C, µg mg^{-1} MBC h^{-1}) in 3 adjacent forest ecosystems

Forest type	MBC	MBN	CO_2-C	qCO_2-C
	(mg kg^{-1})	(mg kg^{-1})		
NF	951a[b]	113.1a	0.503a	0.552a
1R	686a	102.3b	0.414a	0.672a
2R	930a	142.6a	0.571a	0.626a

[a]Means within a column followed by the same letter are not different from each other at 5% level of significance.

Table 6 Soil (0-10 cm) potential mineralizable N (PMN), gross N mineralization (*M*) and immobilization (*I*) in 3 adjacent forest ecosystems[a]

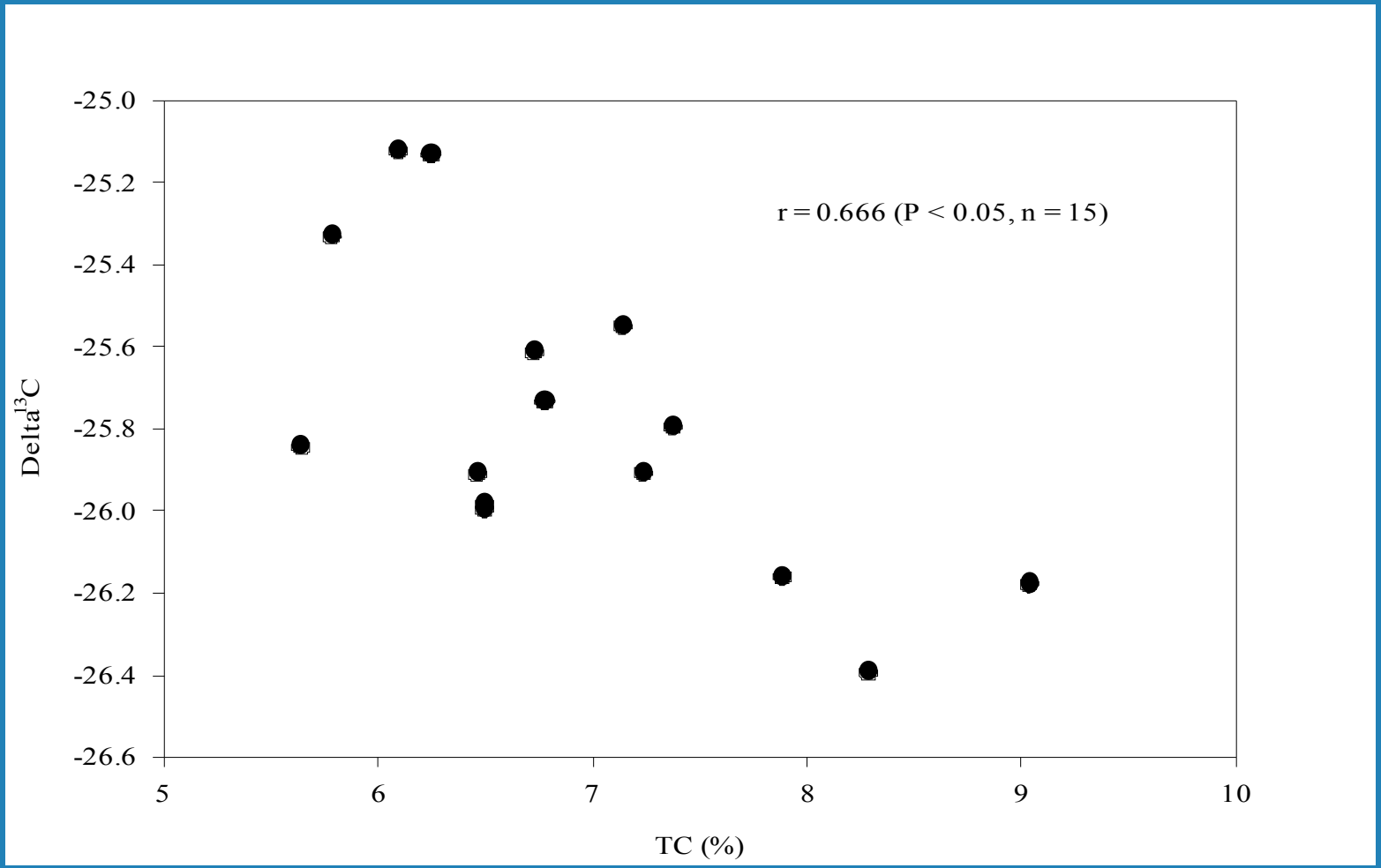
Forest type	**PMN**	*M*	*I*
	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})
NF	114.6a[b]	140.2a	25.6b
1R	62.6b	78.3b	15.8c
2R	58.7b	95.9b	37.2a

[a]PMN, *M* and *I* were obtained with the 5 g soil incubated for a week at 40 °C with 5 μg $^{15}NH_4$-N in 50 ml solution (99% ^{15}N excess); and [b]Means within a column followed by the same letter are not different from each other at 5% level of significance.

Relationships among the soil microbial properties and chemical properties

- There were significant correlations between: (a) soil microbial biomass C and N ($r = 0.655$, $P < 0.01$); and (b) soil microbial biomass N and metabolic quotient (qCO_2-C) ($r = 0.646$, $P < 0.01$);
- Soil total C was significantly related to: (a) total N ($r = 0.945$, $P < 0.01$); (b) potential mineralizable N (PMN) ($r = 0.804$, $P < 0.01$); and (c) gross N mineralization (M) ($r = 0.807$, $P < 0.01$);
- There were significant correlations between: (a) soil total N and PMN ($r = 0.833$, $P < 0.01$); (b) soil total N and M ($r = 0.846$, $P < 0.01$); and (c) PMN and M ($r = 0.976$, $P < 0.01$).

Relationship between soil total C and stable C isotope composition ($\delta^{13}C$, ‰)



Conclusions

- In the 0-10 cm depth, soil total C and N were significantly higher under NF and 1R than those under 2R, while soil total C and N in the 10-20 cm depth were the highest with NF, followed by 1R and then 2R;
- In the top 20 cm soil, soil $\delta^{13}C$ was significantly lower with NF than with 1R and 2R, but soil $\delta^{15}N$ was higher with NF than with 1R and 2R;
- The sample size for detecting soil $\delta^{13}C$ (n: 2-3) appears to be much lower than those for soil total C (n: 6-48), total N (n: 5-31) and $\delta^{15}N$ (n: 4-23);

Conclusions

- In the 0-10 cm depth, soil total P was highest with NF, followed by 1R and then 2R, while soil total K was higher with 2R than those with NF and 1R; there were not significant differences in other soil chemical and physical properties among the NF, 1R and 2R;
- Soil microbial biomass C and N, respiration and metabolic quotient generally did not differ among the NF, 1R and 2R, perhaps due to their too sensitive to spatial variations in soil chemical, physical and biological environments;
- Soil N transformations (PMN, M and I) were rather sensitive to the forest type and management.

Acknowledgement

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Any comments and questions?