- The **Brazilian Amazon** occupies an area of 4.9 million km^2
- **Biodiversity**:
  - 21,000 spp. of higher plants – while the Neotropical forests worldwide have 92,000 spp. (Simberloff, 1982)
  - 280 spp. woody plants per hectare
  - 30% of timber resources on Earth
  - 1,800 spp. → fishes
  - 1.000 spp. → birds
  - 311 spp. → mammals

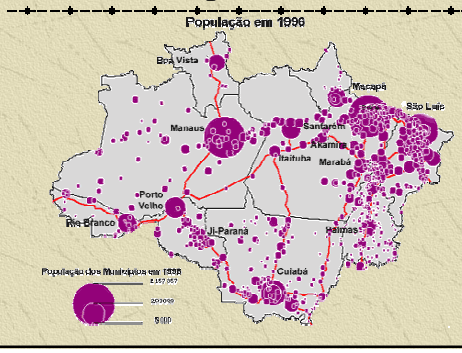
- **50% of the terrestrial organisms' species**

Ecosystem services

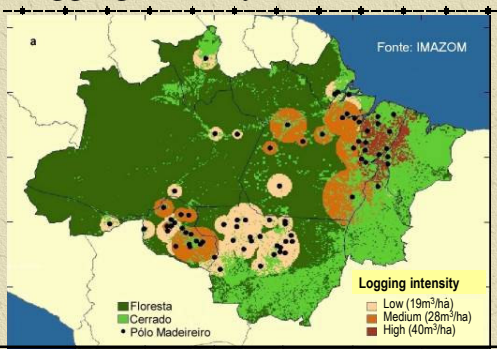
- **Global influence**
  - Biogeochemistry cycles (Carbon; nutrient cycling)
  - Water & climate regulation
- **Genetic resources**
  - Biodiversity

Main causes of habitat loss in the Amazon region

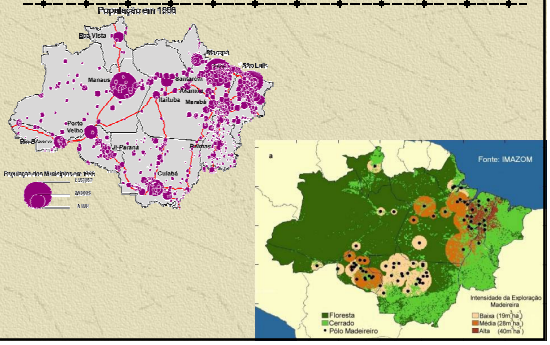
Human Occupation



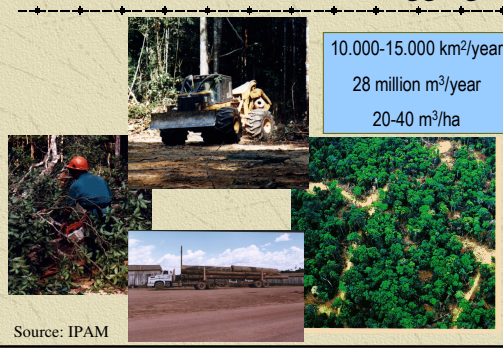
Logging Activity Areas



Human Occupation & Logging Activities



Deforestation – traditional logging



10.000-15.000 km²/year
28 million m³/year
20-40 m³/ha

Source: IPAM

Forest conversion to agriculture


Photo: M. Maués


Photo: J.B.Guerrero


Photo: J.B.Guerrero


Photo: J.B.Guerrero

Flammability


Photo: IPAM

Forest submitted to traditional logging and ground fire on primary forest during "El Niño" year (Tailândia – PA, 1998)


Photo: M. Cochrane

Annually, about 600.000 families slash and burn 1-3 hectares in the Amazon region, for subsistence agriculture (Homma, 1998)

Consequences of Deforestation

- Microclimate changes:
  - 37% canopy opening
  - ↑ flammability risks
- Biodiversity decline:
  - Habitat loss
  - Isolation
  - Changes on migration & dispersion patterns

Large-scale impoverishment of the Amazon forest

Fragmentation and Pollination

- ↓ effective population of woody species
- ↓ number of pollen donors
- ↓ amount of compatible pollen deposited on the stigma
- ↓ population of pollinators

Reduces the fruit set and leads to genetic drift

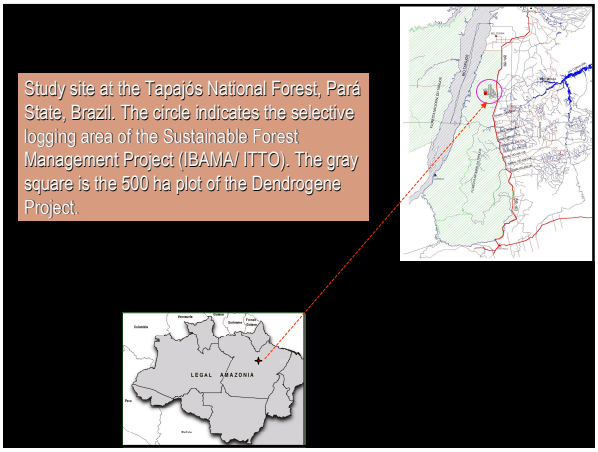
Objectives

- Identification of the pollination agents of two important Amazonian timber species:
  - *Jacaranda copaia* (Bignoniaceae)
  - *Dipteryx odorata* (Leg-Papilionoidae)
- Link the pollination agents with potential disruption of the reproductive process on fragmented forest due to logging activities

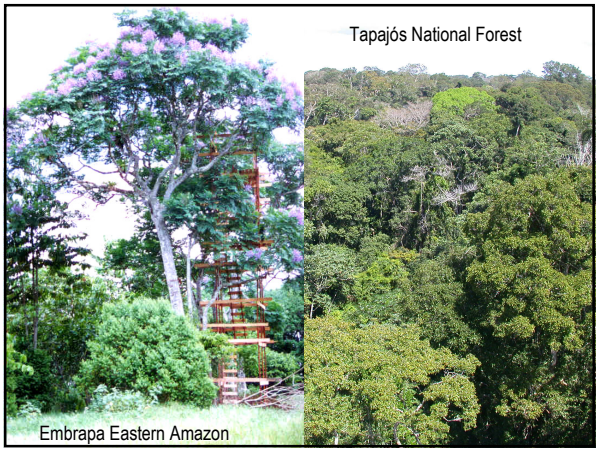
Material & Methods

Study sites:

- Tapajós National Forest (600,000 hectares – Pará State)
  - Primary forest
  - **Ami** climate type (2-3 months dry period, average rainfall of 2,000 mm/year, average annual temperature of 25 ºC)
  - Study plot of 500 ha
- Embrapa Eastern Amazon (Belém, Pará State)
  - Plantation (40 years)
  - **Afi** climate type (annual average rainfall of 2,900 mm average annual temperature of 25.9ºC)

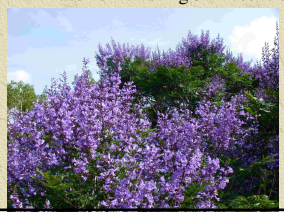


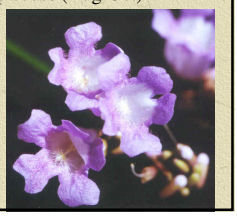
Study site at the Tapajós National Forest, Pará State, Brazil. The circle indicates the selective logging area of the Sustainable Forest Management Project (IBAMA/ ITTO). The gray square is the 500 ha plot of the Dendrogene Project.



Jacaranda copaia (Aubl.) D. Don (Bignoniaceae)

- Pioneer canopy, upper canopy and understory species
- Wood: plywood use
- 30-35 m height
- Massive flowering 3-4 weeks episodes (Aug-Oct)





Dipteryx odorata Willd. (Leguminosae-Papilionoidae)

- Emergent and light demanding species
- Wood: resistant & durable
- 30-35 m height
- Asynchronous flowering pattern, mainly on sep-Nov

Main studies:

- Floral biology
  - anthesis, number of flowers opened/day, flower longevity, duration of flowering, pollen/ovule ratio
- Hand-pollination tests:
  - (1) cross-pollination; (2) self-pollination; (3) spontaneous (automatic) self-pollination; (4) control
- Pollination agents & visitors:
  - (1) species; (2) if there was contact between the visitor body and the reproductive organs of the flowers; (3) if pollen or nectar was collected/consumed

Wood tower used to have access to the canopy at the Tapajós forest

Results

- Floral biology characteristics:

Floral biology	*Jacaranda copaia*	*Dipteryx odorata*
Inflorescence type	Panicle	Panicle
Inflorescence size	Up to 37 cm	Up to 12.9 cm
Flowers/inflorescence	1,900	53
Flowers opened/day	83	14
Flower type	Tubular	Papilionate
Color	Violet	Violet-pink
Anthesis	7:30-8:30h	5:00-6:00h
Important attributes	Staminode	Strong sweet odor

Controlled pollination tests:

Species	*Jacaranda copaia*		*Dipteryx odorata*	
Treatments	Initiated fruits	Mature fruits	Initiated fruits	Mature fruits
Cross-pollination	21.7% (469/2,524)	**6.54**% (173/2,524)	15.04% (465/3,091)	**4,10**% (127/3,091)
Self-pollination	0.06% (1/2,099)	-	8.36% (268/3,206)	**0,16**% (5/3,206)
Automatic SP	-	-	0.19% (16/8,255)	**0.02**% (2/8,255)
Control	4.99% (414/6,932)	**1.06**% (91/6,932)	3.52% (228/6,477)	**0,29**% (19/6,477)

Self-incompatibility system in both species

Self-incompatibility:

- *Jacaranda copaia:* Homomorphic sporophitic self-incompatiblity (SSI)
  - SP pistil abortion within two days
- *Dipteryx odorata*: late-acting self-incompatibility (LSI)
  - SP pistil abortion within 17 (mainly 5) weeks

Both species are obligate-outcrossers

Attractants & flower visitors:

- Bright colors
- Flowering episodes
  - *J. copaia* flowers annually with high synchronization
  - *D. odorata* may flower sub-annually within the population, thus with an asynchronous pattern
- Odor
- Hidden flower resources
  - Nectar
  - Pollen
- Visitors: bees, wasps, flies, moths, butterflies, beetles and hummingbirds

Flower visitors	Locality	Category*	Resource*
INSECTA			
HYMENOPTERA			
Apidae			
Aparatrigona impunctata (Ducke, 1986)	Bel/Tap	O	P
Bombus brevivillus Franklin, 1913	Bel/Tap	P	N
Bombus transversalis (Olivier, 1789)	Bel/Tap	P	N
Centris flavifrons (Fabricius, 1775)	Bel	O	N
Centris similis (Fabricius, 1804)	Bel	O	N
Centris spp. (5 species)	Bel/Tap	P	N, P
Epicharis (Hoplepicharis) affinis Smith, 1874	Bel	P	N
Epicharis rustica (Olivier, 1789)	Bel	O	N
Epicharis spp. (2 species)	Bel	O	N
Eufriesea mussitans (Fabricius, 1787)	Bel	O	N
Euglossa chlorina (Dressler, 1982)	Bel	P	N, P
Euglossa spp. (2 species)	Tap	P	N, P
Eulaema meriana (Olivier, 1789)	Bel	O	N
Eulaema nigrita Lepeletier, 1841	Bel	P	N
Exomalopsis sp.	Bel	O	P
Melipona compressipes (fabricius, 1804)	Tap	O	N, P
Meliponina (6 species)	Tap	O	P
Paratetrapedia spp. (2 species)	Bel	O	P
Xylocopa frontalis (Olivier, 1789)	Bel	R	N
Megachilidae			
Megachile sp.	Bel	O	N
Andrenidae (1 species)	Tap	O	N
Halictidae (5 species)	Tap	O	N
Vespidae (1 species)	Bel/Tap	O	N
DIPTERA			
Bibionidae (1 species)	Tap	O	P
Syrphidae			
Ornidia obesa Fabricius, 1775	Bel	O	P
COLEOPTERA			
Chrysomelidae (4 species)	Tap	O	P
Scarabaeidade – Rutelinae (3 species)	Tap	O	P
LEPIDOPTERA			
Pieridae (1 species)	Tap	R	N
AVES			
Trochilidae (3 species)	Bel/Tap	O	N

Jacaranda copaia visitors & pollinators

▪Bel = Belém; Tap = Tapajós National Forest

▪*p = legitimate pollinator; o = occasional pollinator; r = pollen/nectar robber

▪*Floral resources used by the visitors/pollinators (N = nectar; P = pollen)

Flower visitors	Locality	Category	Resource
INSECTA			
HYMENOPTERA			
Apidae			
Bombus brevivillus Franklin, 1913	Bel	P	N
Bombus transversalis (Olivier, 1789)	Bel/Tap	P	N
Centris sp.1	Bel	P	N,P
Epicharis (Hoplepicharis) affinis Smith, 1874	Bel	P	N
Epicharis rustica (Olivier, 1789)	Bel	P	N
Epicharis sp. (2 species)	Bel	P	N
Eulaema meriana (Olivier, 1789)	Bel	P	N
Eulaema nigrita Lepeletier, 1841	Bel	P	N
Meliponina (5 species)	Tap	O	N,P
Trigonisca sp. 1	Tap	O	P
Xylocopa frontalis (Olivier, 1789)	Bel	O	N
Vespidae (1 species)	Bel	O	N
COLEOPTERA			
Chrysomelidae (2 species)	Bel/Tap	O	P
Scarabaeidae – Rutelinae (3 species)	Bel/Tap	P	P
LEPIDOPTERA			
Heliconidae (1 species)	Tap	O	N
Nimphalidae (1 species)	Tap	O	N
Papilionidae (2 species)	Tap	O	N
Pieridae (1 species)	Tap	O	N
AVES			
Trochilidae (2 species)	Bel/Tap	O	N

Dipteryx odorata visitors & pollinators

▪Bel = Belém; Tap = Tapajós National Forest

▪*p = legitimate pollinator; o = occasional pollinator; r = pollen/nectar robber

▪*Floral resources used by the visitors/pollinators (N = nectar; P = pollen)

Pollination system:

- Both species are bee-pollinated
- *J. copaia* is mainly pollinated by small-bodied *Euglossa* and *Centris* species
- *D. odorata* is mainly pollinated by medium-bodied *Bombus, Centris, Eulaema, Epicharis* species

Large Euglossini bees ⇒ long distance fliers and trapliners

Logging & pollination:

- Selective logging modifies the spatial structure of woody trees, reducing the effective population of pollen donors
- Studies in Central Amazon region indicated a decrease of Euglossini due to habitat fragmentation (Powell & Powell, 1987; Becker *et al.*, 1991)
- Logging affects directly the population of native bees by removing nesting places or killing bees colonies living in felled trees (Elz *et al.*, 2003)
- The reproductive health of the remnant stands may be affected

- Given that native bees were the most important pollinators of the studied species, their preservation within the remnant stands of native forests is vital for the reproductive health of the woody upper canopy stratum of tropical forests

Concluding remarks

- Efforts should be addressed in order to improve the forest management techniques aiming to preserve adequate conditions for nesting and foraging of native pollinators for conservation purposes, and as a means of maintenance of genetic diversity within tree population.

- Disruption of pollination services in fragmented forests is a major concern for the maintenance of the sustainability of forest management through low impact logging.