UN expert group meeting on:
Sustainable land management and agricultural practices in Africa: Bridging the gap between research and farmers

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‘Agro-bio-climatic models: Towards a generic Land Management Typology’

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Synopsis

[These introductory notes are prepared as background to a Powerpoint presentation (see * below)]

The need for generic typologies
As indicated in the notes provided by the Secretariat for this meeting, there are a number of relevant issues and questions as follows:

- Much information about SLM and SA has been collected over past decades but exists mainly in scattered repositories that are difficult to collate, let alone integrate.
- Lessons learnt in one area should, ideally, be framed in a consistent way that facilitates comparison and inference with land management practices in another area.
- Differing methods of farming system assessment greatly limit objective, comparative assessment of agricultural management practices.
- Existing, largely qualitative (subjective) farming system classifications, while locally useful, cannot be readily used to quantitatively assess and monitor land management practices.
- Generic, user-friendly, and preferably quantitative typologies are therefore needed to facilitate comparison within and between regions and to assist in appropriate planning and decision support applications.
- While present discussion is focused on Africa, successful applications there would help pave the way for more global applications as the overall principlesare largely generic.

Where possible, typologies should be generic – i.e. encompassing all possibilities for variation in a system. They should be logical. Perhaps the best known classification of farming systems was developed by Dixon *et al.*, (2001) and was designed for developing countries. As such it does not take into account global gradients of farming systems that have the capacity to occupy the full extent of physical environmental regimes where there is potential for plant growth. In addition, most farming system typologies tend to focus on agricultural cropping systems with only limited treatment of forest-based systems ranging from NTFPs in natural forests to agrosilvopastoral systems. From a programmatic perspective it is worth considering the possibility of a genuinely global (generic) land management typology. If this can be achieved, it should provide a much more open framework for discussion than exists at present.

The ‘Dixon’ method is based on 8 core categories that are designed for practical descriptive purposes. Five of the eight relate to water supply, the remaining three do not. These categories are expanded in a relatively idiosyncratic way to cover 72 different farming systems. In this respect there is no formal structure and thus no simple or ready means of comparing one system with another. There is a close analogy here with numerous descriptive classifications of vegetation. In developing a more comprehensive strategy for SLM an expanded version of the Dixon *et al.*, is proposed in which the 8 primary categories are increased to 15 (Table 1). These primary categories are then further categorized according to area and terrain, the ambient growth conditions based on Agroecological Zone classifications and finally inputs and outputs. This table allows a more synthetic approach to SLM in which land management typology is sufficiently generic to encompass farming systems in virtually any country. A typology of this kind allows a comprehensive description of any farming system to which relative values can be added to weight each attribute. Algorithms exist that can exploit this arrangement via a combinatorial rule set that permits quantitative comparison of land management types within and between regions. For example using the existing codes a **complex multistrata agroforest** might be s described as (cm); 2-10 ha (hb); hilly (hl); humid (hu); megatherm (mg); rainfed (rf); Integrated Nutrient Management (INM) adding (ad); INM saving (sv); inorganic fertilizer (in); organic fertilizer (or); high N stocks (hi); fibre – wood (fw); fibre non-wood (fn); vegetables (vg); fruit (fr); medicinal (md); other plant (op); (Pucallpa, Perúvian Amazon basin). [cm hb hl hu mg rf ad sv in or hi fw fn vg fr md op]. A representative 40xm transect contained 29 vascular species 22 PFTs At this stage it is important to emphasize that this table represents only the biophysical components and other socioeconomic descriptors require further attention.

The purpose of the exercise is to ilustrate how LMTs can be parameterized according to key biophysical attributes (socioeconomic ones can be treated separately). The grammar layout below should be relatively easy to interpret. Once the grammar and rule set are developed it can be read in a special notation that is computer-readable. Based on the rule set the grammar is used to construct a finite constellation of all possible combinations of LMTs. Using an arbitrary set of transformation costs (what it would 'cost' to change from one LMT element to another e.g. rainfed to irrigated, organic to inorganic fertilizer etc.). A specific metric is used to compute a distances between all sites (LMTs) that is written as a symmetrical matrix. The values from the matrix can then be subjected to a wide range of statistical analyses. In the present example I have generated a dendrogram and an ordination to show relative relationships between all LMTs. The gradient values (eigenvector scores) can be regressed against any other site related value (biodiversity, soil nutrients, profitability, income status…). The advantage of this approach is that, unlike traditional farming and land management that are largely intuitive and/or idiosyncratic, this very user-friendly quantitative tool can be used to rapidly compare and assess actual and potential land management scenarios for planning purposes. As more baseline data are added, the better it should become.

I am indebted to Guy Carpenter who took time off to write the initial computer program. As with VegClass, LMT can be set up with a graphic user interface whereby values can be keyed in directly. The software is quite sophisticated and is capable of generating a distance matrix within a few seconds. It is an analogue of the now well established VegClass system (Gillison and Carpenter, 1997); Gillison, 2002).

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Note: As these notes are intended to provide background for the attached Powerpoint presentation that represents work-in-progress neither these notes or the PPTy should not be quoted in publication without reference to the author.

References

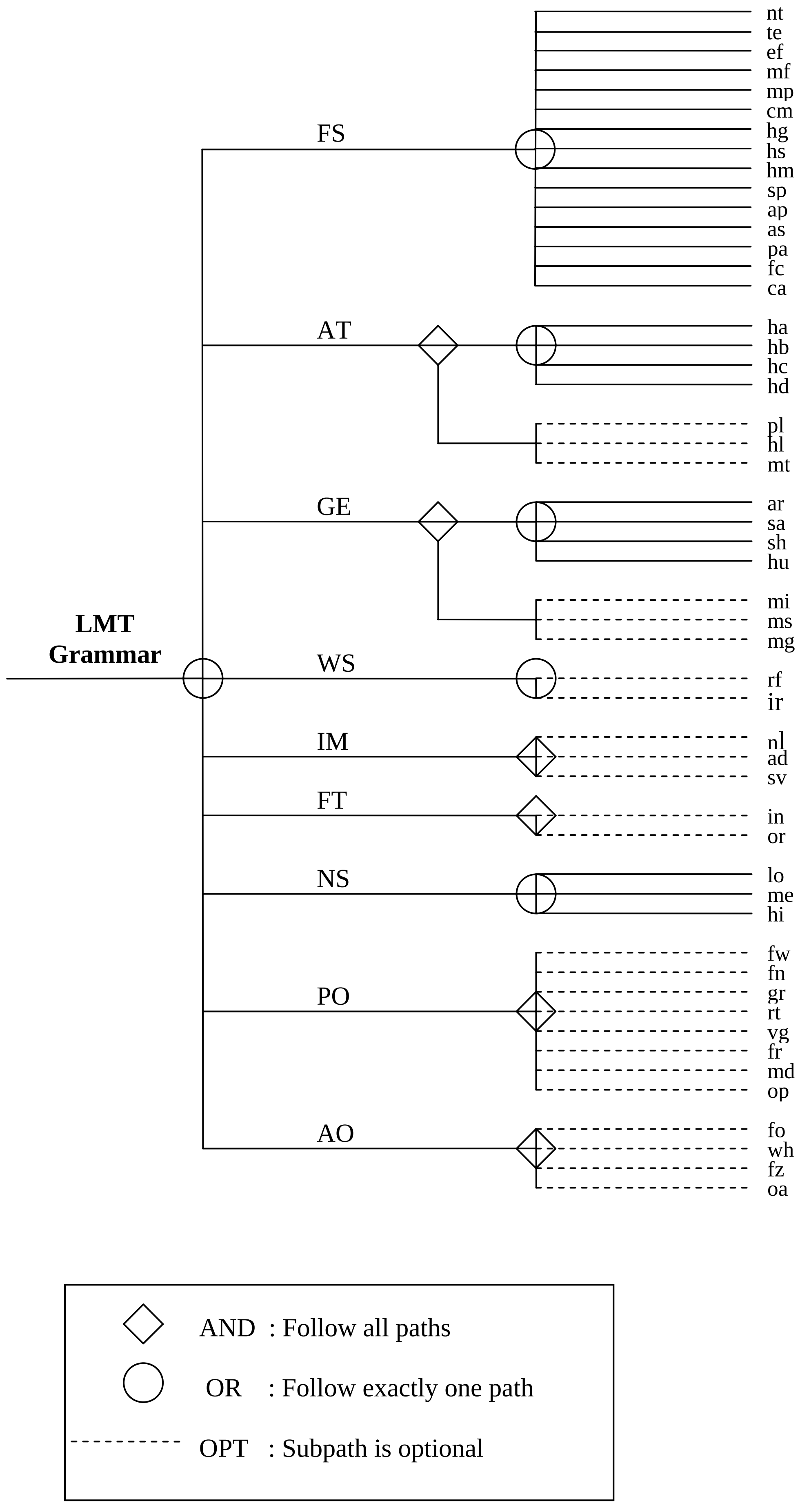
Dixon, J., Gulliver, A. and Gibbon, D. (2001). *Farming Systems and Poverty: Improving Farmer's livelihoods in a Changing World.* FAO and World Bank, Rome and Washington D.C.

Gillison, A.N. (2002). A generic, computer-assisted method for rapid vegetation classification and survey: tropical and temperate case studies. *Conservation Ecology* 6: 3. [online] URL: http://www.consecol.org/vol6/iss2/art3

Gillison, A.N. and Carpenter, G. (1997). A generic plant functional attribute set and grammar for dynamic vegetation description and analysis. *Functional Ecology* 11, 775-783.

Table 1. Land Management Types: Attributes and elements

Attribute	Element	Description
FARMING SYSTEM **FS**	nt	Forest - non-timber forest extraction
	te	Natural forest timber extraction
	ef	Enriched natural forests
	mf	Monocropping forest plantation
	mp	Mixed species forest plantation
	cm	Complex, multistrata agroforestry
	hg	Home gardens
	hs	Horticulture simple, monocrop
	hm	Horticulture complex, mixed species
	sp	Silvopastoral
	ap	Agropastoral
	as	Agrosilvopastoral
	pa	Pastoral
	fc	Fallow cropping
	ca	Continuous annual cropping
AREA & TERRAIN **AT**	ha	Area < 2 ha
	hb	2-10 ha
	hc	10-100 ha
	hd	> 100 ha
	pl	Plain
	hl	Hilly
	mt	Mountainous
GROWTH ENVIRONMENT **GE** **(Modified AEZ)**	ar	Length of growing period (LG) <75 days
	sa	LG 75-180
	sh	LG 180-270
	hu	LG > 270
	mi	Microtherm – growing period mean monthly temp < 5deg C
	ms	Mesotherm - growing period mean monthly temp 5-20 deg C
	mg	Megatherm – Growing period mean monthlytemp > 20 deg C
	ud	Soil moisture regime (USDA Soil Taxonomy..), udic etc.
	us	
INPUTS		
Water source **WS**	rf	Rainfed
	ir	Irrigated (including periodic natural flooding)
INM **IM**	nl	Neutral (free lunch)
	ad	Adding
	sv	Saving
Fertilizer **FT** (Including mulches)	in	Inorganic
	or	Organic
N stocks **NS**	lo	Low (< 1000 kg ha^{-1})
	me	Medium (1000 – 3500 kg ha^{-1})
	hi	High (> 3500 kg ha^{-1})
OUTPUTS		
Plant **PO**	fw	Fibre: wood, timber, charcoal, fuel
	fn	Fibre: non-wood
	gr	Grain
	rt	Root
	vg	Vegetable
	fr	Fruit
	md	Medicinal (including drugs, cocaine, opium..)
	op	Other (e.g oil, sugar, dyes ..)
Animal **AO**	fo	Food e.g. meat and other products
	wh	Fibre e.g. wool, hair, hides
	fz	Fertilizer
	oa	Other, including medicinal, fuel…


LMT
Grammar
FS
nt
te
ef
mf
mp
cm
hg
hs
hm
sp
ap
as
pa
fc
ca
AT
ha
hb
hc
hd
pl
hl
mt
GE
ar
sa
sh
hu
mi
ms
mg
WS
rf
ir
IM
nl
ad
sv
FT
in
or
NS
lo
me
hi
PO
fw
fn
gr
rt
vg
fr
md
op
AO
fo
wh
fz
oa
AND : Follow all paths
OR : Follow exactly one path
OPT : Subpath is optional

Box 1

Land Management Typology
Using Backus – Naur Form (BNF)

X = FS AT GE WS IM FT NS PO AO
FS = nt | te | ef | mf | mp | cm | hg | hs | hm | sp | ap | as | pa | fc | ca |
AT = ha | hb | hc | hd | [pl] [hl] [mt]
GE = ar | sa | sh | hu | [mi] [ms] [mg]
WS = [rf] [ir]
IM = [nl] [ad] [sv]
FT = [in] [or]
NS = lo | me | hi |
PO = [fw] [fn] [gr] [rt] [vg] [fr] [md] [op]
AO = [fo] [wh] [fz] [oa]

Backus-Naur Form (BNF) is a formal metasyntax used to express context-free grammars.

Explanatory notes for Table 1.

'FREE LUNCHES' are available when opening up virgin land, and are relatively sustainable if subsequent fallow periods are long enough. If population pressure goes up though, too much land is opened up and may be degraded to levels beyond repair. The areas concerned generally have strongly acidic soils with a very low natural fertility (Congo Basin, Amazon)

SAVING refers mainly to low-external input systems, which focus much on good use of 'Internal Flows', such as the links between crop residue removal and application of manure.

ADDING new nutrients to the system takes place in mineral fertilizers, and by amendments such as rock phosphates, lime and dolomite (although the latter are primarily meant to resolve acidity problems). Organic inputs from outside the farm (manure from animals that roam outside the farm, concentrates and other animal feeds, compost from town, non-farm food waste, etc. can be important, and so is the fixation of atmospheric nitrogen by Rhizobia in leguminous species, non-symbiotic fixers, and by algae and Azolla in wetland systems. In wetlands and irrigated systems, nutrients are also added from outside as they receive water that contains sediments and dissolved nutrients.

From E. Smaling Pers. Comm. (2006).

Examples of Land Management Types (LMTs) in Africa and other developing countries

(coded by AG according to preliminary LMT grammar)

1. Primary forest timber extraction
(pe); > 100 ha (hd); hilly (hl); humid (hu); megatherm (mg); rainfed (rf); INM neutral (nl); high ? N stocks (hi); timber (fw)
(Cameroon, Congo basin) 103 species 43 PFTs
[te hd hl hu mg rf nl hi fw]

2. Non-Timber Forest Products
(nt); > 100 ha (hd); hilly (hl); humid (hu); megatherm (mg); rainfed (rf); INM neutral (nl); high ? N stocks (hi); fibre, non-wood (fn); root (rt); fruit (fr); medicines (md); other plant (op); animal food (fo); fur and hides (wh); other animal (oa).
(Kuludagi, South New Britain, Papua New Guinea) 99 species 52 PFTs
[nt hd hl hu mg rf nl hi fn rt fr md op fo wh oa]

3. Complex multistrata agroforestry
(cm); 2-10 ha (hb); hilly (hl); humid (hu); megatherm (mg); rainfed (rf); INM adding (ad); INM saving (sv); inorganic fertilizer (in); organic fertilizer (or); high N stocks (hi); fibre – wood (fw); fibre non-wood (fn); vegetables (vg); fruit (fr); medicinal (md); other plant (op);
(Pucallpa, Perúvian Amazon basin) 29 species 22 PFTs
[cm hb hl hu mg rf ad sv in or hi fw fn vg fr md op]

4. Monocropping forest plantation
(mf); 10-100ha (hb); hilly (hl); humid (hu); megatherm (mg); rainfed (rf); INM adding (ad); inorganic fertilizer (in); medium N stocks (me); timber (fw);
(Jambi, Lowland Sumatra, *Albizia* plantation) 42 species 27 PFTs
[mf hb hl hu mg rf ad in me fw]

5. Horticulture simple monocrop
(hs); 10-100 ha (hb); plain (pl); humid (hu); megatherm (mg); rainfed (rf); INM adding (ad); inorganic fertilizer (in); high N stocks (hi); other plant product (oil) (op);
(Manaus, Eastern Amazon basin, Oil Palm) 23 species 21 PFTs
[hs hb pl hu mg rf ad in hi op]

6. Fallow crop - Slash & burn
(fc), < 2ha (ha); mountainous (mt); humid (hu); mesotherm (ms); rainfed (rf); INM neutral (free lunch) (nl); medium N stocks (me); Grain (gr), Root (rt), Fruit (fr), Medicinal (md);
(Mt Makiling, Philippines)
[fc ha mt hu ms rf nl me gr rt fr md]. 48 species 44 PFTs

7. Fallow crop - Slash & burn
(fc), < 2ha; hilly (hl); humid (hu); megatherm (mg); rainfed (rf); INM neutral (free lunch) (nl); medium N stocks (md); Grain (gr),
(Kerinci Seblas uplands, Sumatra, upland dry rice) 12 species 11 PFTs (est)
[fc ha hl hu mg rf nl me gr].

8. Fallow crop - Slash & burn

(fc), < 2ha (ha); hilly (hl); humid (hu); mesotherm (ms); rainfed (rf); INM neutral (free lunch) (nl); medium N stocks (me); opium (mc),
(N. Burmese foothills - hypothetical) (estimated 10 species 10 PFTs – based on N. Thailand plots)
[fc ha hl hu ms rf nl me mc].

9. Continuous annual cropping
(ca), 2-10 ha (hb); plain (pl); humid (hu); mesotherm (ms); rainfed (rf), irrigated (ir); adding (ad); inorganic (in) and organic (or) fertilizer; high N stocks (hi); grain (rice) (gr);
(Gamani, Balipara, N. Assam, India - padi rice) 18 species 14 PFTs
[ca hb pl hu ms rf ir ad in or hi gr]

10. Continuous annual cropping
(ca), <2 ha (ha); mountainous (mt); semi-arid (sa); microtherm (mi); rainfed (rf), INM adding (ad); INM saving (sv); (or) fertilizer; medium N stocks (md); root (potato) (rt);
(sub-alpine Inti-ilimani basin, Bolivia) 10 species 9 PFTs
[ca ha mt sa mi rf ad sv or me rt]

11. Continuous annual cropping
(ca); > 100 ha (hd); plain (pl); humid (hu); megatherm (mg); rainfed (rf), INM adding (ad); inorganic fertilizer (in); high N stocks (hi); grain (soya) (gr);
(Brazilian Western Amazon basin) 12 species 10 PFTs (estimated)
[ca hd pl hu mg rf ad in hi gr]

12. Continuous annual cropping
(ca); < 2ha (ha); plain (pl); semi-arid (sa); mesotherm (ms); rainfed (rf); irrigated (ir); INM adding (ad); INM saving (sv); organic fertilizer (or); ? high N stocks (hi); grain (millet) (gr)
(San Village, Mali, sub-sahelian savanna) 10 species 7 PFTs
[ca ha pl sa ms rf ir ad sv or hi gr]

13. Agropastoral
(ap); 10-100 ha (hc); plain (pl); semi-arid (sa); megatherm (mg); rainfed (rf); INM adding (ad); INM saving (sv); organic fertilizer (or); low N stocks (lo); grain (sorghum, maize) (gr); fruit (egusi melon) (fr); vegetables (vg); meat (fo); fur & hides (wh); fertilizer (fz); other animal (oa)
(Bafia, SubSahelian Cameroon) 51 species 37 PFTs
[ap hc pl sa mg rf ad sv or lo gr fr vg fo wh fz oa]

14. Pastoral
(pa); > 100 ha (hd); plain (pl); semi arid (sa); mesotherm (ms); rainfed (rf); INM adding (ad); organic (or); low N stocks (lo); meat (fo); fur & hides (wh); fertilizer (fz); other animal (oa)
[Wakoro, Mali sub-sahelian savanna – cattle] 24 species 18 PFTs
[pa hd pl sa ms rf ad or lo fo wh fz oa]

15. Agrosilvopastoral
(as); 10-100 ha (hc); hilly (hl); humid (hu); megatherm (mg); rainfed (rf); INM adding (ad), INM saving (sv); inorganic fertililizer (in) organic fertilizer (or); medium N stocks (me); fuelwood (fw), grain (gr), root (rt), vegetables (vg), fruit (fr), medicinal (md), other (op); meat (fo); fur, hides (wh), fertilizer (fz), medicinal, fuel (oa);
[Ji Parana, Rondônia, Brazil] 16 species 13 PFTs
[as hc hl hu mg rf ad sv in or me fw gr rt vg fr md op fo wh fz oa]

Table of transformation costs (currently based on a 10-point scale and open to comment)

FS
nt <-> te :4
te <-> ef :3
ef <-> mf :6
mf <-> mp :4
mp <-> cm :5
cm <-> hg :3
hg <-> hs :6
hs <-> hm :4
hm <-> sp :6
sp <-> ap :4
ap <-> as :5
as <-> pa :4
pa <-> fc :7
fc <-> ca :3

AT
ha <-> hb :4
hb <-> hc :6
hc <-> hd :7
pl <-> {} :5
hl <-> {} :4
mt <-> {} :3

GE
ar <-> sa :3
sa <-> sh :3
sh <-> hu :3
mi <-> {} :4
ms <-> {} :5
mg <-> {} :6

WS
rf <->{} :5
ir <-> {} :3

IM
nl <-> {} :2
ad <-> {} :2
sv <-> {} :2

FT
in <-> {} :3
or <-> {} :5

NS
lo <-> me :4
me <-> hi :4

PO
fw <-> {} :6
fn <-> {} :4
gr <-> {} :4
rt <-> {} :3
vg <-> {} :3
fr <-> {} :4
md <-> {} :5
op <-> {} :5

AO
fo <-> {} :7
wh <-> {} :5
fz <-> {} :3
oa <-> {} :3

LMT summary data

te hd hl hu mg rf nl hi fw
nt hd hl hu mg rf nl hi fn rt fr md op fo wh oa
cm hb hl hu mg rf ad sv in or hi fw fn vg fr md op
mf hb hl hu mg rf ad in me fw
hs hb pl hu mg rf ad in hi op
fc ha mt hu ms rf nl me gr rt fr md
fc ha hl hu mg rf nl me gr
fc ha hl hu ms rf nl me md
ca hb pl hu ms rf ir ad in or hi gr
ca ha mt sa mi rf ad sv or me rt
ca hd pl hu mg rf ad in hi gr
ca ha pl sa ms rf ir ad sv or hi gr
ap hc pl sa mg rf ad sv or lo gr fr vg fo wh fz oa
pa hd pl sa ms rf ad or lo fo wh fz oa
as hc hl hu mg rf ad sv in or me fw gr rt vg fr md op fo wh fz oa

Dendrogram based on lower half of a similarity matrix derived from the LMT grammar using a Wald-Wolfowitz algorithm

```
                |               |               |               |               |
te      1)_______
mf      4)______|__________
cm      3)___________          |
hs      5)__________|_____|_____
nt      2)_____________________|_____________________________________________________
fc      6)__                                                                        |
fc      8)_|__                                                                      |
fc      7)___|_______________                                                       |
ca      9)_                 |                                                       |
ca     12)|__________       |                                                       |
ca     10)__________|__     |                                                       |
ca     11)____________|______|__________________                                    |
ap     13)________                             |                                    |
pa     14)_______|_________                    |                                    |
as     15)_________________|____________________|___________________________________|
          |               |               |               |               |         |
       15.0000       59.0000       103.0000       147.0000       191.0000       235.0000
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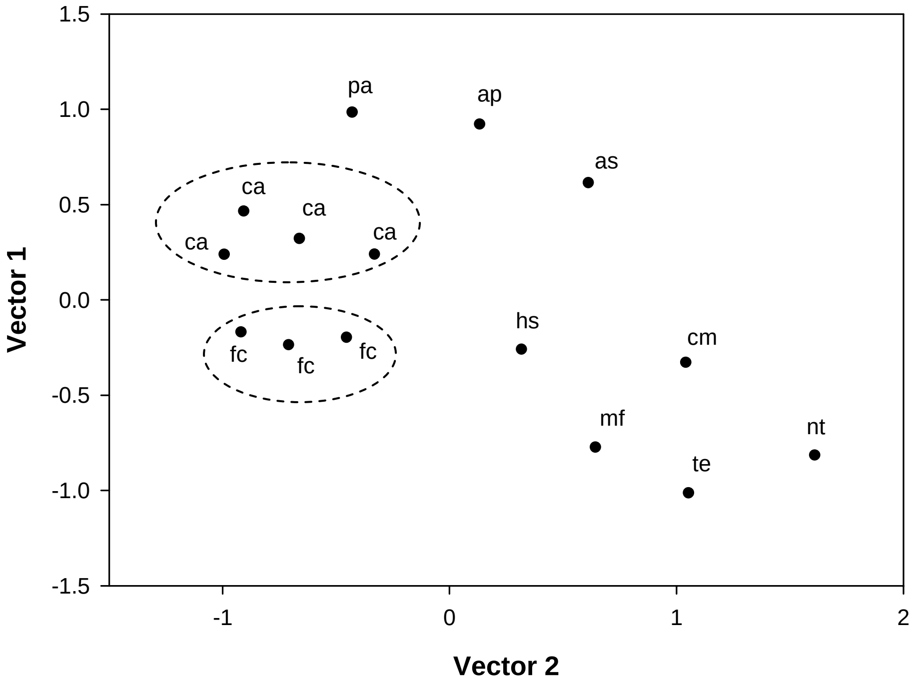
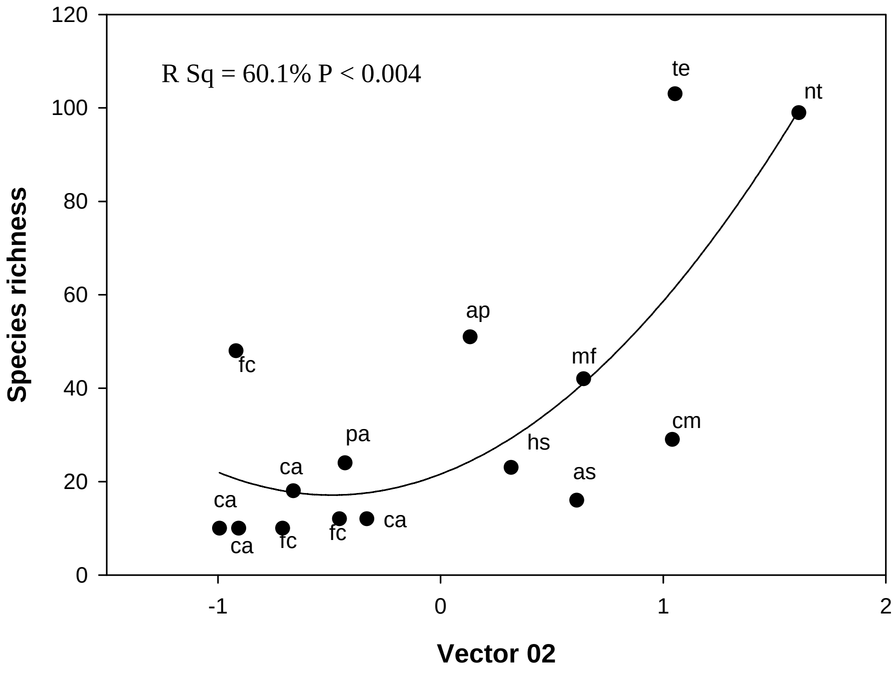


Multidimensional scaling of best two eigenvectors from similarity matrix derived from LMT grammar. Shows interpretable clustering of LMTs and provides a basis for quantitative comparison within and between types.



Values from MDS vector 2 of grammar regressed against species richness (plant biodiversity)