Relay floristics as a model for rain forest restoration

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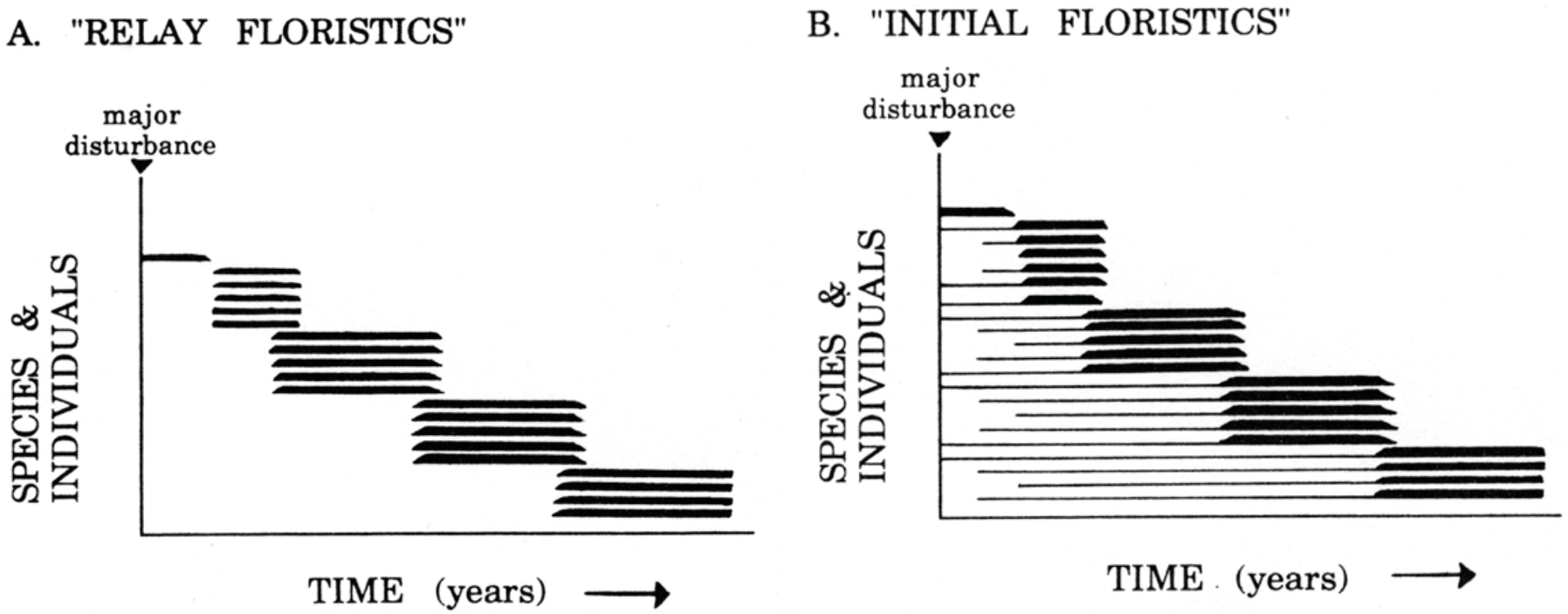
Relay Floristics as a Concept



(after Oliver and Larson, 1996)

Succession Theory

Relay versus Initial

Clements (1916) – Egler (1954)

Initial Floristics

Adaptation to disturbance in a Sri Lankan Rain Forest

25 y old; 1% PPFD

Ashton, 1992, Kluwer; Ashton et al., 2001, For.Ecol.Mgt.

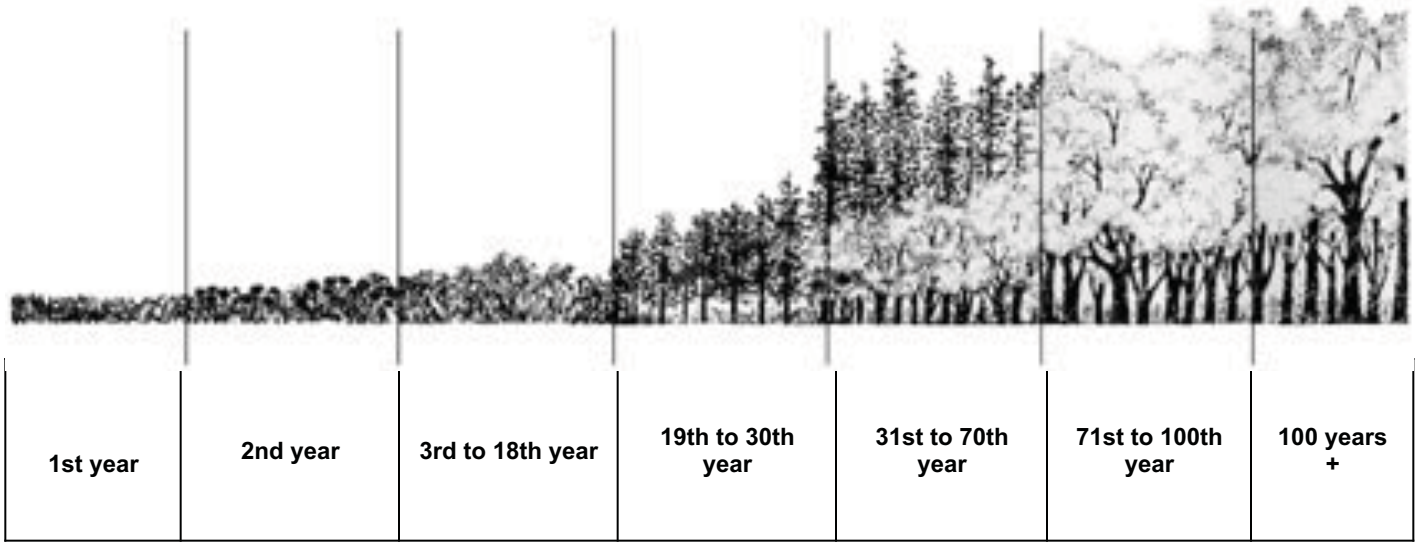
Relay Floristics

Maladaptation to disturbance

Sri Lanka – chena – abandoned tea cultivation
Dicronopteris linearis

Panama – abandoned pasture
Saccharum spontaneum

Old Field Pine as a Relay Floristics Model

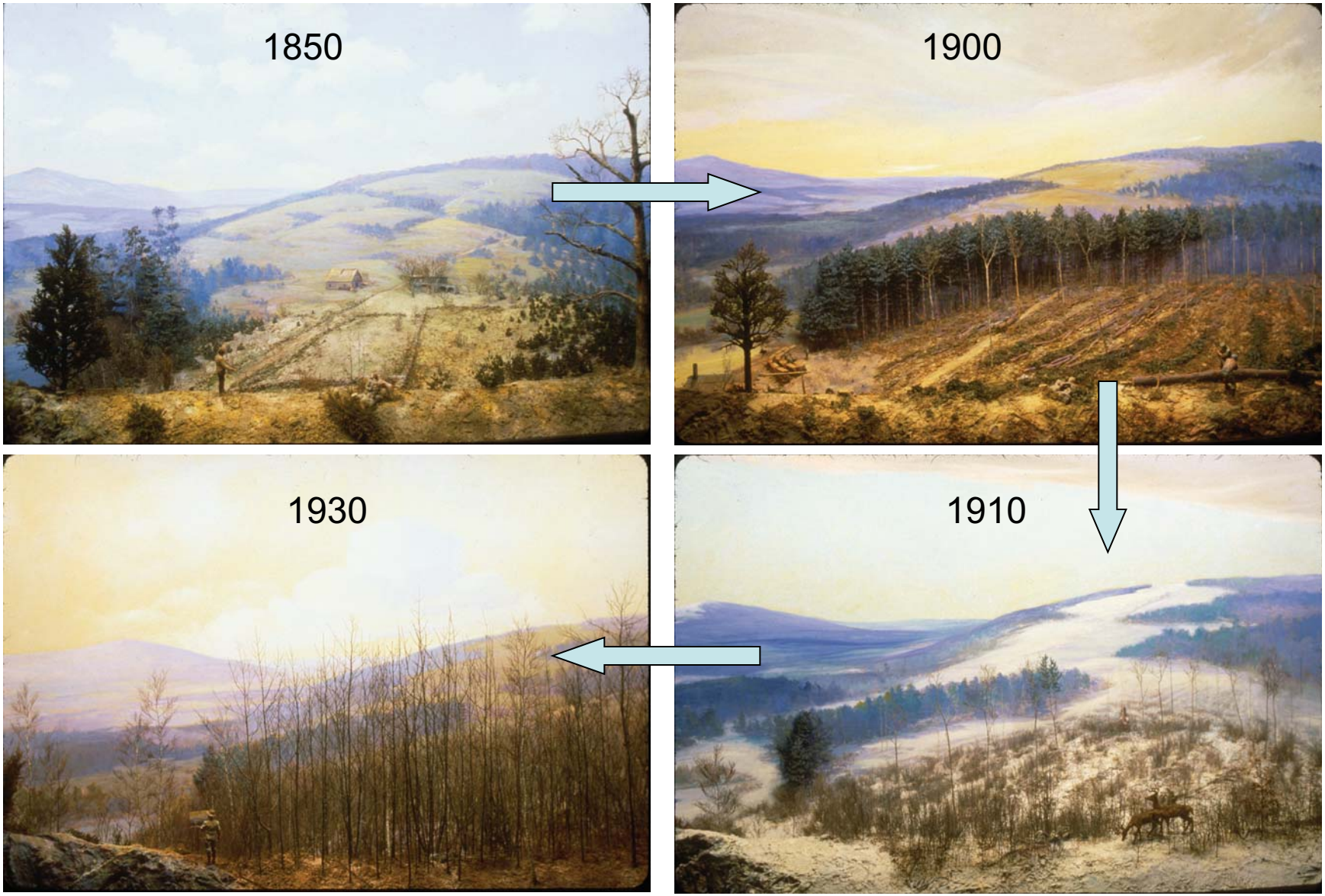


- **Succession in the North Carolina Piedmont (Duke Forest)**
- **1st year:** Horseweed dominant; crabgrass, pigweed
- **2nd year:** Asters dominant; crabgrass
- **3rd to 18th year:** Grass scrub community; broomsedge grass, pines coming in during this stage
- **19th to 30th year:** Young pine forest
- **30th to 70th year:** Mature pine forest; understory of young hardwoods 70th to 100th year: Pine to hardwood transition
- **100th year plus:** Oak-hickory forest

Bormann, Ecol. (1954)

Old field pine succession

Harvard Forest Dioramas



Old field pine examples

25 year old *P. strobus* (New England, USA)

35 year old *P. patula* (Oaxaca, MX)

Understory recruitment in tropical tree plantations

- Parrotta, J.A. 1995 (Puerto Rico)
- Fimbel, R. A., and C. C. Fimbel. 1996 (Uganda)
- Parrotta, J. A., J. W. Turnbull and N. Jones. 1997 (Brazil)
- Carnevale, N. J., and F. Montagnini. 2002 (Costa Rica)
- Cusack, D., and F. Montagnini. 2004 (Costa Rica)

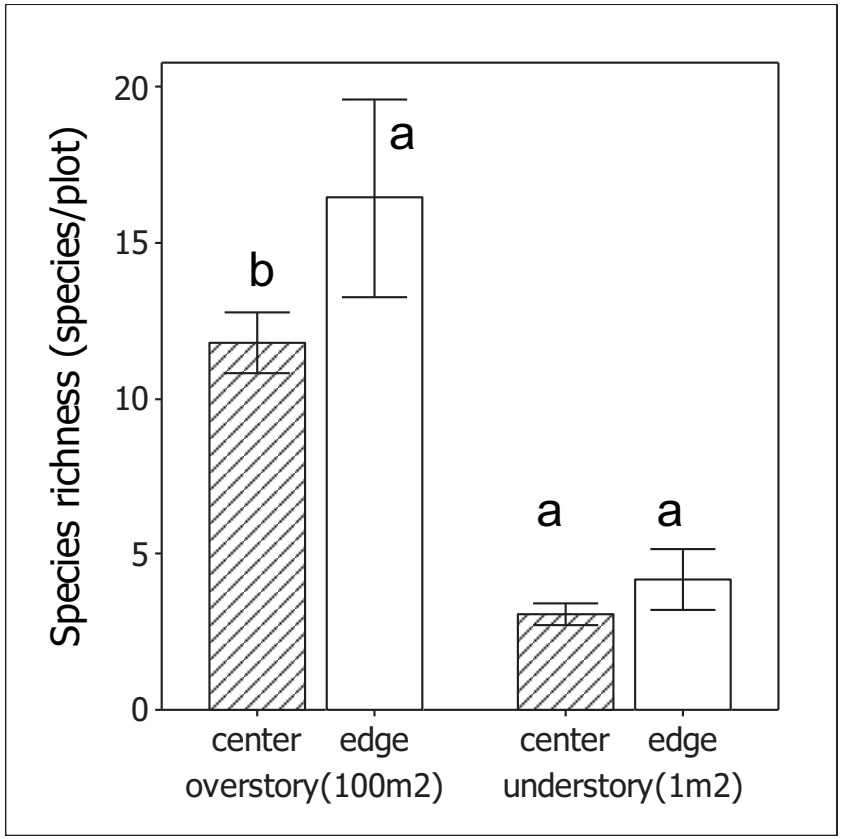
1970's reforestation with *P. caribaea* – Sri Lanka

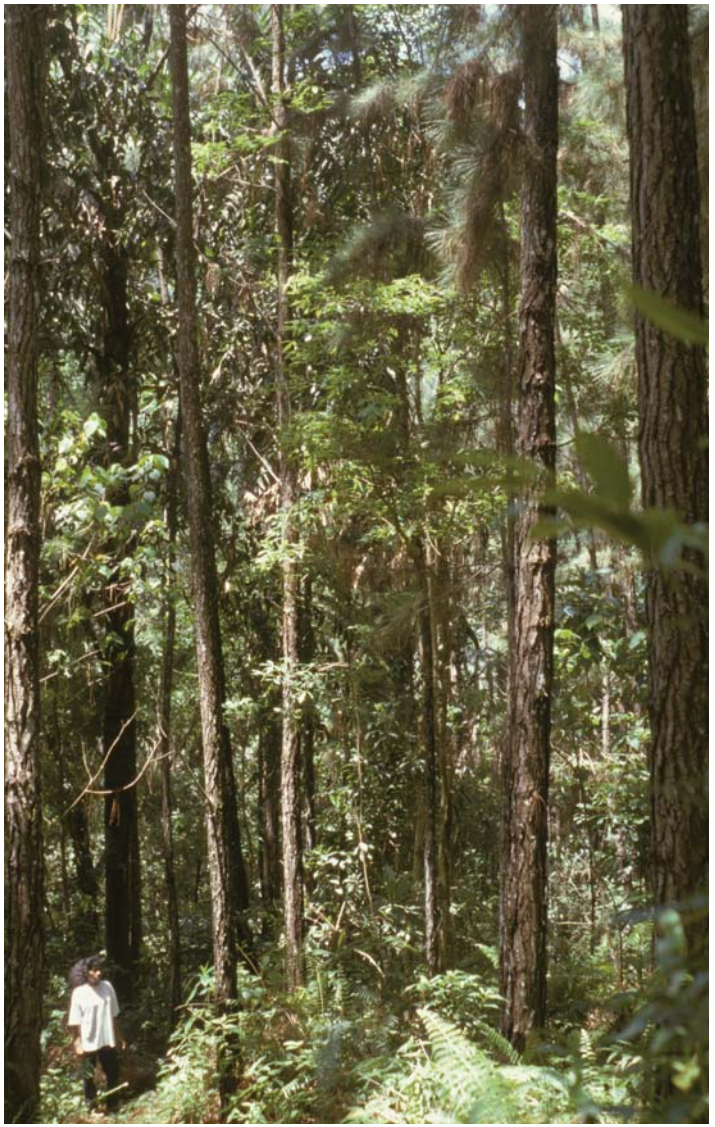
Studies on Native Species Recruitment beneath *P. caribaea*

- Conducted in the buffer zone of the Sinharaja MAB reserve
- Started in 1990 – NORAD/MacArthur
- Study 1 – natural regeneration after 25 years – dispersal syndromes – edge effects
- Study 2 – effects of fire on recruitment
- Study 3 – enrichment planting beneath the canopy and across openings

Study 1 - natural regeneration after 25 years

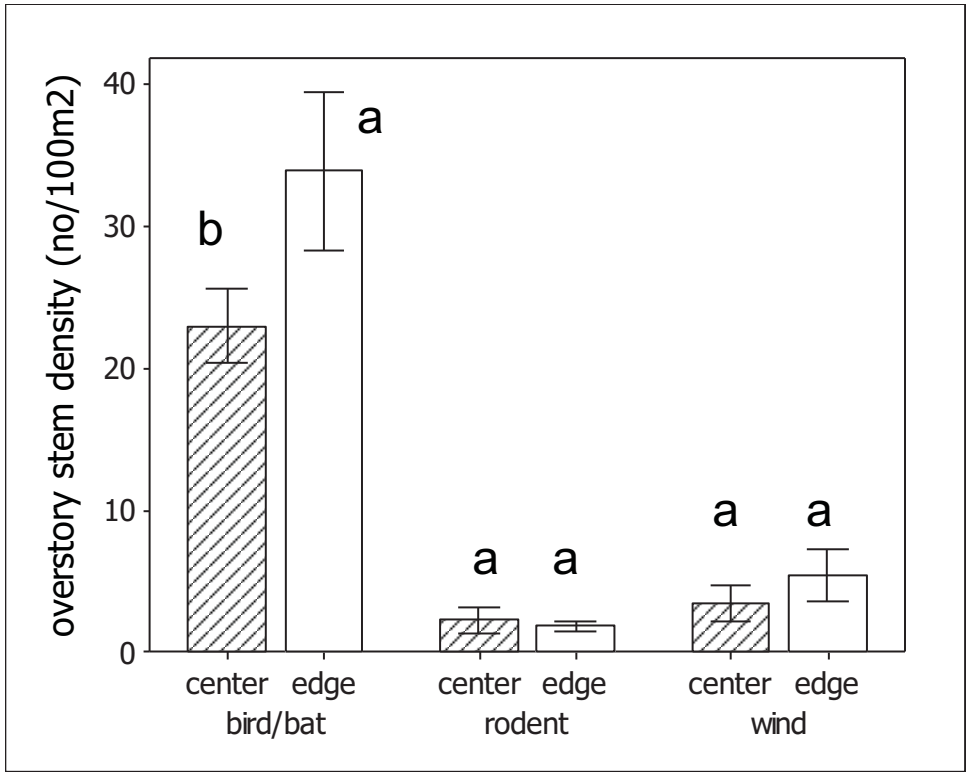
Overstory recruitment - ≥1 m
Understory recruitment - < 1 m

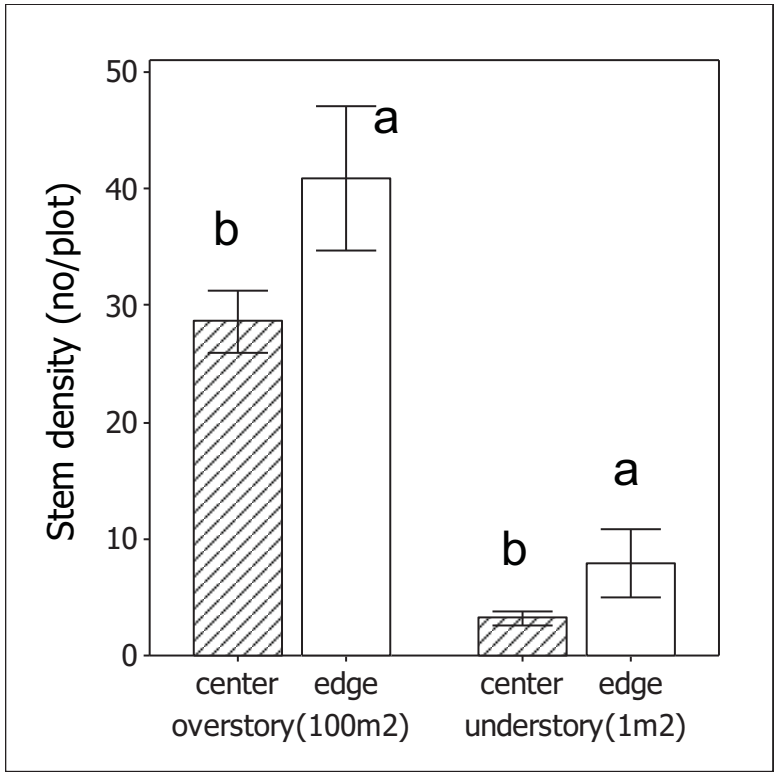




Tomimura et al., 2012, J.Sus.For.

Study 1 - natural regeneration after 25 years





Tomimura et al., 2012, J.Sus.For.

Species	Family	Origin[1]	Guild[2]	Dispersal vector[3]	DBH	HT	N[4]	RDe[5]	F[6]	RF[7]	RDo[8]	IVI[9]
Schumacheria castaneifolia	Dilleniaceae	E	E	Bb	3.0	3.9	412	21.7	0.85	6.6	9.54	37.89
Alstonia macrophylla	Apocynaceae	X	E	W	6.3	7.5	193	10.2	0.61	4.8	18.44	33.38
Neolitsea cassia	Lauraceae	N	L	B	5.1	3.4	35	1.8	0.37	2.9	13.30	18.04
Gomphia serrata	Ochnaceae	N	L	B	2.6	3.9	162	8.5	0.57	4.5	2.64	15.63
Thottea siliquosa	Aristolochiaceae	N	L	B	1.3	2.1	217	11.4	0.43	3.3	0.92	15.67
Wendlandia bicuspidata	Rubiaceae	E	E	B	8.0	6.0	56	3.0	0.47	3.6	7.09	13.67
Dillenia triquetra	Dilleniaceae	N	E	Bb	2.1	3.1	116	6.1	0.60	4.7	1.18	11.96
Eurya acuminata	Theaceae	N	I	B	3.2	4.3	83	4.4	0.49	3.8	1.43	9.64
Litsea longifolia	Lauraceae	E	I	B	1.6	2.4	78	4.1	0.40	3.1	0.53	7.75
Acronychia pedunculata	Rutaceae	N	I	B	8.3	7.3	34	1.8	0.24	1.9	3.65	7.31
Clerodendrum infortunatum	Verbenaceae	N	E	B	6.4	4.9	30	1.6	0.20	1.6	3.93	7.07
Chaetocarpus castanocarpus	Euphorbiaceae	N	L	R	2.3	3.8	55	2.9	0.37	2.9	0.77	6.57
Hedyotis fruticosa	Rubiaceae	N	E	B	1.3	2.6	67	3.5	0.37	2.9	0.22	6.65
Anisophillea cinnamomoides	Rhizophoraceae	E	L	B	4.8	5.8	32	1.7	0.23	1.8	1.67	5.12
Glochidion zeylanicum	Euphorbiaceae	N	L	B	1.3	2.2	42	2.2	0.35	2.7	0.12	5.03
Syzygium rubicundum	Myrtaceae	N	L	B	1.5	2.8	43	2.3	0.33	2.6	0.17	5.02
Vitex altissima	Verbenaceae	N	E	B	6.3	6.7	24	1.3	0.24	1.9	1.69	4.82
Croton laccifer	Euphorbiaceae	N	E	B	3.4	4.6	41	2.2	0.20	1.6	0.86	4.57
Symplocos cochinchinensis	Symplocaceae	N	L	B	2.8	3.9	29	1.5	0.28	2.2	0.48	4.19
Syzygium operculatum	Myrtaceae	N	I	B	6.2	5.6	11	0.6	0.11	0.8	2.60	4.00
Gaertnera vaginans	Rubiaceae	N	L	B	2.4	2.8	38	2.0	0.15	1.1	0.52	3.67
Caryota urens	Arecaceae	N	I	H	26.5	10.2	3	0.2	0.04	0.3	2.84	3.31
Elaeocarpus serratus	Elaeocarpaceae	N	I	Bb	9.1	9.0	11	0.6	0.12	0.9	1.85	3.36
Aporusa cardiosperma	Euphorbiaceae	N	I	B	2.9	3.9	22	1.2	0.20	1.6	0.55	3.27
Macaranga peltata	Euphorbiaceae	N	E	Bb	7.1	7.0	14	0.7	0.17	1.3	1.05	3.14
Aporusa acuminata	Euphorbiaceae	N	I	B	2.7	3.9	20	1.1	0.23	1.8	0.31	3.12
Syzygium makul	Myrtaceae	N	L	B	2.5	4.3	20	1.1	0.20	1.6	0.26	2.87

Common species found in 10x10m plots in the order of higher to lower importance value index (in the last column).

[1]E: endemic, N: native, X: exotic
[2]E: early, I: Intermediate, L: late, blank: not identified
[3]B: bird, Bb: bird and bat, W: wind, M: mammal
[4] The total number of plants found in this study
[5] Relative density = number of individuals of a species / total number of individual of all species x 100
[6] Frequency = number of plots in which a species occurred / total number of plots
[7] Relative frequency = frequency of a species / total frequency of all species x 100
[8] Relative dominance = total basal area of the species / total basal area of all species x 100
[9] Importance Value Index = Relative density + relative frequency + relative dominance

Tomimura et al., 2012, J.Sus.For.

Study 2 – effects of fire on recruitment

Understory composition	Plantation history: Unburned	Plantation history: Once burned
***Density*(stems/ha)**		
Bamboo	1167 (618)a	0 (0)a
Ferns	17 (16)a	0 (0)a
Shrubs	1617 (378)a	50 (23)b
Trees	2825 (870)a	358 (113)b
Vines	258 (70)a	17 (15)b
***Basal area* (m2/ha)**		
Bamboo	0.061 (0.040)a	0 (0) a
Ferns	0.055 (0.041)a	0 (0) a
Shrubs	0.888 (0.340)a	0.009 (0.006)a
Trees	2.475 (0.865)a	1.033 (0.350)a
Vines	0.044 (0.015)a	0.002 (0.001)a
Number of species	59	9
Shannon-Weaver		
Diversity = H	3.023	1.189
Equitability = J	0.809	0.611
Simpson		
Diversity = D	14.169	2.160
Equitability = E	0.337	0.309

Density and basal area by growth habit, and diversity indices of native vegetation beneath the *Pinus* plantations with different fire histories. Means followed by different letters demonstrate differences (P > 0.5) among plantations.

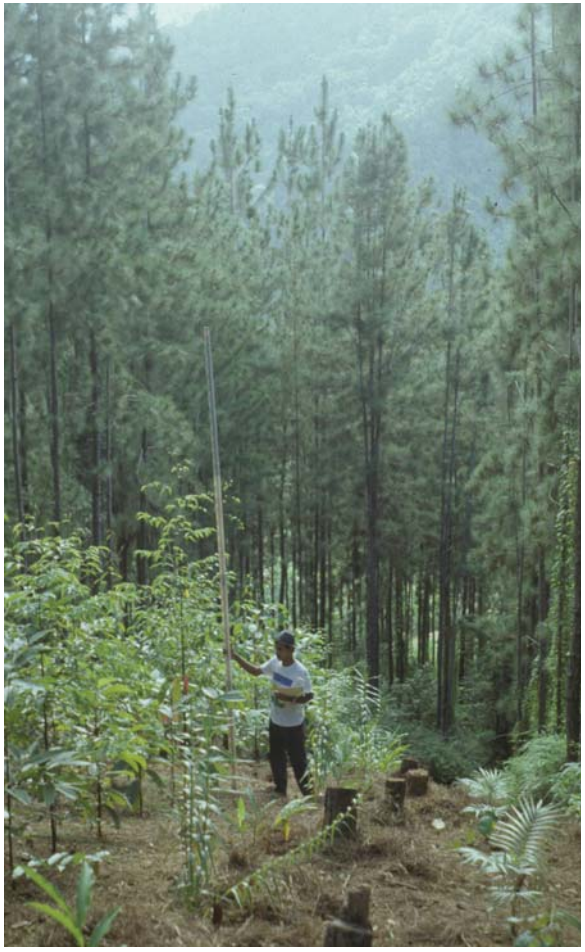
Shibayama et al., 2007, For.Ecol. Manage

Study 3 – enrichment planting beneath the canopy and across openings

Treatments: understory, 3 row underplanting, 1 row removal, 3 row removal and open

0 y

2 y

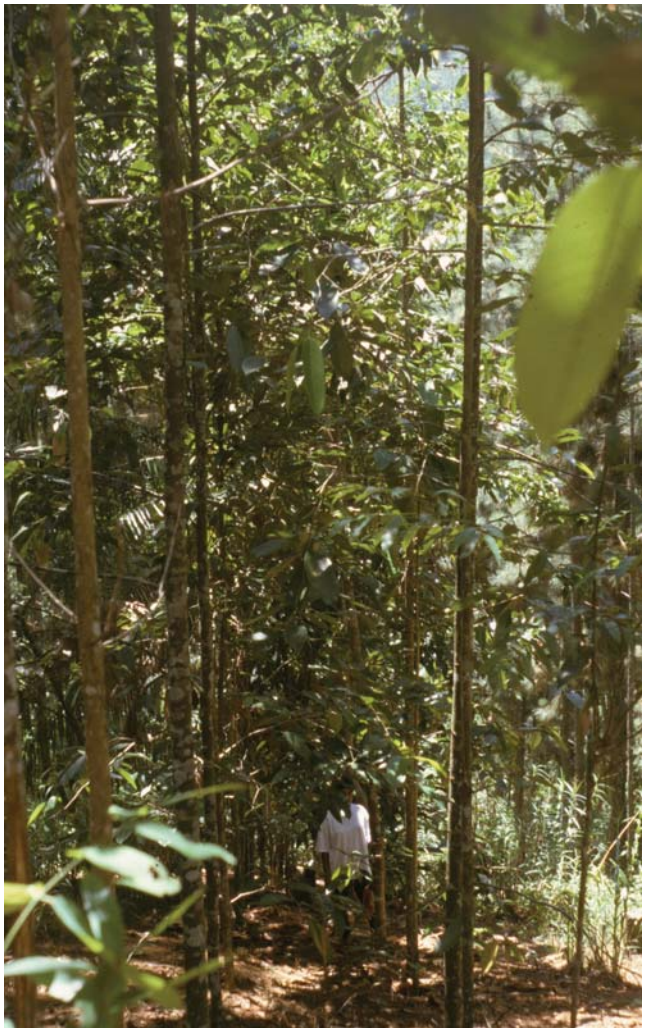


6 y

Ashton et al., 1997, J. Appl. Ecol.; Ashton et al., 1998, For.Ecol. Manage.

8 y

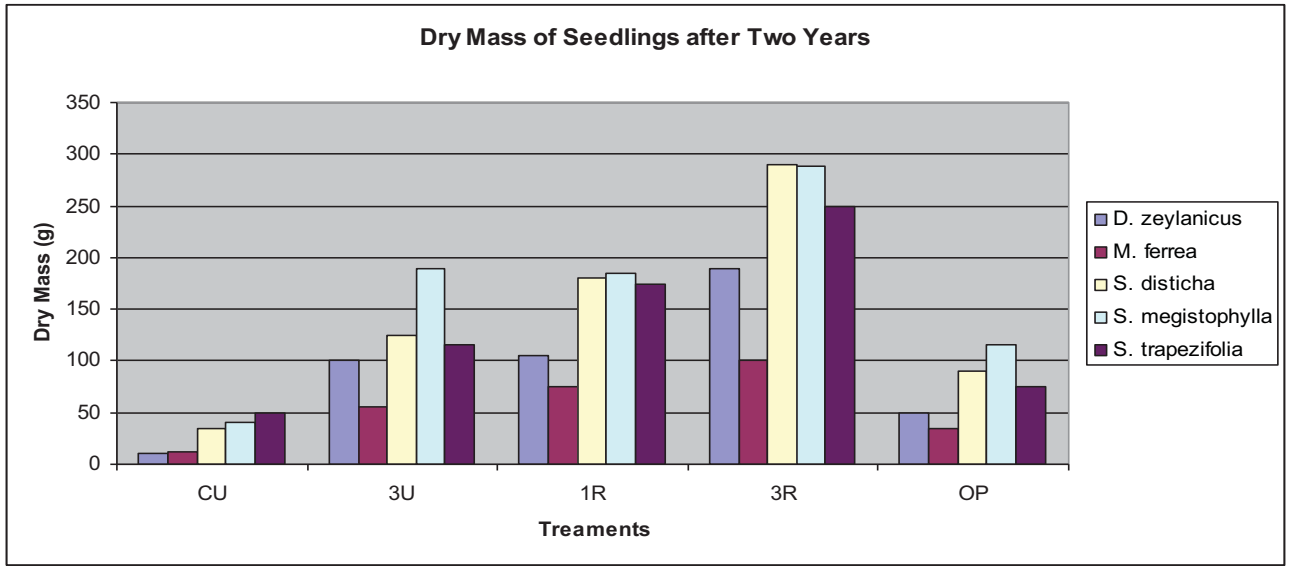
Pine opening

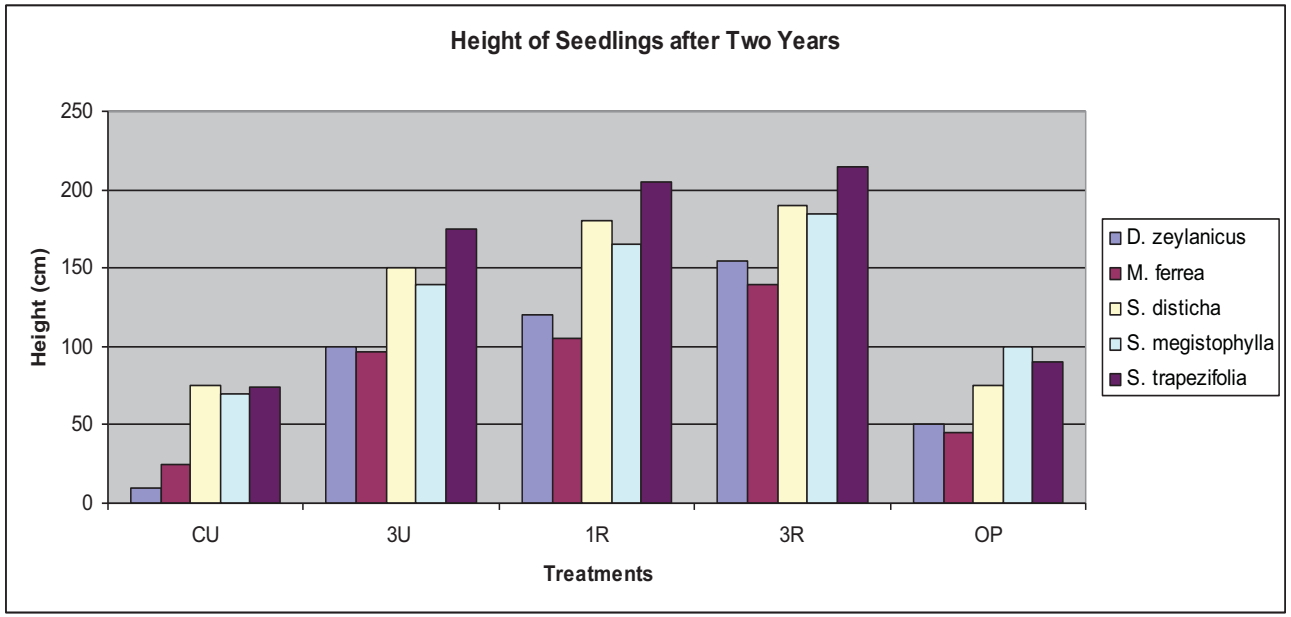


open

Ashton et al., 1997, J. Appl. Ecol.; Ashton et al., 2998, For.Ecol. Manage.

Study 3 – enrichment planting beneath the canopy and across openings

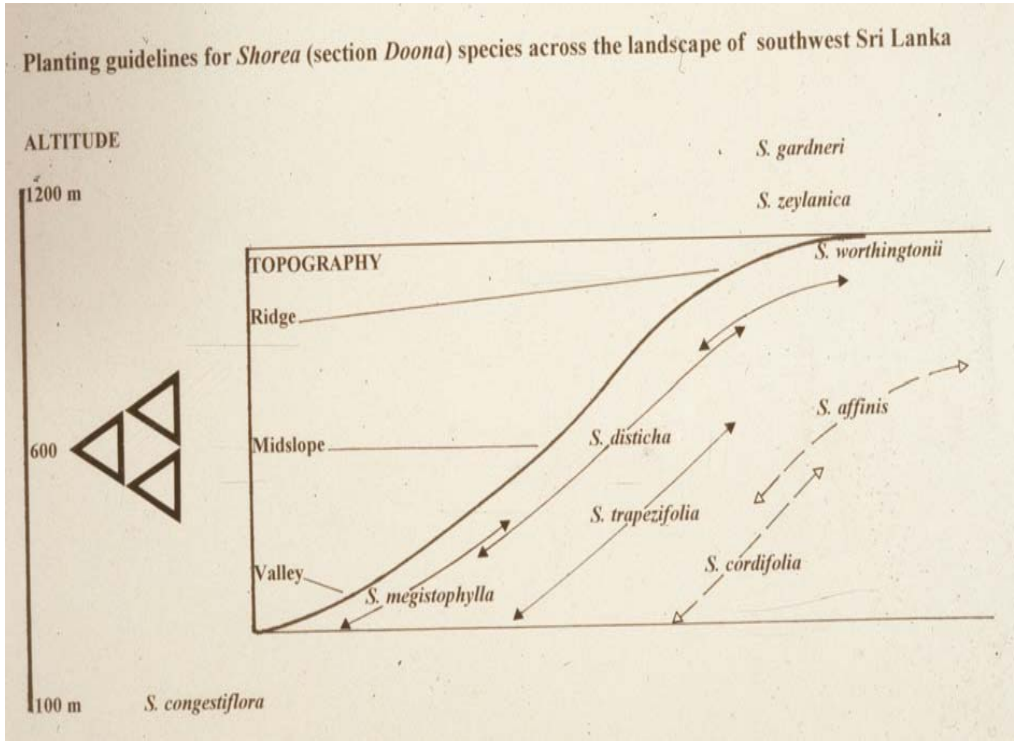




CU – underplanting
3U – 3 row underplanting
1R – 1 row removal
3R – 3 row removal
OP - open

Enrichment planting guidelines

1. 3R – best treatment in height growth and dry mass
2. *S. trapezifolia, S. megistophylla, S. disticha* – midslopes/mid elevation
3. Can develop compatible stratified mixtures e.g. *S. trapezifolia* with *M. ferrea*
4. Topographic and elevation affinities



Pine – potential facilitation?

	P. caribaea	Valley	Midslope
% soil carbon	6.02a	2.05b	1.44b
PPFD (mols d-1)	2.30-5.06	0.69-0.92	0.26-0.58
R:FR ratio	0.87	0.35	0.38

Some other considerations

- Competitive exclusion of shade intolerant herbs and colonizing invasives?
- Ectomycorrhizal – nutrient pump? Amelioration of nutrient poor soils?

Management Implications

- Pine can passively facilitate natural regeneration of second growth rainforest – site generalists – bird and bat dispersed – edge effect – protect from fire
- Pine can be used as a nurse for site restricted late successional rainforest tree species – creation of canopy openings and knowledge of topographic affinity important

Economics?

Managed facilitation*

	return $/ha	period of maturation
Pine – structural timber/resin	1,500	10-15y
Cardamom – spice	1,148	15-20y
Cane – artisanal	128	20-25y
Sugar palm	11,013	15-25y
Timber – structural/dimension	5,000	35-50y
- artisanal/furniture/flooring	6,231	50-60y
TOTAL	**25,020**	

Unmanaged facilitation*

TOTAL	**5,670**	15-60y

Comparative land use – poor tea land

Tea	**15,734**	5-30y

(Discount rate – 4%; in 2000 dollars)

* Does not include water regulation and quality values or conservation values

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