INTRACO – Monday, Sept. 2020, 7th – CESAB Montpellier

twoe (2e): Simulating tropical forest dynamics from permanent sample plot data

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twoe

- `twoe` (2e) is the combination of:
  - **an R package**: to estimate species demographic parameter from permanent sample plot data
  - **a Java forest dynamics simulator**: to simulate tropical forest dynamics
- http://twoe.sourceforge.net (very old)

Permanent sample plot data

	A	B	C	D	E	H	I	J	K	L	M	N
1	"Plot"	"Tree"	"X"	"Y"	"Species"	"D1995.03.15"	"D1996.03.01"	"D1998.02.15"	"D2000.03.15"	"D2002.08.31"	"D2003.06.01"	"D2004.07.31"
223	"P11"	"P11T309"	58	147	"Sp306"	32.5	34.7	36.3	37.6	39.2	40.6	41.7
224	"P11"	"P11T310"	57	150	"Sp22"	20.8	20.8	21.2	20.8	21.5	21.6	22.6
225	"P11"	"P11T311"	55	150	"Sp218"	16.6	16.7	16.7	16.6	16.7	16.7	17.3
226	"P11"	"P11T312"	58	154	"Sp19"	17.7	18.3	18.3	18	18.3	18.3	18.6
227	"P11"	"P11T313"	58	154	"Sp216"	11.1	11.1	11.1	11.1	11.3	11.3	11.5
228	"P11"	"P11T316"	56	164	"Sp325"	33.9	34.2	34.1	34.1	34.2	34.2	35
229	"P11"	"P11T317"	55	169	"Sp559"	19.7	19.7	19.7	19.7	19.9	19.9	20.7
230	**"P11"**	**"P11T319"**	**53**	**167**	**"Sp266"**	**14**	**14.3**	**15**	**14.6**	**14.6**	**14.8**	**14.8**
231	"P11"	"P11T320"	54	165	"Sp22"	11.1	11.3	11.9	11.8	12.1	12.3	12.9
232	"P11"	"P11T321"	57	172	"Sp265"	22.4	22.4	22.4	22.1	22.4	22.4	23.6
233	"P11"	"P11T322"	54	175	"Sp713"	18.8	18.9	18.8	18.8	19.3	19.4	20.1
234	**"P11"**	**"P11T323"**	**53**	**173**	**"Sp222"**	**11.1**	**11.3**	**0**	**0**	**0**	**0**	**0**
235	"P11"	"P11T324"	51	172	"Sp109"	32.5	32.8	33.7	33.7	0	0	0
236	"P11"	"P11T325"	51	170	"Sp243"	28.2	28.6	29	28.6	0	0	0
237	"P11"	"P11T327"	54	162	"Sp256"	33.4	33.6	33.7	33.7	34.1	34.1	34.2
238	"P11"	"P11T328"	54	159	"Sp9"	38.2	39.2	41.4	44.2	44.6	44.7	46.2
239	"P11"	"P11T329"	54	161	"Sp559"	22	22.6	23.6	23.6	23.9	23.9	24
240	"P11"	"P11T330"	54	162	"Sp259"	11.5	11.5	11.5	11.3	11.5	11.6	11.6
241	"P11"	"P11T331"	51	182	"Sp16"	82.4	84.7	87.2	87.2	89.8	90.4	93.9
242	"P11"	"P11T332"	52	182	"Sp306"	26.6	27.5	26.7	27.9	28	28	28.6
243	"P11"	"P11T333"	54	181	"Sp14"	28.6	29.8	31.7	32.8	35.2	36.9	40.1
244	**"P11"**	**"P11T334"**	**56**	**180**	**"Sp713"**	**0**	**0**	**0**	**0**	**0**	**0**	**10.2**
245	"P11"	"P11T335"	55	183	"Sp22"	10.5	10.7	11	11	11	11	11
246	"P11"	"P11T336"	58	182	"Sp300"	29.1	29.3	29.3	29.3	29.1	29.4	30.6

Extract of MBaiki data-base (Central African forest)

R package

Provides functions to:

- **Format** the permanent sample plot data for demographic parameter inference (compute annual growth, competition indices, time interval between censuses, etc.).
- **Estimate** the species parameters for three demographic processes: growth, mortality, and recruitment.

Java simulator

- Simulate the forest dynamics from a set of demographic parameters for each species.
- Providing summary outputs.
- Using the Capsis plateform https://capsis.cirad.fr

Growth

Error process

$G_{ik}^{\text{obs}} \sim \text{Normal}(G_{ik}^{\text{true}}, V_i^{\text{err}})$
$V_i^{\text{err}} = (0.927 + 0.0038 D_i)^2$

Growth process

$\log(G_{ik}^{\text{true}}) \sim \text{Normal}((\beta_0 + b_{0,k}) + (\beta_1 + b_{1,k})\log(D_i) + (\beta_2 + b_{2,k})\log(C_i + 1), V)$

Priors

$[\beta_0, \beta_1, \beta_2] \sim \text{Normal}_3(\mu_\beta, V_\beta)$
$[b_{0,k}, b_{1,k}, b_{2,k}] \sim \text{Normal}_3(0, V_b)$
$V_b \sim \text{Inverse-Wishart}(r, rR)$
$V \sim \text{Inverse-Gamma}(\nu, \delta)$

G_{ik} is the growth (mm.yr^{-1}) of tree i of species k between census c and $c+1$
D_i is the diameter (cm) of tree i at census c
C_i is the competition index (m^2.ha^{-1}) in the neighborhood of tree i at census c
$b_{0,k}, b_{1,k}, b_{2,k}$ are the species random effects

Mortality

Mortality process

$S_{ik} \sim \text{Bernoulli}(\theta'_{ik})$
$\theta'_{ik} = 1 - (1 - \theta_{ik})^{Y_i}$
$\text{logit}(\theta_{ik}) = (\beta_0 + b_{0,k}) + (\beta_1 + b_{1,k})(D_i - 20) + (\beta_2 + b_{2,k})(C_i - 20) + \epsilon_i$

Priors

$\epsilon_i \sim \text{Normal}(0, V = 1)$
$[\beta_0, \beta_1, \beta_2] \sim \text{Normal}_3(\mu_\beta, V_\beta)$
$[b_{0,k}, b_{1,k}, b_{2,k}] \sim \text{Normal}_3(0, V_b)$
$V_b \sim \text{Inverse-Wishart}(r, rR)$

S_{ik} is the status (0=alive, 1=dead) of tree i of species k between census c and $c+1$
Y_i is the time interval (yr) between census c and $c+1$
θ'_{ik} is the mortality rate for time interval Y_i
θ_{ik} is the annual mortality rate
D_i is the diameter (cm) of tree i at census c
C_i is the competition index ($m^2.ha^{-1}$) in the neighborhood of tree i at census c
$b_{0,k}, b_{1,k}, b_{2,k}$ are the species random effects

Recruitment

Recruitment process

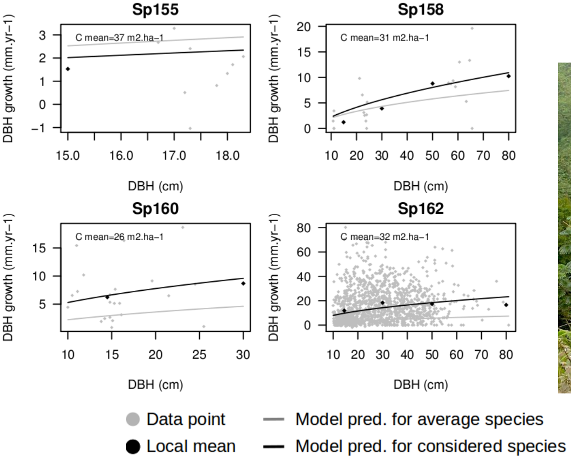
$R_{jk} \sim \text{Poisson}(\lambda'_{jk})$
$\lambda'_{jk} = \lambda_{jk} Y_j A_j$
$\log(\lambda_{jk}) = (\beta_0 + b_{0,k}) + (\beta_1 + b_{1,k})(BA_{jk} - 0.5) + (\beta_2 + b_{2,k})(C_j - 20) + \epsilon_j$

Priors

$\epsilon_j \sim \text{Normal}(0, V = 1)$
$[\beta_0, \beta_1, \beta_2] \sim \text{Normal}_3(\mu_\beta, V_\beta)$
$[b_{0,k}, b_{1,k}, b_{2,k}] \sim \text{Normal}_3(0, V_b)$
$V_b \sim \text{Inverse-Wishart}(r, rR)$

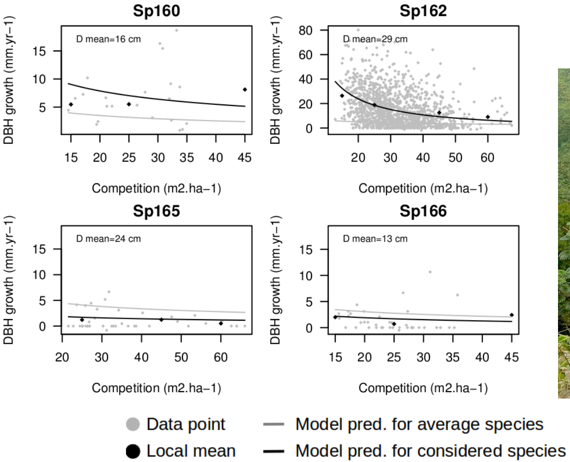
R_{jk} is the number of recruits of quadrat j for species k between census c and $c+1$
Y_j is the time interval (yr) between census c and $c+1$
A_j is the area (m^2) of quadrat j
λ'_{jk} is the mean number of recruits for time interval Y_j and area A_j
λ_{jk} is the mean number of recruits ($.yr^{-1}.m^{-2}$)
BA_{jk} is the basal area of conspecific trees ($m^2.ha^{-1}$) for sp. k in the quadrat j at census c
C_j is the competition index ($m^2.ha^{-1}$) in the quadrat j at census c
$b_{0,k}, b_{1,k}, b_{2,k}$ are the species random effects

Model predictions per species



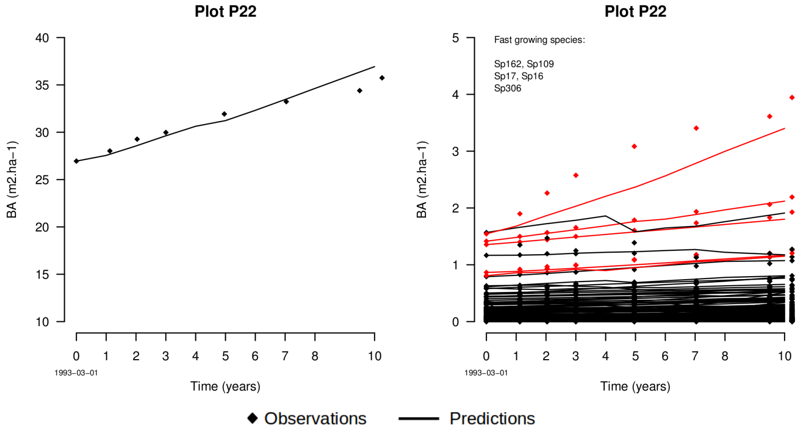
Sp162 = *Musanga cecropioides* R.Br. & Tedlie

Model predictions per species

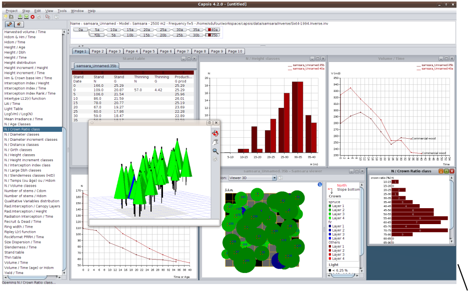


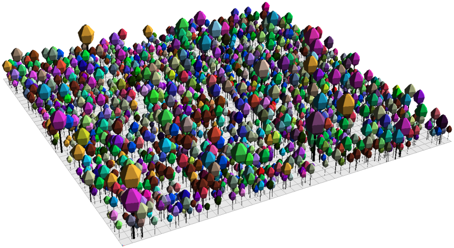
Sp162 = *Musanga cecropioides* R.Br. & Tedlie

Simulations



Summary outputs





Intraspecific variability

- Could enter the model through:
  - Individual random effects
  - Either structured spatially or not
- Individual random effects could be estimated from the data
- Would be hard to include multiple environmental factors (explicit niche multidimensionality)
- Strong link with the theoretical model suggested previously

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