Biodiversity measurement

Viikki Tropical Resources Institute (VITRI)
FOR-247 Course

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Biodiversity definition

Biological diversity means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Convention on Biological Diversity 1992).

Biodiversity and hierarchical categories

Biodiversity can be divided into three hierarchical categories:

- Genetic diversity refers to the variation of genes within species covering distinct populations of the same species or genetic variation within populations.

- Species diversity refers to the variety of living organisms on earth.

- Ecosystem diversity refers to the variability of habitat and biotic communities including the variety of ecological processes within ecosystems (Smitinand 1994).

Diversity at different spatial scales

Biodiversity is scale-dependent

□ Point diversity, the diversity of a microhabitat or sample taken from within a homogenous habitat.

□ Alpha diversity is within-habitat diversity.

□ Gamma diversity is the diversity of a larger unit such as a landscape.

□ Epsilon diversity is the diversity of biogeographic province (Magurran 2004).

Differentiation diversity

- **Pattern diversity** describes the variation in diversity between sample plots

- **Beta diversity** is diversity between habitats

- **Delta diversity** the change in species composition (abundance) between units of gamma diversity within a area of epsilon diversity.

Why measure biodiversity

- Biodiversity plays a fundamental role in maintaining the integrity of the natural environment and promotes the overall well-being of plant and animal life. It underpins ecosystem functions and services (Gerardo et al. 2015)

- Globally, ecosystems, species, wild populations local varieties and breeds of domesticated plants and animals are shrinking, deteriorating or vanishing, threatening ecosystem services and human well-being (IPBES 2019; Ceballos et al. 2015)

Why measure biodiversity

- The global rate of species extinction is at least tens to hundreds of times higher than the average rate seen previously in Earth's history (IPBES 2019)

- Mainly because of human activities, up to one million plant and animal species face extinction, many within decades (IPBES 2019)

- Measuring biodiversity is important for assessment, conservation and sustainable management of biological resources (Dudley et al. 2005)

Agarwood (*Aquilaria malaccensis*) is critically endangered. Source: IUCN

Biodiversity assessment

- A biodiversity assessment is a measure of some defined components of an ecosystem—most often components that are thought of as indicators (or surrogates) of the conservation status of a species or area (Schipper and Rovero 2018).

- Biodiversity monitoring is similar to assessment except that it is repeated over time to capture information about trends and possible future trajectories of population, species, or communities in the natural system being studied (Schipper and Rovero 2018).

Biodiversity assessment

Biodiversity baseline study is the work done to collect and interpret information on the biodiversity values occurring at a site, their current condition, and trends before a project commences (Gullison et al. 2015).
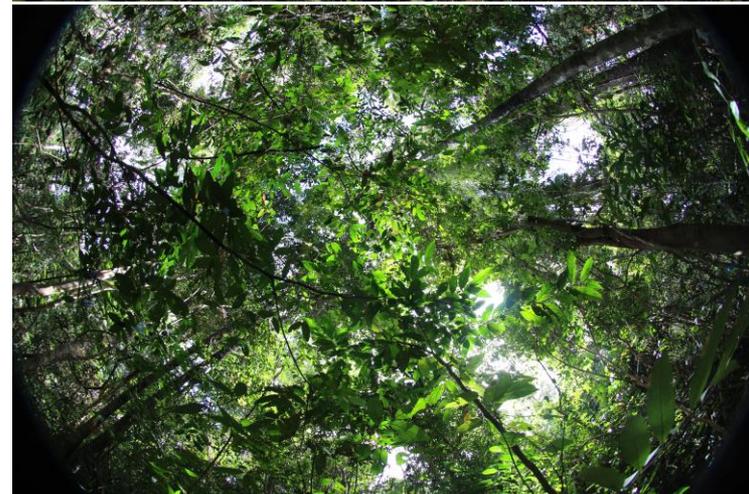
Forests in Luang pra bang, Laos. Eshetu 2019

Biodiversity measurement

Biodiversity measurements are based on three assumptions:

- All species are equal

- All individuals are equal

- Abundance has been recorded using appropriate and comparable units

  (Source: Magurran 2004)

Biodiversity measurement

- Diversity consists of not one but two components. These are first the variety and secondly the relative abundance of species (Magurran 1988).

- Species richness — The number of species within a specified region or locality.

Biodiversity measurement

- Abundance - The number of individuals of a species within a specified region or locality.

- Evenness (equitability) - The degree to which the number of individual organisms are evenly divided between different species of the community.

A

B
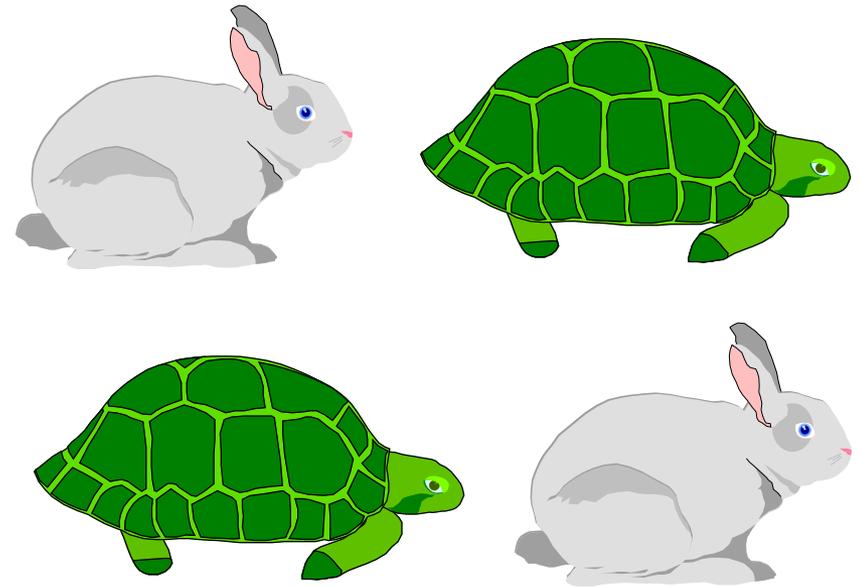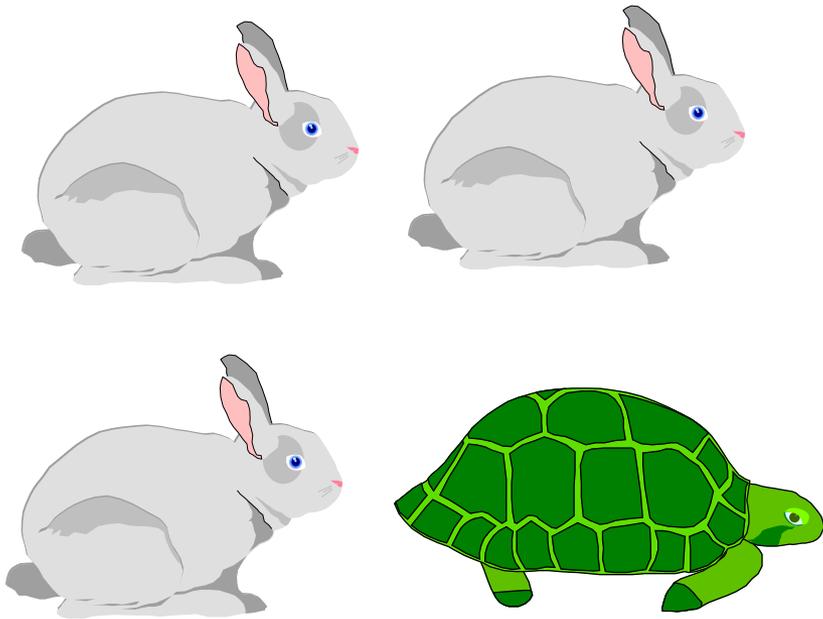
Which community/group is more diverse?

Forest biodiversity inventory
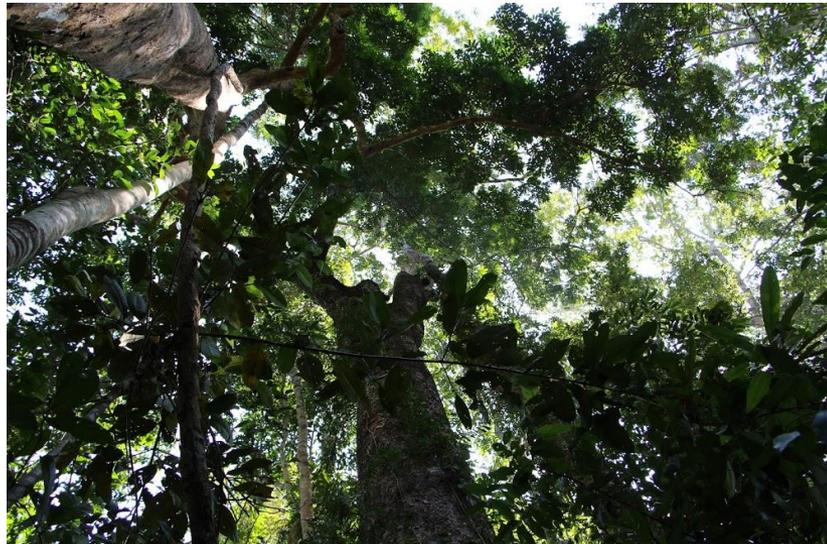
Biodiversity inventory – local knowledge

Biodiversity inventory – local knowledge

- Indigenous peoples with a historical continuity of resource-use practices often possess a broad ecological knowledge including on biodiversity and its uses in their own localities.

- Recognize and respect the contribution of indigenous and local knowledge to the conservation and sustainable use of biodiversity and ecosystems (UNEP 2010).

- Indigenous knowledge of the local people can be used for rapid biodiversity assessment.

Biodiversity inventory – local knowledge

Questionnaires are prepared and local people are interviewed to get information on:

- Past history of the study site

- Current status of the site (change from the past)

- Abundance and extinction of species

- Important uses of the plant and animal species

- Reasons for the decline or conservation of the biodiversity

Sampling design example from Laos (field course)

- Systematic plot sampling
- Circular plots with a radius of 7.98 m and an area of 200 m^2
- The distance between the sample plots and line transects was 50 m
- The initial plot was randomly selected

< 20m   50 m   < 20m

Forest edge   50 m   Forest edge

Sampling design example from Laos (field course)

200 m²

rope = 7,98m

pole

1m

1m
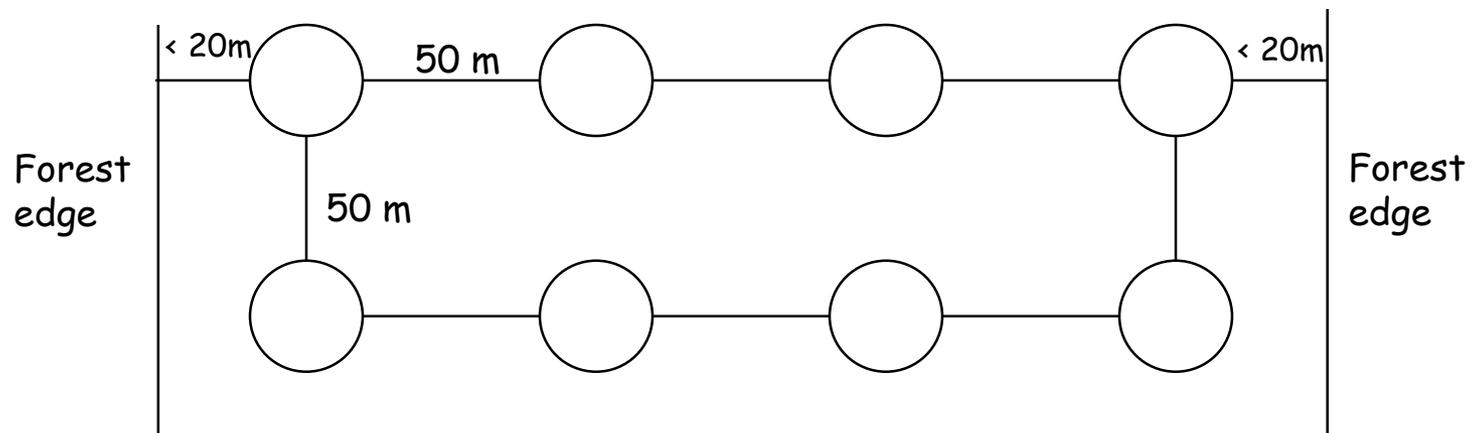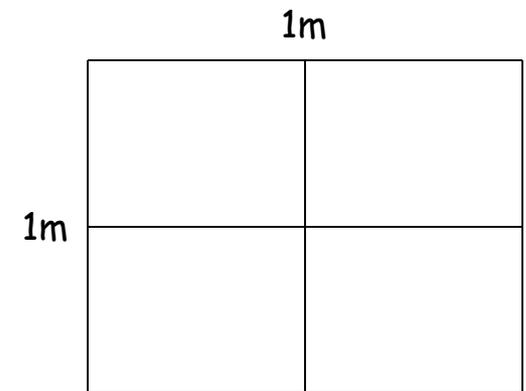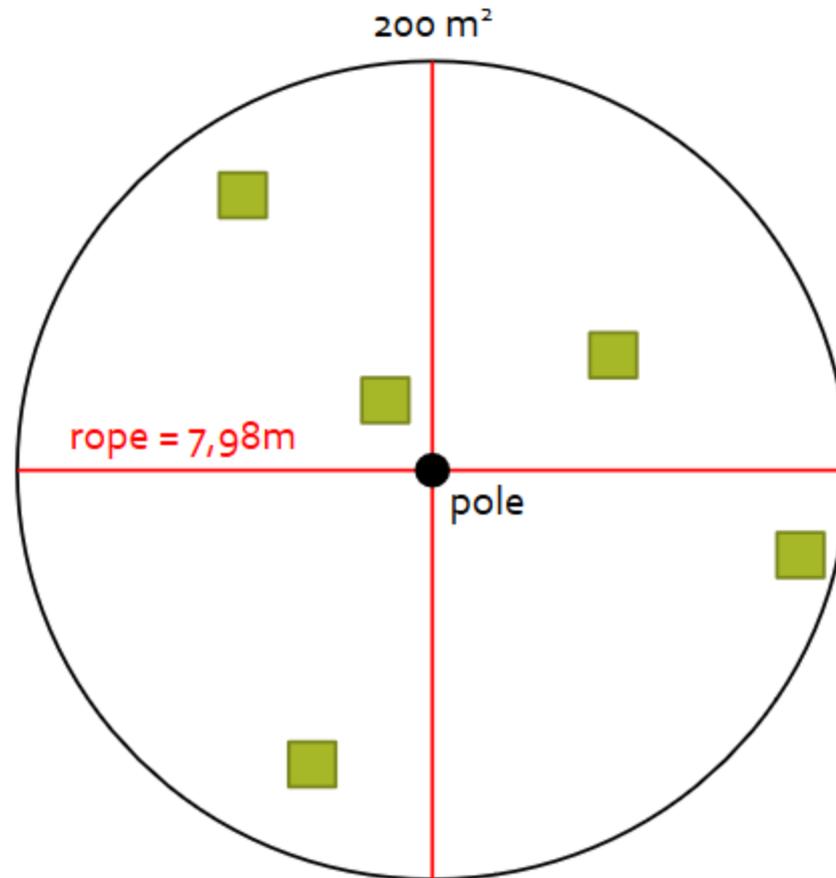
1 m² frame used for herbaceous ground cover measurement

Source: Group report 2019

Biodiversity inventory – Woody species

The woody species are grouped by size classes:

- Germinants - height ≤ 0.05 m. Germinants are not counted. They are not included in the analysis

- Seedlings - 0.05 < height < 1.3 m. Species are identified and counted

- Saplings - height ≥ 1.3 m and DBH < 2.5 cm. Species are identified and counted

- Mature - height ≥ 1.3 m and DBH ≥ 2.5 cm. Species are identified and counted

Biodiversity inventory – Woody species

- Woody species are registered as native or exotic (introduced)

- Bamboo clumps are counted. Species identification very difficult (genus if possible)

- Rattans are counted and identified
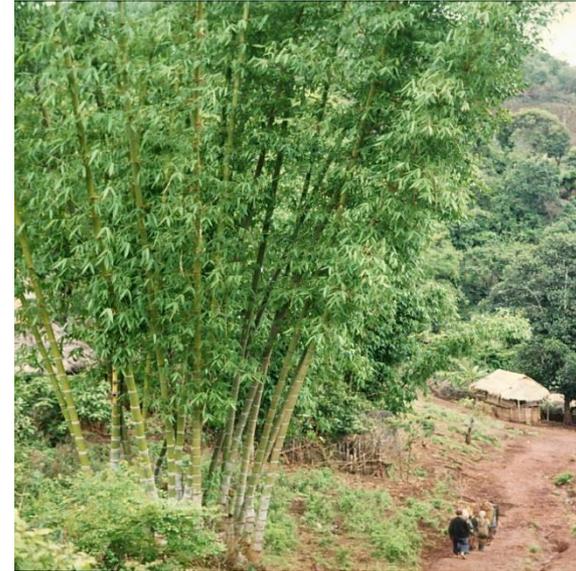
Biodiversity inventory – Woody species

Biodiversity inventory – Woody species

Laos biodiversity inventory. Eshetu 2017.

Biodiversity inventory – Woody species

Laos biodiversity inventory. Eshetu 2019.

Biodiversity inventory – herbaceous layer

- Five 1-m^2 quadrats are randomly placed in each sample plot for estimating the average ground cover percentage of the herbaceous layer. The average of the five values is used to estimate the ground cover percentage.

- The dominant species of the herbaceous layer are identified (forbs, grasses).

Biodiversity inventory – climbers and epiphytes

- Climber species are identified, but not counted

- Epiphytic flora – high ≥ 85%, 85% > Medium ≥ 60%, Low < 60% of the stem and main branch cover. The life form of the epiphytic flora is identified, i.e. (mosses, lichens, ferns, herbs). The herbs are identified at the genus level

Biodiversity inventory – fauna

Local people are interviewed to find out the fauna present in the area, particularly mammals and birds

Scientific names identified

Common – rare

Exotic - native

Biodiversity inventory – species identification

Plant species will be identified using:

- Local knowledge – using ethnobotanist; names registered in vernacular language and later scientific names are identified

- Botanical keys – (books, monograph, online, etc.)

- National Herbariums (Universities, research institutes, etc.)

The family of each species and authors are also identified

Inventory forms

INVENTORY FORM I

Site_____   Block_____   Date_____

Plot no.	Description of topography	GPS coordinates	Altitude (m)	Slope (%)	Aspect (º)	Canopy cover (%)	Remark

INVENTORY FORM II

Site_____   Block_____   Date_____

Plot no.	Species name	Life form	Crown position	Abundance	Basal area	Dominant height	Causes of disturbance

Inventory forms

INVENTORY FORM III

Site_____Block_____Date_____

Plot no.	Species name	DBH (mm)	Remark

INVENTORY FORM IV

Site_____   Block_____   Date_____

| Plot No.	Dominant herbaceous species name	Herbaceous cover (%)	Remark

Biodiversity data analysis
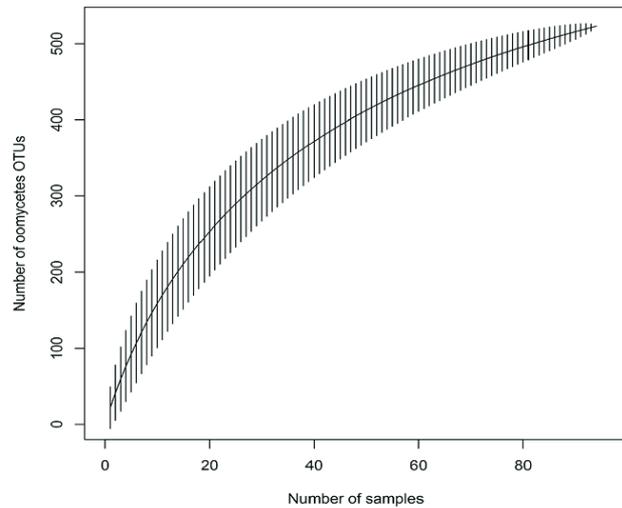

Source: Cerri et al. 2017
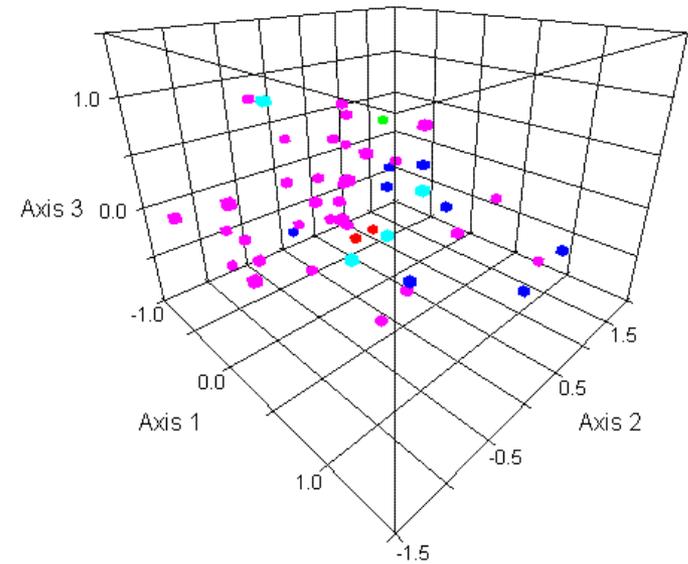
Source: PC-ORD manual
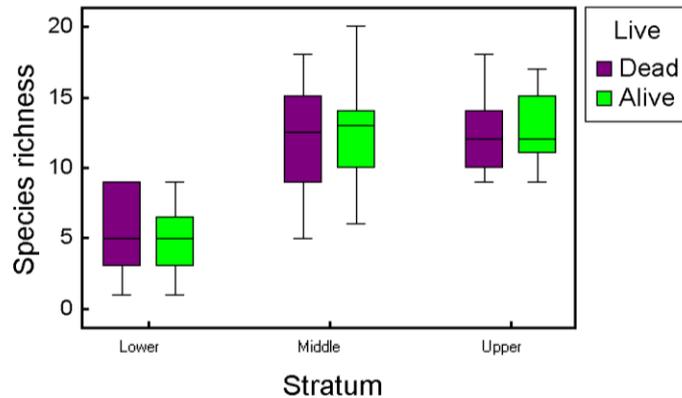
Source: PC-ORD manual
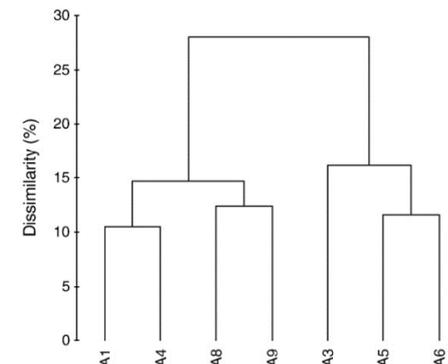
Source: Macho et al. 2010

Abundance and density

- Relative abundance – the abundance of a species, divided by the total abundance of all species combined

- Density - the number of individuals per unit area (Ex. trees/ha)

- Relative density $_j$ = $\dfrac{Density_{\,j}}{\sum_{j=1}^{p} Density_{\,j}}$ * 100

Frequency and dominance

- Frequency – the proportion of sample units in which a species occurs

- Relative frequency – Number of occurrences of a species as a percentage of the total number of occurrences of all species

- Dominance - Sum of the basal area of each tree of a species from all plots divided by the total area of all of the measured plots (m^2/ha)

- Relative dominance - Basal area of a given species divided by the sum of the basal areas of all of the species * 100

Importance value index

Importance Value Index - This index is used to determine the overall importance of each species in the community structure. In calculating this index, the percentage values of the relative frequency, relative density and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species (Curtis, 1959).

IVI = Relative frequency + Relative density + Relative dominance

Diversity indices

There are several diversity indices

- Shannon diversity index $H' = -\sum p_i \ln p_I$
- The log series $\alpha = N(1-x)/x$
- Brilloin index $HB = (\ln N! - \sum \ln n_i!)/N$
- Simpson's index $D = \sum (n_i(n_i - 1))/(N(N-1))$
- Mc Intosh's index $U = \sqrt{(\sum n_i^2)}$
- Berger - Parker index $d = Nmax/N$
- Shannon evenness $E = H'/\ln S$

Diversity indices

- Many of the differences between indices lie in the relative weighting that they give to evenness and species richness (Magurran 1988).

- Biodiversity is fundamentally multidimensional concept and it can not be reduced sensibly to a single number (Purvis 2000).

Diversity indices

- There is little consensus on the best diversity measures to use and no index has received the backing of the majority of workers in the field (Magurran 1988).

- Computer softwares that calculate the different diversity indices are available.
  Ex. PC-ORD, BioDiversity Pro, R, etc.

Diversity indices

Stand	Plots no.	Species no.	Abundance	Shannon index	Log series	Evenness
EG2M	10	10.6 (0.69)ab	197 (40.8)a	1.988 (0.053)a	2.493 (0.156)a	0.850a
EG2C	10	9.9 (0.45)a	165 (28.5)a	1.926 (0.029)a	2.433 (0.099)a	0.844a
EG4	10	12.3 (1.7)b	333 (40.2)ab	1.981 (0.041)a	2.574 (0.108)a	0.792b
NF	10	16.2 (1.8)c	425 (73.9)b	2.302 (0.023)b	3.474 (0.152)b	0.828ab
F-value		24.1	6.2	20	14	5.4
P-value		<0.001	0.002	<0.001	<0.001	0.004

(Data source Eshetu Yirdaw and Luukkanen 2003)

# Similarity indices

There are several similarity indices:

- Jaccard index C_j = j/(a+b-j)
- Sorenson index Cs = 2j/(a+b)
- Sorenson quantitative C_N = 2_{jn}/(aN+bN)
- Renkonen's index P = Σ minimum (P_{i1} P_{i2})

Ordination and similarity

- Ordination analysis uses community composition data to order samples along axes according to their resemblance (similarity or dissimilarity measures) such that sites that are close together are similar in species composition and sites that are far apart are dissimilar in species composition (Cuffeney et al. 2014).

- Ordination is a collective term for multivariate techniques that summarize community data by reducing the high dimensionality of the data (number of dimensions equals the number of species) to produce a low-dimensional ordination space that captures as much of the original structure in the data as possible.

Ordination and similarity
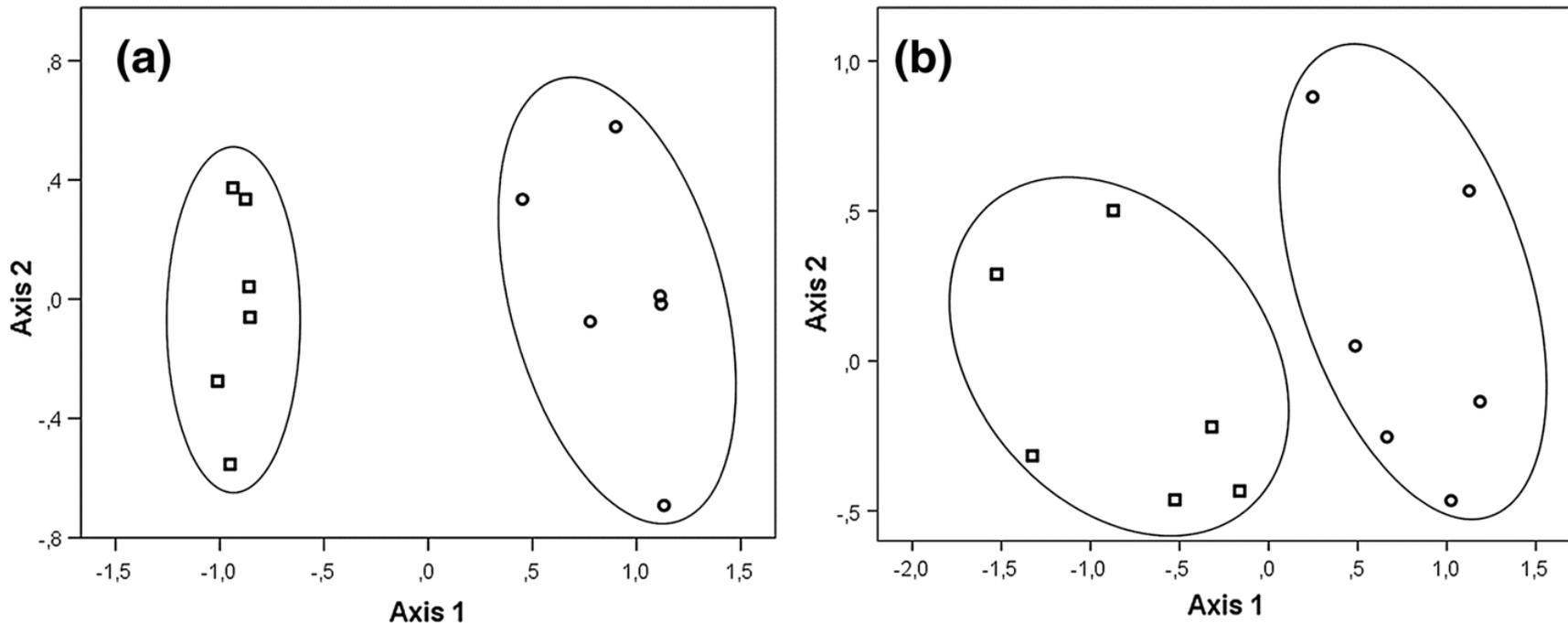
Non-metric multidimensional scaling (NMDS) ordination of the old-growth and regrowth forests in Napo (a) and Dong Na Tard (b). The circle represents the old-growth forests while square represents the regrowth forests (Source: Yirdaw et al. 2018

Rarity

There are several definitions of rarity:

□ Gaston (1994) – rare species are those falling within the first quartile in terms of species abundance (at the lower end)

□ Novotny and Basset (2000) – rare species were classified as those represented by a single individual (singleton)

Species accumulation curves

- Species accumulation curves, which are sometimes called collector curves, plot the cumulative number of species recorded (s) as a function of sampling effort (n)

- Effort can be the number of individuals collected, or a surrogate measure such as the cumulative number of samples or sampling time

Species accumulation curves
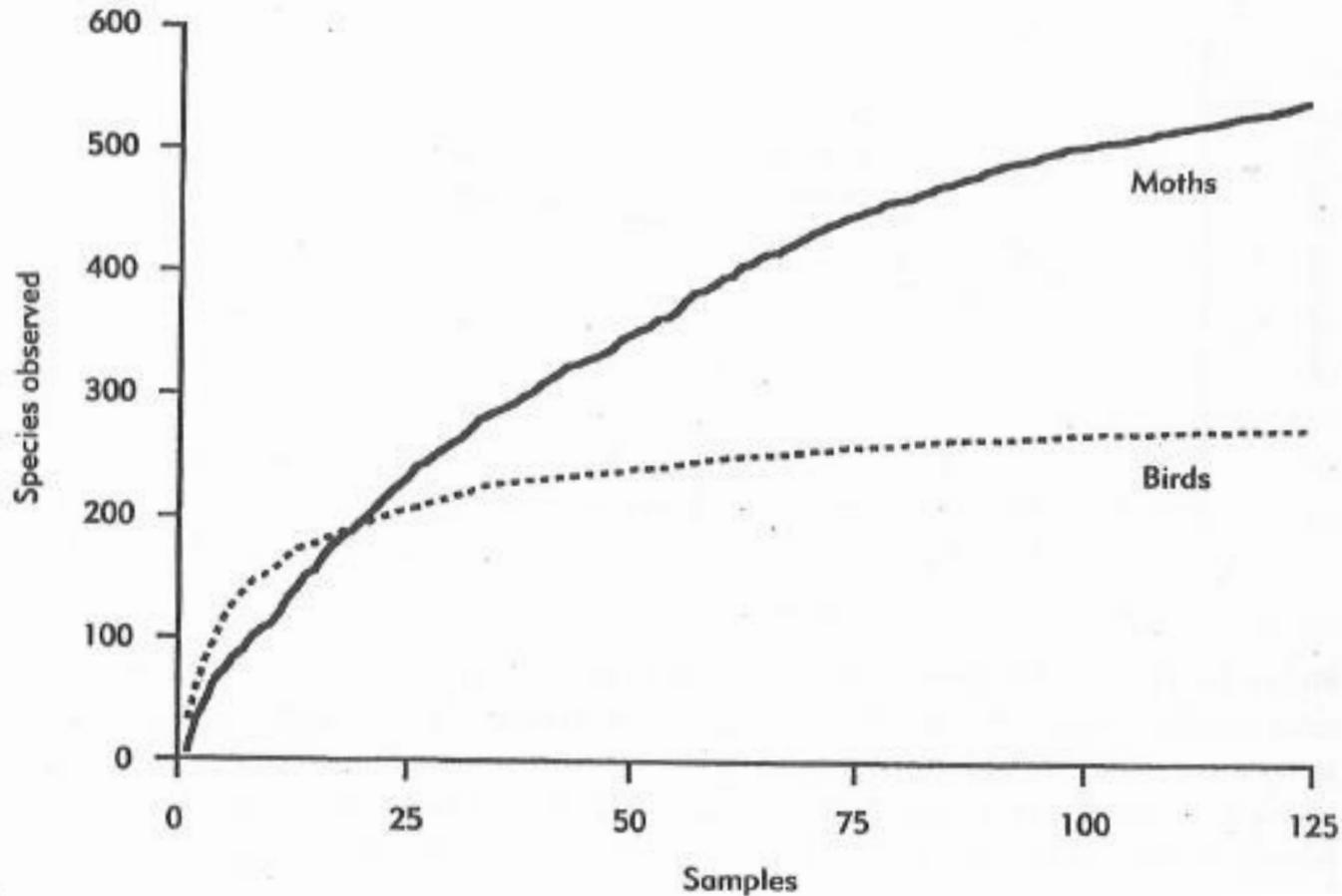
Source: Magurran 2004

Cluster analysis

- Cluster analysis is a multivariate method used for combining similar objects into groups or clusters

- The two most similar sites are combined to form a single cluster

- Similarity or distance measures are used to measure the distance between all pairs of sites

- The analysis proceeds successively clustering similar sites until a single dendrogram is constructed

Cluster analysis
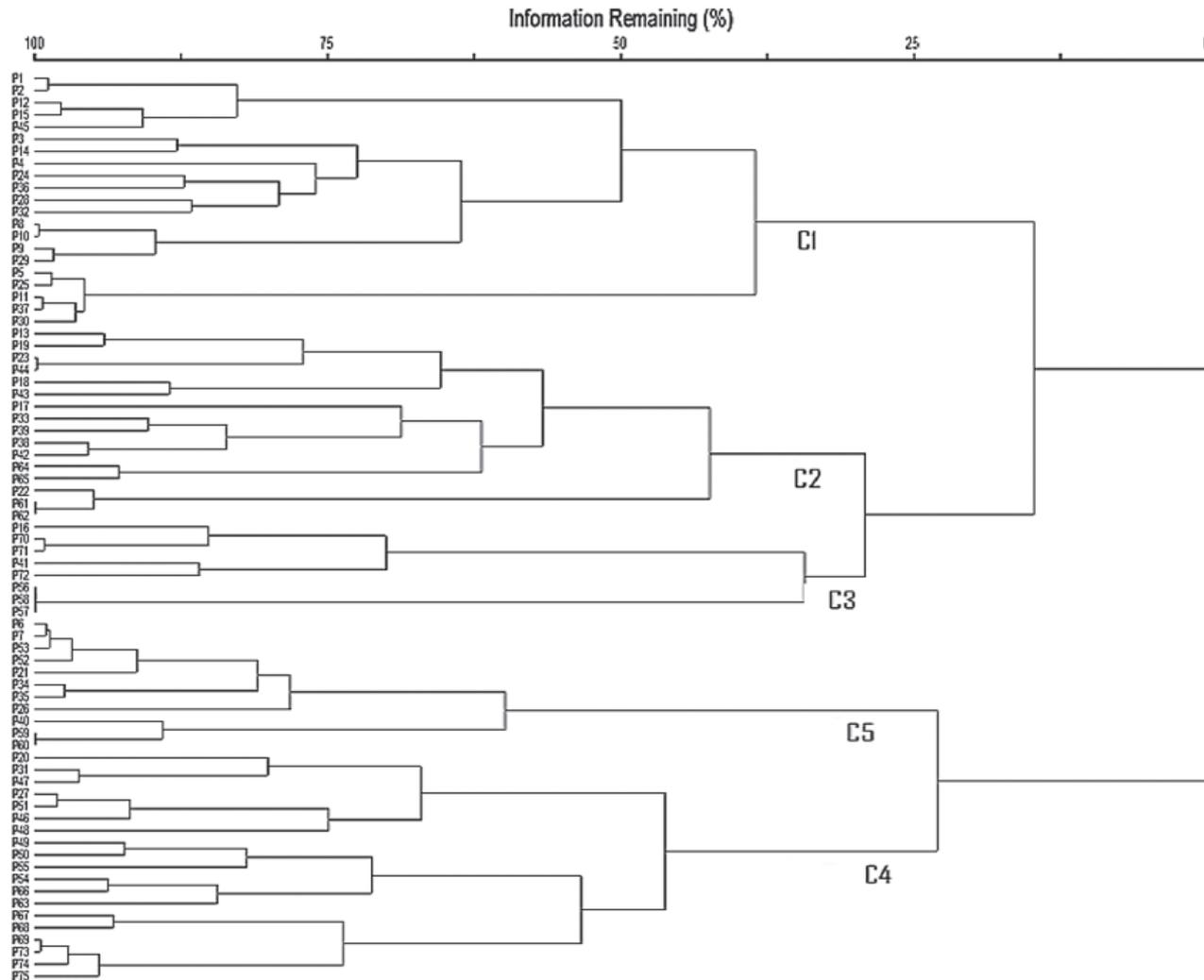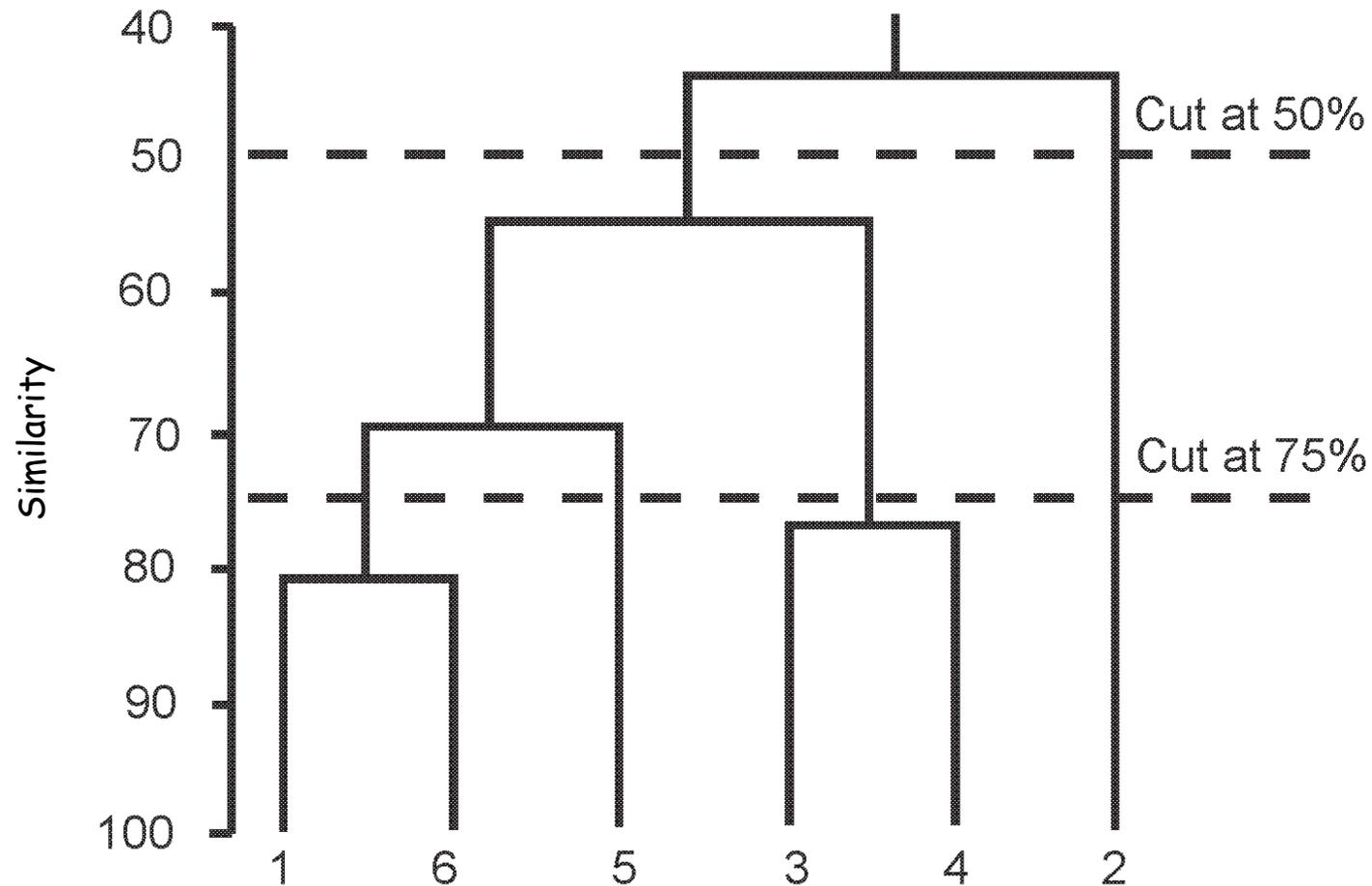
Cluster analysis

Source: Kwak and Patterson (2007)

Cluster analysis

- Using a dendrogram to define groups requires cutting the dendrogram, the position of the cut defining the number of resulting groups.

- Cutting the dendrogram demands a compromise between homogeneity of the groups and the number of groups.

- Multi-response permutation procedures (MRPP) can be used to test if there are significant differences in species composition between the plant community groups and to test within-group level of homogeneity.

Indicator species analysis

- Indicator species analysis is used among others to describe community types. It determines the value of different species for indicating environmental conditions.

- Indicator species analysis method combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence in a particular group.

Indicator species analysis

- A perfect indicator of a particular group should be faithful to that group (always present). It should be exclusive to that group, never occurring in other groups.

- The indicator values range from 0 (no indication to 100 (perfect indication).

- Indicator values are tested for statistical significance using a randomization (Monte Carlo) technique (Source: McCune & Grace 2002).

Indicator species analysis

Column	Avg	Max	MaxGrp	Group 1 (Seq 1, 12 items)	Group 2 (Seq 2, 12 items)	Group 3 (Seq 3, 5 items)	Group 4 (Seq 4, 7 items)
1 HagAby	25	52	2	34	52	15	0
2 RapSim	25	66	2	20	66	12	2
3 SchVol	25	37	2	35	37	22	5
4 HypRev	25	61	4	10	21	8	61
5 DisPen	25	57	3	16	25	57	2
6 Meraro	25	100	1	100	0	0	0
7 Shasheme	25	76	1	76	24	0	0
8 Agedena	25	68	1	68	0	32	0
9 AruAlp	25	100	1	100	0	0	0
10 Gora	25	59	1	59	5	36	0
11 Andode	25	100	1	100	0	0	0
12 Kombolch	25	72	2	28	72	0	0
13 Guri	25	91	1	91	9	0	0
14 Lalesa	25	100	1	100	0	0	0
15 EriArb	25	80	4	0	17	4	80
16 Hara	25	77	2	0	77	23	0
Averages	25	75		52	25	13	9

Column	Maxgrp	Observed Indicator Value (IV)	IV from randomized groups Mean	IV from randomized groups S.Dev	p *
1 HagAby	2	25.9	23.6	9.10	0.3029
2 RapSim	2	66.5	33.3	7.96	0.0012
3 SchVol	2	33.9	28.1	5.71	0.1532
4 HypRev	4	61.0	32.7	6.65	0.0004
5 DisPen	3	57.0	32.3	7.38	0.0058
6 Meraro	1	16.7	12.0	6.51	0.2565
7 Shasheme	1	31.5	19.2	9.25	0.1030
8 Agedena	1	62.2	22.4	8.53	0.0018
9 AruAlp	1	33.3	13.5	7.78	0.0378
10 Gora	1	49.1	22.3	7.89	0.0088
11 Andode	1	8.3	11.1	4.28	1.0000
12 Kombolch	2	17.9	18.5	8.65	0.4309
13 Guri	1	53.3	18.0	8.22	0.0040
14 Lalesa	1	8.3	11.1	4.26	1.0000
15 EriArb	4	79.7	29.2	7.82	0.0002
16 Hara	2	19.2	14.0	8.00	0.2567

Source: Yirdaw et al. 2015

Thank you!