N_2 fixation by natural stands of tree and shrub legumes in Botswana: Implications for climate change scenario

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Presentation Outline

- Background
- Objectives
- Methodology
- Results
- Conclusions

Background

- Botswana semi arid country
- 5 agro-ecological zones
- Differences in soils, rainfall, temperature and evapotranspiration
- Climate change models have predicted that most parts of Southern Africa will get drier (Tompkins, 2005)
- The implications of changes predicted by such models are particularly significant for areas already under climate-related stress

Background

- **Stable isotopes of C & N**
  - $\delta^{13}C$ ($^{13}C/^{12}C$) of C3 plants is an integrated record of ci/ca during CO_2 fixation
  - It reflects the balance between C assimilation rate and stomatal conductance or WUE
  - When water is limiting, the infleunce of WUE on $\delta^{13}C$ is enhanced
  - Thus low moisture can result in stomatal closure and a decrease in isotopic discrimination

Background

- $\delta^{13}C$ and WUE
  - Higher discrimination = Lower WUE (most negative)
  - Lower discrimination = Greater WUE (least negative)

$$\delta^{13}C = \left[\frac{\left({}^{13}C / {}^{12}C \right)_{sample}}{\left({}^{13}C / {}^{12}C \right)_{standard}} - 1 \right] \times 1000$$

(Stout and Rafter, 1978)

Background

- $\delta^{15}N$
  - N isotopic discrimination is related to availability of N in different pools
  - Where N is readily available in soil, plants become isotopically more enriched, suggesting the loss of the lighter ^{14}N isotope through volatilisation, mineralisation or denitrification

Background

- $\delta^{15}N$

$$\delta^{15}N = \frac{\left[{}^{15}N/{}^{14}N\right]_{sample} - \left[{}^{15}N/{}^{14}N\right]_{standard}}{\left[{}^{15}N/{}^{14}N\right]_{standard}} \times 1000$$

(Mariotti, 1983)

Questions

- What are the levels of $\delta^{15}N$ and $\delta^{13}C$ of shrub and tree legume species in the studied agro-zones?
- Can $\delta^{15}N$ and $\delta^{13}C$ values of species be used to predict plant responses to soil moisture imposed by rainfall?

Methodology

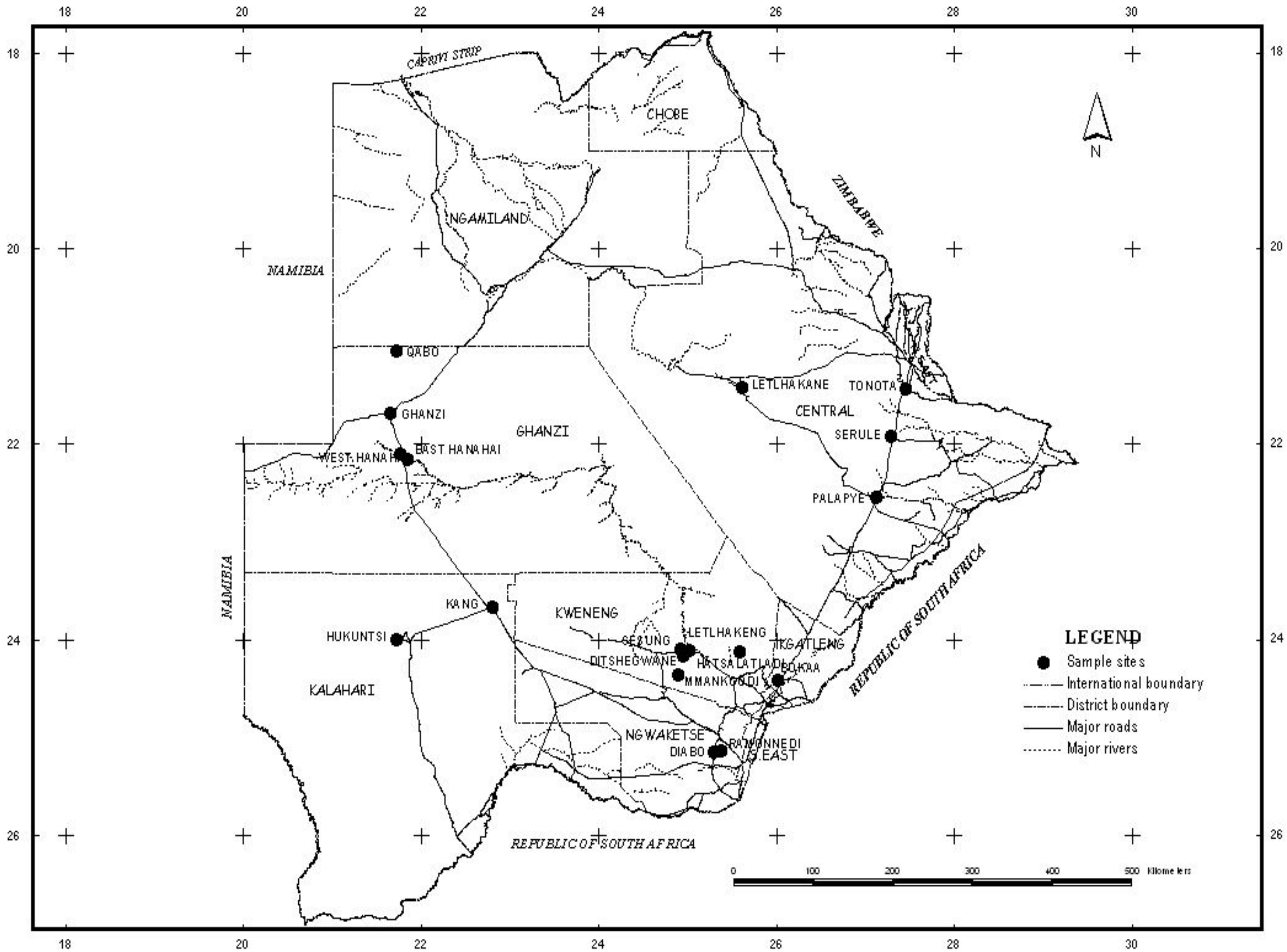


Figure 1: Map of Botswana showing study sites

Methodology

- Fully-opened leaves of 4 plants per species sampled into brown paper bags
- Samples oven dried over 48 h @ 60 °C
- Leaves milled to a fine powder
- Isotope analysis carried out with a mass spec

Methodology

- One Way ANOVA used:
  - to compare the species in each agro-ecological zone
  - to compare species across all the five agro-ecological zones studied

- Correlation analysis was used to establish relationships between $\delta^{15}N$ and $\delta^{13}C$ of plant species

Results

Table 1: Putative N_2-fixing plant species found in 5 AEZ of Botswana

Decreasing rainfall →

Ngwaketse	Gaborone	Central	Ghanzi	Kalahari
Acacia hebeclada	*Acacia karroo*	*Acacia fleckii*	*Dichrostachys cinerea*	*Acacia fleckii*
Acacia mellifera	*Acacia nilotica*	*Acacia erubescens*	*Acacia erioloba*	
Dichrostachys cinerea	*Acacia leuderitzii*		*Acacia fleckii*	
Acacia erioloba				
Acacia nilotica				
Acacia tortilis				
Acacia robusta				
Acacia caffra				
Acacia fleckii				

- Numbers of putative N_2-fixing plants decreased with mean annual rainfall

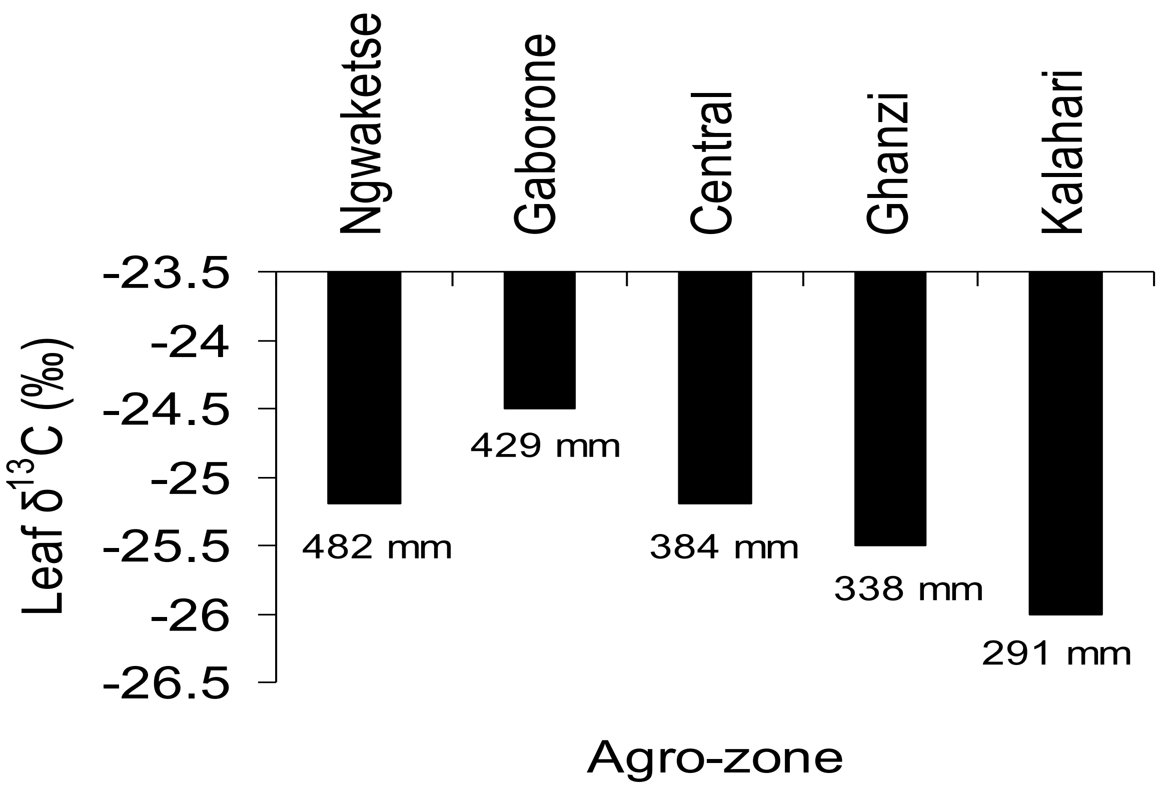
Table 2: $\delta^{15}N$ values of species in different AEZ. (-) = not found. (Values >

Plant species	Ngwaketse	Gaborone	Central	Ghanzi	Kalahari
Acacia hebeclada	2.9±0.6d	6.1±0.1b	7.9a	5.4±0.1bc	6.2±0.2bc
Acacia mellifera	4.5±0.3c	6.1±0.3ab	7.9±0.5a	7.6±0.7a	6.9±0.5ab
Dichrostachys cinerea	3.0±0.0d	4.9±0.7bc	6.7±0.7a	2.2±0.5e	5.4±0.0ab
Acacia erioloba	3.9±0.5c	7.8±0.3a	8.14±0.6bc	3.9±0.3c	5.6±0.3b
Acacia karroo	7.4±0.6a	4.3±0.3b	7.8±0.9a	-	-
Acacia nilotica	3.4±0.2b	3.4±0.8b	5.3±0.4a	-	-
Acacia tortilis	4.8±0.6bc	6.4±0.2b	6.4±1.0b	10.1±0.7a	-
Acacia robusta	4.0±0.4ab	6.4±0.4a	-	-	-
Acacia caffra	-1.3±0.8b	6.3±0.2a	-	-	-
Acacia leuderitzii	6.1±0.3a	4.8±0.2b	-	5.6±0.1ab	6.2±0.3a
Acacia fleckii	3.9±0.2b	6.7±0.4a	4.0±0.3b	3.9±0.3b	4.4±0.3b
Acacia erubescens	-	6.5±0.4b	4.8±0.6c	10.0±0.2a	-
Boscia albitrunca (Ref)	9.7±0.3a	10.6±0.6a	10.4±0.4a	-	10.6±0.3a

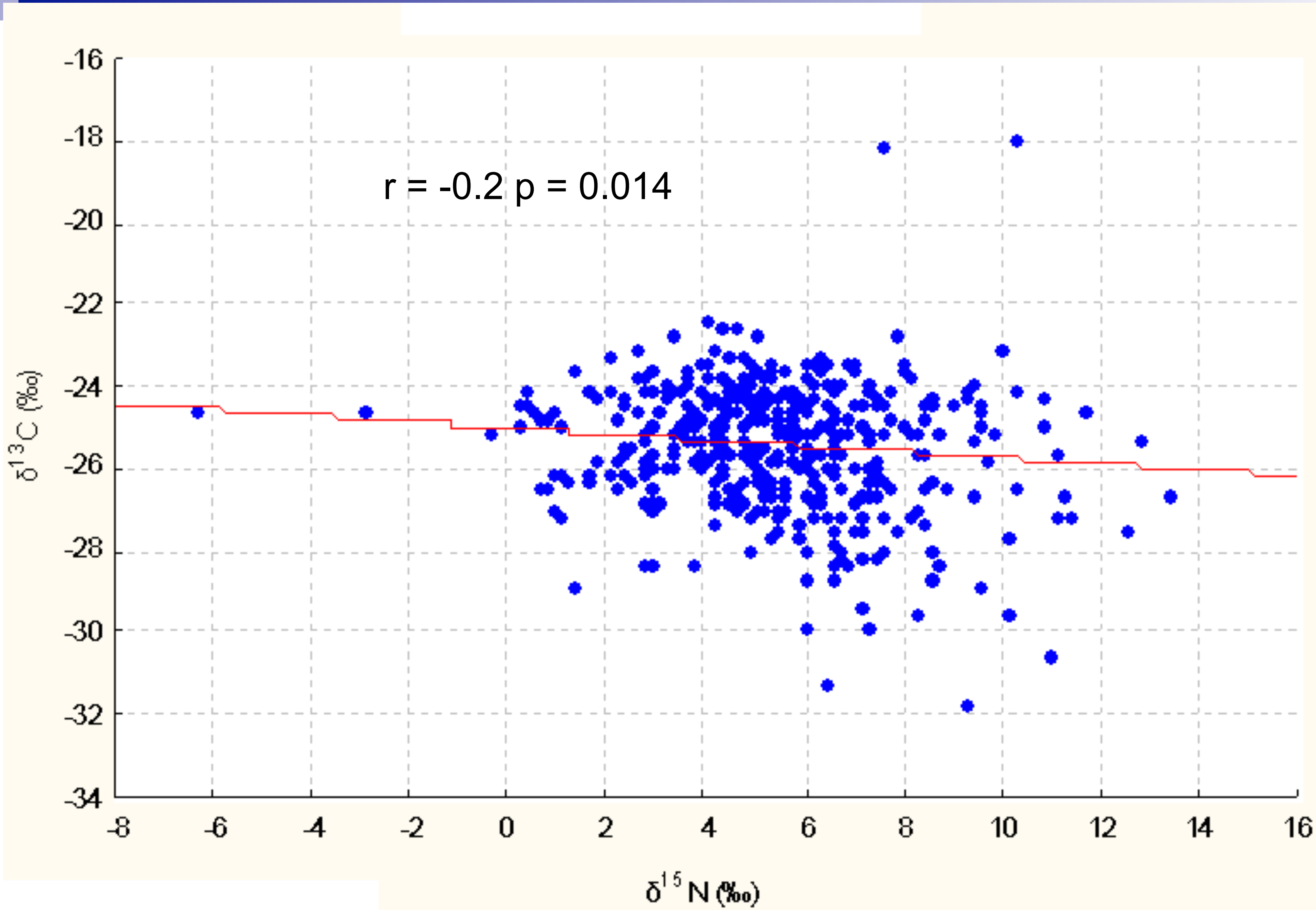
Table 3: $\delta^{13}C$ values of nodulating and non-nodulating legume species in 5 agro-zones of Botswana

Plant species	482 mm	429 mm	384 mm	338 mm	291 mm
Peltophorum africanum	-25.5a	-26.4ab			
Colophospermum mopane			-24.3		
Bauhinia petersiana				-25.8	
Albizia anthelminca				-26.3	
Acacia ataxacantha				-27.0	
Acacia hebeclada	-25.5b	-25.7b	-24.0a	-26.2c	-26.5cd
Acacia mellifera	-25.0ab	-24.0a	-25.8b	-27.3lc	-28.5d
Dichrostachys cinerea	-24.3a	-24.4a	-24.6ab	-24.9ab	-23.9a
Acacia erubescens		-24.7ab	-25.4b	-24.0a	
Acacia erioloba	-25.2b	-20.7a	-25.6b	-26.4bc	-25.8b
Acacia nigrescens			-24.9		
Acacia karoo	-27.5d	-23.9a	-26.3bc	-25.7b	
Acacia nilotica	-24.8ab	-23.9a	-24.6ab		
Acacia tortilis	-24.4a	-24.7ab	-25.5b	-25.6b	
Acacia robusta	-24.7a	-24.5a			
Acacia leuderitzii	-25.0a	-25.2a		-26.0b	-26.1b
Acacia fleckii	-24.8a	-26.6cd	-25.7bc	-26.0bc	-25.2ab

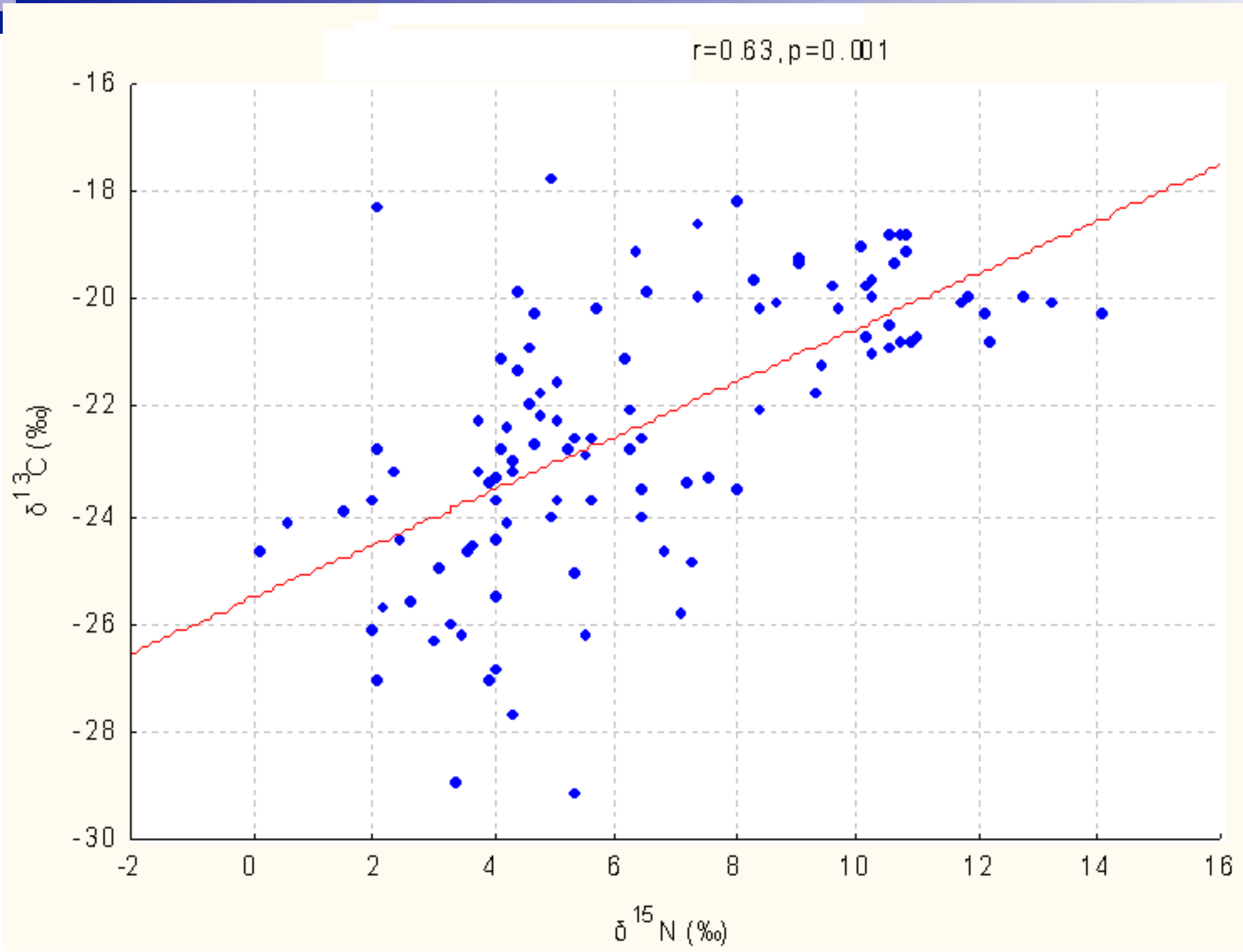
Legumes species in drier areas are comparatively less water-use efficient



Average $\delta^{13}C$ values of plant species per agro-zone



Depleted values of $\delta^{15}N$ associated with less negative values of $\delta^{13}C$ (most water-use efficient)



Enriched values of $\delta^{15}N$ for non-legumes associated with most negative values of $\delta^{13}C$ (least water-use efficent)

Conclusions

- Number of N_2-fixing species decreased with aridity
- $\delta^{15}N$ values of species became enriched with aridity

Implications for climate change

- Fewer legumes likely to fix N_2
- Nodulating legumes will function as non-legumes
- Prolonged fallows will lead to lower N accumulation

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