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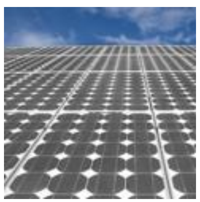

Tropical forests, tipping points and the social cost of deforestation

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Main contributions

- New framework for calculating the marginal economic value of a standing tropical forest.
- An estimate of the economic impact of a forest-savanna transition.
- New costing method: the average incremental cost method, instead of the marginal cost method, for the design of
  - optimal land-use policy, and
  - payments for ecosystem services.

The Amazon rainforest

Covers 530 million ha of land (2006).

Located in 9 different countries.

Provides a range of ecosystem services:

- Private; Public
- Local; Regional; Global.

The Amazon forest contains one-tenth of the global carbon stored in land ecosystems (approx. 100 billion tons of carbon).

The concept of total economic value (*TEV*)

$$\begin{aligned} TEV &= Direct\ use\ value + Indirect\ use\ value \\ &+ Option\ value + Existence\ value \end{aligned}$$

Direct use value: Sustainable harvesting of timber and non-timber products, and ecotourism.

Indirect use value: Ecological functions such as water recycling, soil and watershed protection, and carbon storage.

Option value: Refers to uncertain benefits that can be realized at some point in the future.

Existence value: Willingness to pay for the existence of an environmental asset without ever directly using it.

Present value of the foregone benefits due to one hectare of deforestation, PVo_t, ...

Table 1	(*US$ per ha*)	***Sources and comments***
Direct use value		
Timber prod.	1,553	*Andersen et al., 2002; Margulis, 2004.*
Non-timber	19	*“*
Ecotourism	287	*“*
Indirect use value		
Carbon storage	1,046	*Andersen et al., 2002; Mar 2004.*
Water recycling	0	*Andersen et al., 200*
Nutrient recycling	0	*Andersen et al., 200*
Protection against fires	618	*Andersen et al., 2002.*
Watershed protection	0	*Andersen et al., 2002.*
Option value		
Biodiversity protection	34	*Andersen et al., 2002.*
Existence value	56	*Andersen et al., 2002.*
TOTAL	**3,613**	

Marginal values

... has been incorrectly interpreted as the marginal economic value of a standing tropical forest

Present value of foregone economic benefits due to one hectare of deforestation

PVo_t

vs

Present value of future economic benefits of alternative land uses (e.g., crops and cattle ranching)

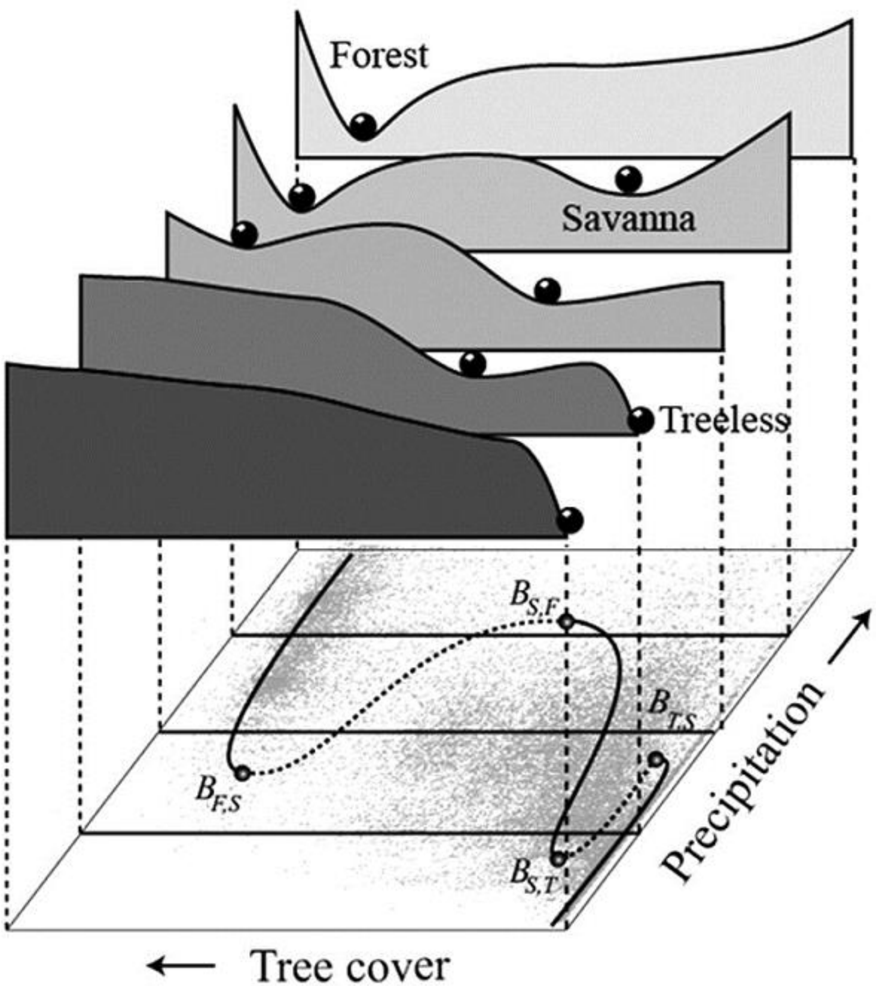
AU_t

Is that true?

Deforestation cost studies have shown that at current deforestation levels, AU_t is much greater than PVo_t.

Some authors argue that once the forest area is reduced below some critical threshold, additional deforestation can result in rapid increases in marginal economic value.

Tropical forests and savannas represent alternative stable states



(Hirota, Holmgren, Van Nes, & Scheffer, 2011)

Ecosystems are exposed to gradual changes.

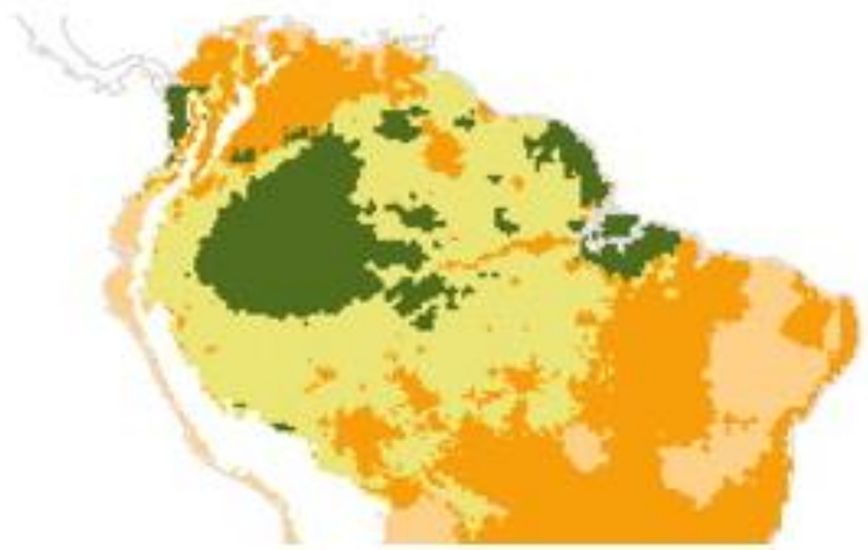
Smooth change can be interrupted by sudden switches to a contrasting state.

A tipping is a situation in which an ecosystem experiences a drastic shift to a new state.

Tropical forests and savannas represent alternative stable states.

Resilience can be measured by the width of the basin of attraction around a stable state

A large part of the Amazon forest supports biome bistability



(Staver, Archibald, & Levin, 2011)

Although currently in the forest state, a sufficiently severe perturbation can bring the ecosystem into the basin of attraction of the savanna state.

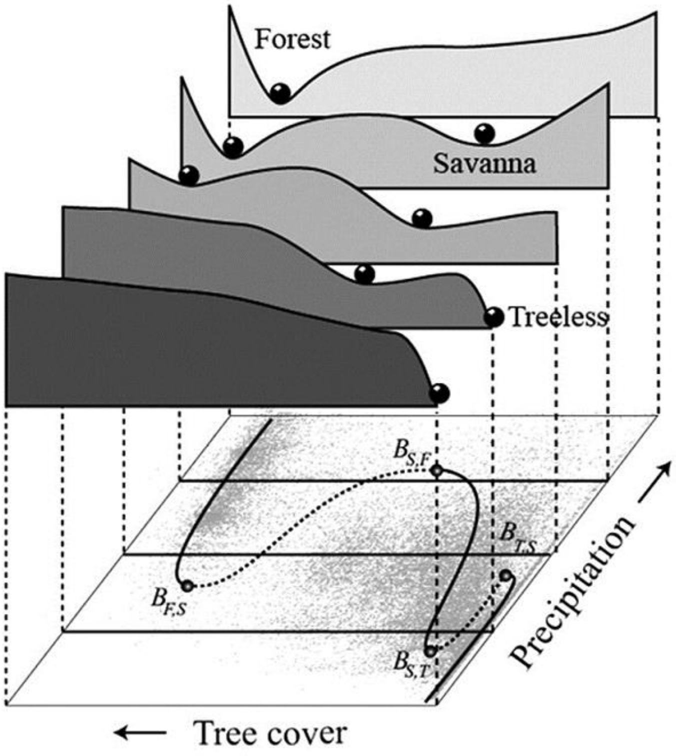
Amazon forest may cross a tipping point if deforestation exceeds 40%

Amazon rainfall patterns are, in part, maintained by the forest itself.

Half of the in-forest precipitation is derived from water that recycles through evapotranspiration.

The size of the Amazon forest is now approaching 80% of its original area

Although Brazil has reduced deforestation, others have increased.



What is missing in all existing marginal cost calculations?

None of the existing studies have accounted for the likelihood and possible economic impact of a forest-savanna transition.

The characteristic tree cover of forests and savannas remain remarkably constant over a wide range of rainfall levels.

- Forests: 80% tree cover
- Savannas: 20 % tree cover

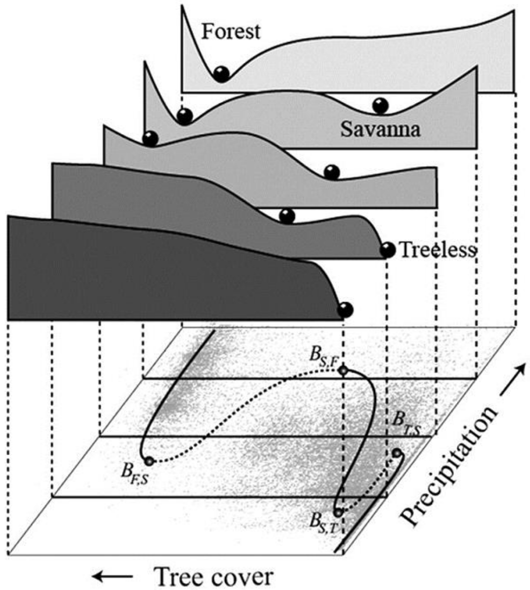
When the first economic impact of forest degradation appears, the forest ecosystem may have already started the self-propagating transition to the savanna state.

A new framework that takes into account changes in forest resilience ...

Forest resilience: $R_t = f(d_t)$

$f(0) = \alpha$, $\alpha \leq 1$, and $f(d^*) = 0$,

d^* is the deforestation threshold.



Ecosystem divided into grid cells of one hectare each.

Marginal economic value: $V_\psi(S_t)$

ψ indicates ecosystem's state (forest or savanna)

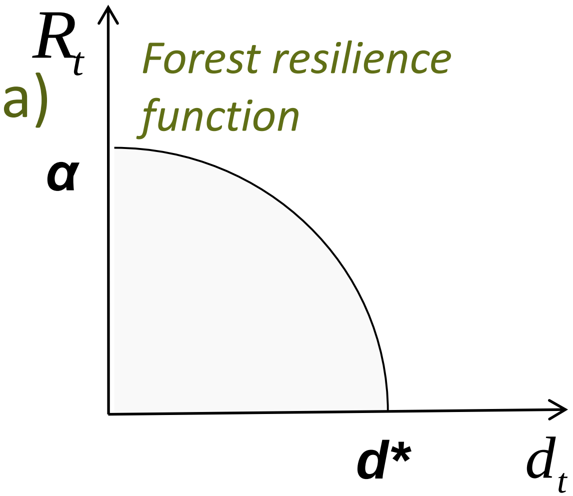
S_t is the vector of state variables:

$$S_t = [E_t, N_t, R_t]$$

Economic variables

Nature variables

Forest resilience



... to calculate the marginal social cost of deforestation

In the pre-threshold regime $\left(i.e., R_t > 0\right)$:

$$MSCD = V_F(E_t, N_F, R_t) = \begin{array}{c} Change\ in\ TEV\ due\ to\ an\ additional \\ hectare\ of\ deforestation \end{array}$$

(1)

At the threshold $\left(i.e., R_{t*} = 0\right)$:

$$MSCD = V_F\left(E_{t*}, N_F, 0\right)$$

$$\approx PVo_{t*} + \left(\frac{1}{r\tau}\right)\left[\overline{V_F} - \overline{V_S}\right] F_{t*}\left(1 - e^{-r\tau}\right)$$

(2)

PV of foregone benefits due to one hectare of deforestation

Total economic loss due to the forest-savanna transition of the remaining forest area (assuming that the transition occurs at a constant rate of time, and it takes τ years to achieve the savanna state)

Change in average economic value of a representative hectare of forest that undergoes the transition

Table 2	(US$ per ha)
Direct use value	
Timber prod.	1,109
Non-timber	13
Ecotourism	205
Indirect use value	
Carbon storage	7,500
Water resource value	12,747
Option value	
Biodiversity protection	985
Existence value	1,596
TOTAL	**24,156**

Sources and comments

Andersen et al., 2002; Margulis, 2004.

Andersen et al., 2002; 2004; Pindyck, 2016; calculations.

De Groot et al., 2012; calculations.

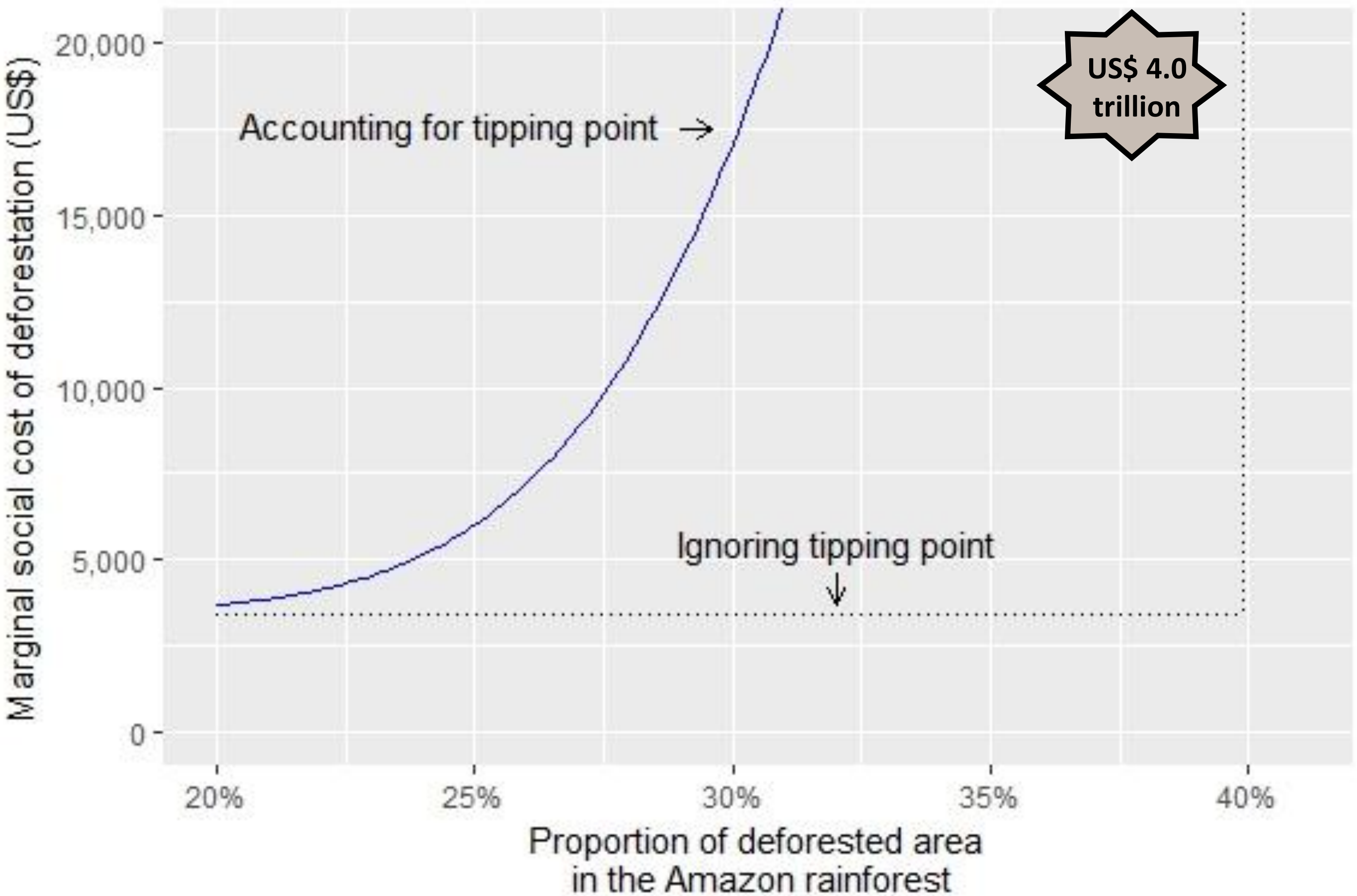
Margulis, 2004; De Groot et al., 2012; Authors' calculations.

Margulis, 2004.

Average values

The marginal social cost of deforestation from the perspective of the Amazon region

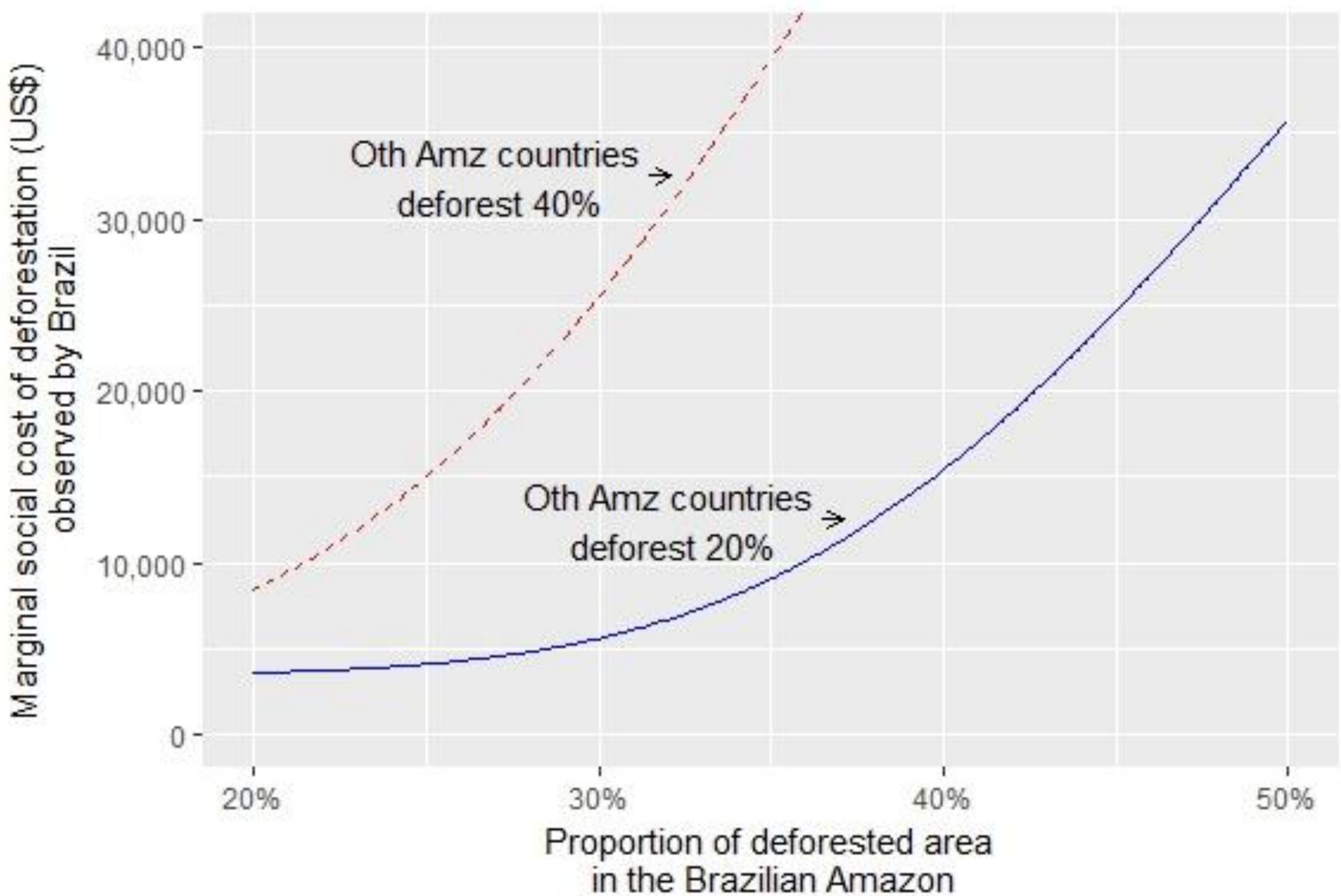
The deforestation threshold, *H*, is uncertain. I use Normal distribution with mean 40%.



The marginal social cost of deforestation from the perspective of an individual country

$$H_B = \frac{H - (.4)d_{O,t}}{(.6)}$$

(This is the deforestation threshold of the Brazilian Amazon that triggers the forest-savanna transition.)



The average incremental social cost of deforestation

Think of the increment as the size of an additional area that gets deforested:

$$AISCD = \frac{\Delta TEV}{\Delta F}$$

Change in total economic value

The size of an additional area that gets deforested

For the design of payments for ecosystem services

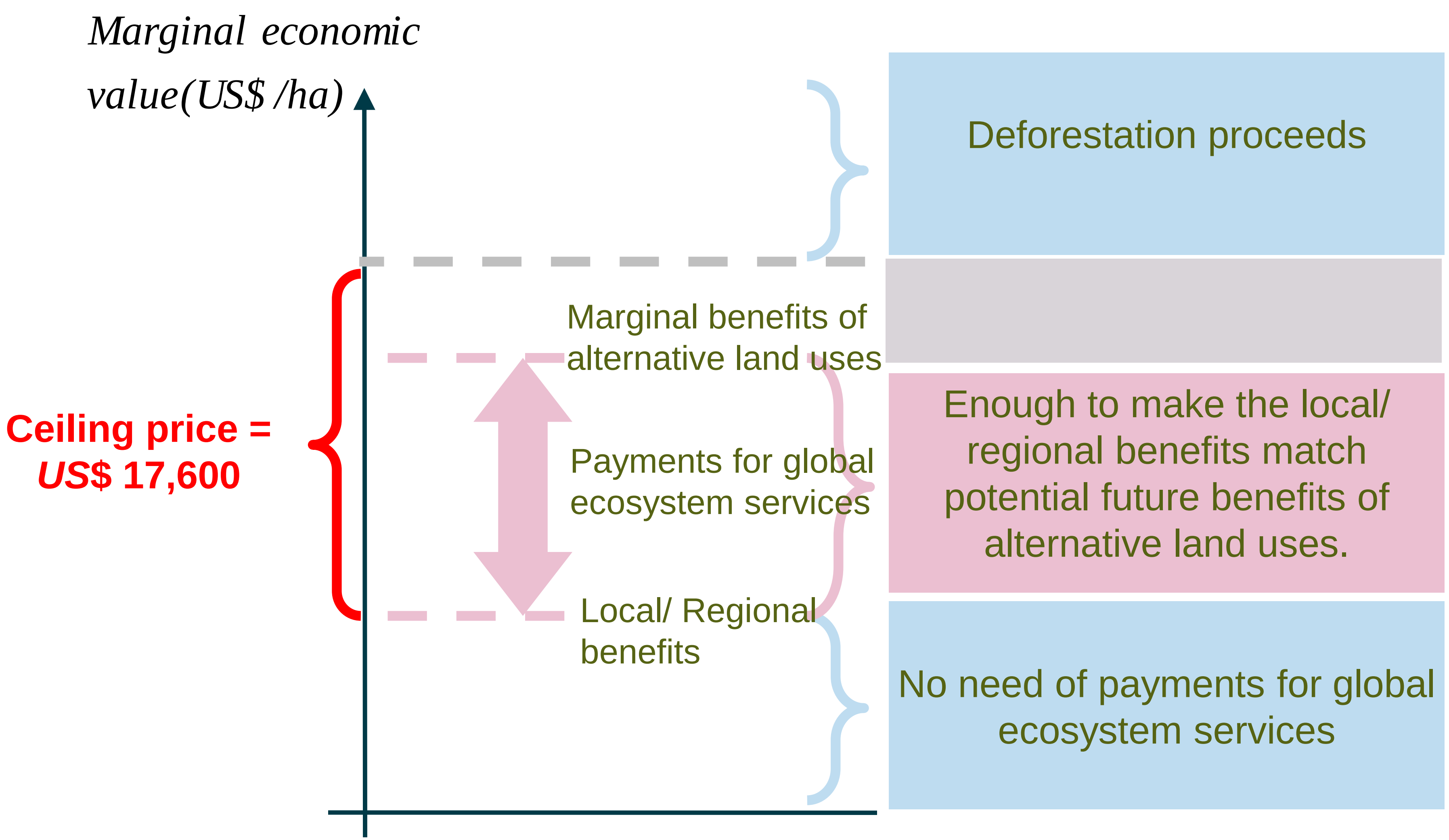
Consider the choice of the increment as the size of deforested area that brings the ecosystem to the tipping point (i.e., a r.v.),

$$\Delta F = \left(H - d_{t_0}\right)A.$$

The average incremental social cost of deforestation linked to carbon storage, biodiversity protection and existence value is

$$AISCD_{\substack{tip \\ gbl}} = E\left[\frac{\Delta TEV}{\Delta F} \mid H > d_{t_0}\right] = US\$17{,}600.$$

Ceiling price that the international community may be willing to pay



Concluding remarks

There will be no advance warning in the form of a rapid increase in the present value of foregone benefits, the way it is calculated today.

Deforestation cost studies must take into account the likelihood and possible economic impacts of a forest-savanna transition

Marginal cost calculations are not suited to the design of optimal land-use policy or payments for ecosystem services. Use the average incremental cost method, instead.

The social cost of deforestation observed by one Amazon country largely depends on the land-use policy adopted by the others.

Payments for ecosystem services may be necessary to ensure the continued provision of global benefits such as carbon storage.

Thank you for your attention!

Questions? *Please ask, or contact me at:*

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