# The impact of global mangrove degradation on the climate: Is a kilogram of shrimp worth a tonne of greenhouse gases?

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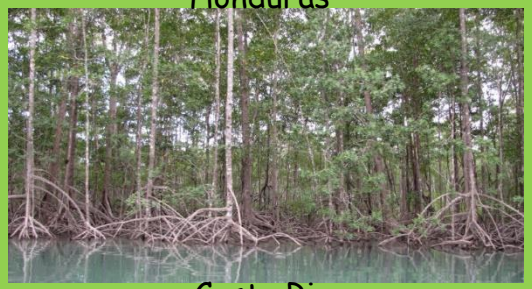
# **Mangroves** – a unique & diverse tropical forest type

138,000 – 152,000 Km$^2$ (145,000 Km$^2$)

- Widely Distributed -124 countries
- Mangroves inhabit approximately 0.5% of total global coastal area but account for approximately 10–15% of total carbon sequestration in the coastal ocean (Alongi 2014).
- Mangroves are among the most productive plants in the sea. Net primary production is as high as 19 Mg C ha$^{-1}$ y$^{-1}$.
- Ecosystem-scale carbon stocks average 885 Mg C ha$^{-1}$.
- Comprise <1% of all tropical forests, but may be the source of as much as 10-12% of the GHG emissions from tropical deforestation

Papua

Honduras



Costa Rica

Papua

Dom Republic

Borneo

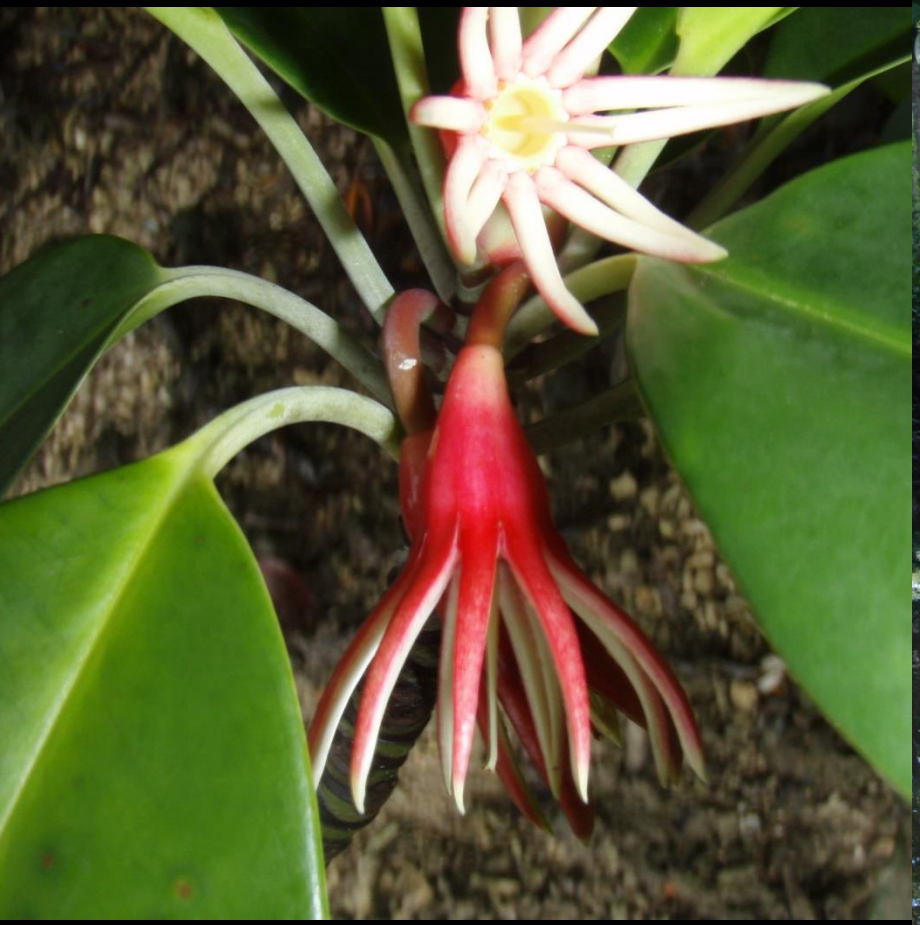
# Mangroves – Tremendous range in structural diversity

Seneboi River Delta, Papua, Indonesia

Tall mangrove (*Rhizophora racemosa*) Ndougou Lagoon, Gabon 2014


Mangle Baja, Sian Kaan ,Mexico

Sonneratia alba, Yap, FSM



Brugiera gymnorrhiza, Palau


(Crocodylus porosus), Significant barrier to science progress

No Work Today!

Mahakam Delta, Kalimantan

# My Dominican Republic study sites last week!
# Hurricane Irma, September, 2017

# Mangrove Ecosystems are "keystone" ecosystems for humanity

Fishing village, Papua, Indonesia

They provide a disproportionate number of services relative to their very small global area.

The coastal biome, which makes up only 4% of the planet's total land area, is home to one-third of the world's population, and this population is predicted to double over the next 15 years (Wells et al 2006)

Fish for sale, Liberia 2014

Fruit bat for dinner, Liberia February 2014

Widows of honey collectors killed by tigers Sundarbans Bangladesh

# Ecosystem Services of Mangroves

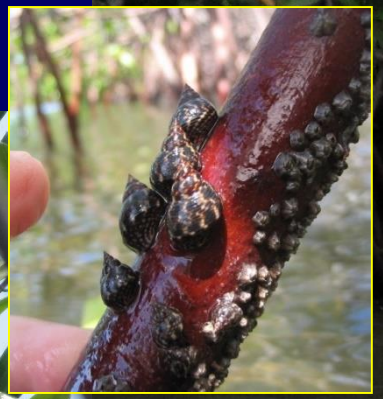
- Provisioning services
  - Fish, shellfish, seeds, medicines, wood, energy
- Regulating Services
  - Timing of flows, C and nutrient cycling, decomposition, climate regulation
- Supporting Services
  - water and air purification, pollination, seed dispersal , biocontrol, protection from storm surges
- Cultural Services
  - Cultural and spiritual inspiration, recreation, scientific inquiry,
- Preserving Services
  - Diversity for future use; preserving options, climate change mitigation and adaptation

# Servicios Ecosistémicos

- The annual economic values of mangroves, estimated by the cost of the products and services they provide, have been estimated to be \$2000–9000 $ha^{-1}$ /yr (Wells et al.2006).

- Ecosystem services are worth an estimated US\$33-57,000 per hectare per year to the national economies of developing countries with mangroves (UNEP 2014).

There exists unique biodiversity values in mangroves



A unique biodiversity exists in tropical wetlands

Mangroves have strong linkages to coral reefs, seagrass, and upland forests


Mangroves: The nursery of the Seas

# 6. Servicios de los Ecosistemas – Pescados

**32-75% of all tropical commercial fish** species pass part of their lives in the mangroves, where they encounter:

- nursery grounds
- shelter
- food

32-75% de todas las especies comerciales de peces tropicales pasan parte de su vida en los manglares, donde se encuentran:

- zonas de cría
- Abrigo/refugio
- fuentes de comida

# MANGROVES
# Los Manglares

- **In spite of their importance to people, mangroves are consistently undervalued and do not figure adequately in decision making about coastal development so that mangroves continue to be lost at a rate that is 3-5 times greater than global deforestation rates (UNEP 2014).**
- A pesar de su importancia para las personas, los manglares son constantemente infravalorados y no figuran adecuadamente en la toma de decisiones sobre el desarrollo costero para que los manglares sigan perdiéndose a una tasa 3-5 veces mayor que las tasas mundiales de deforestación

# Between 1-7% of blue carbon sinks are being lost annually

Upstream disruptions

Salt Ponds

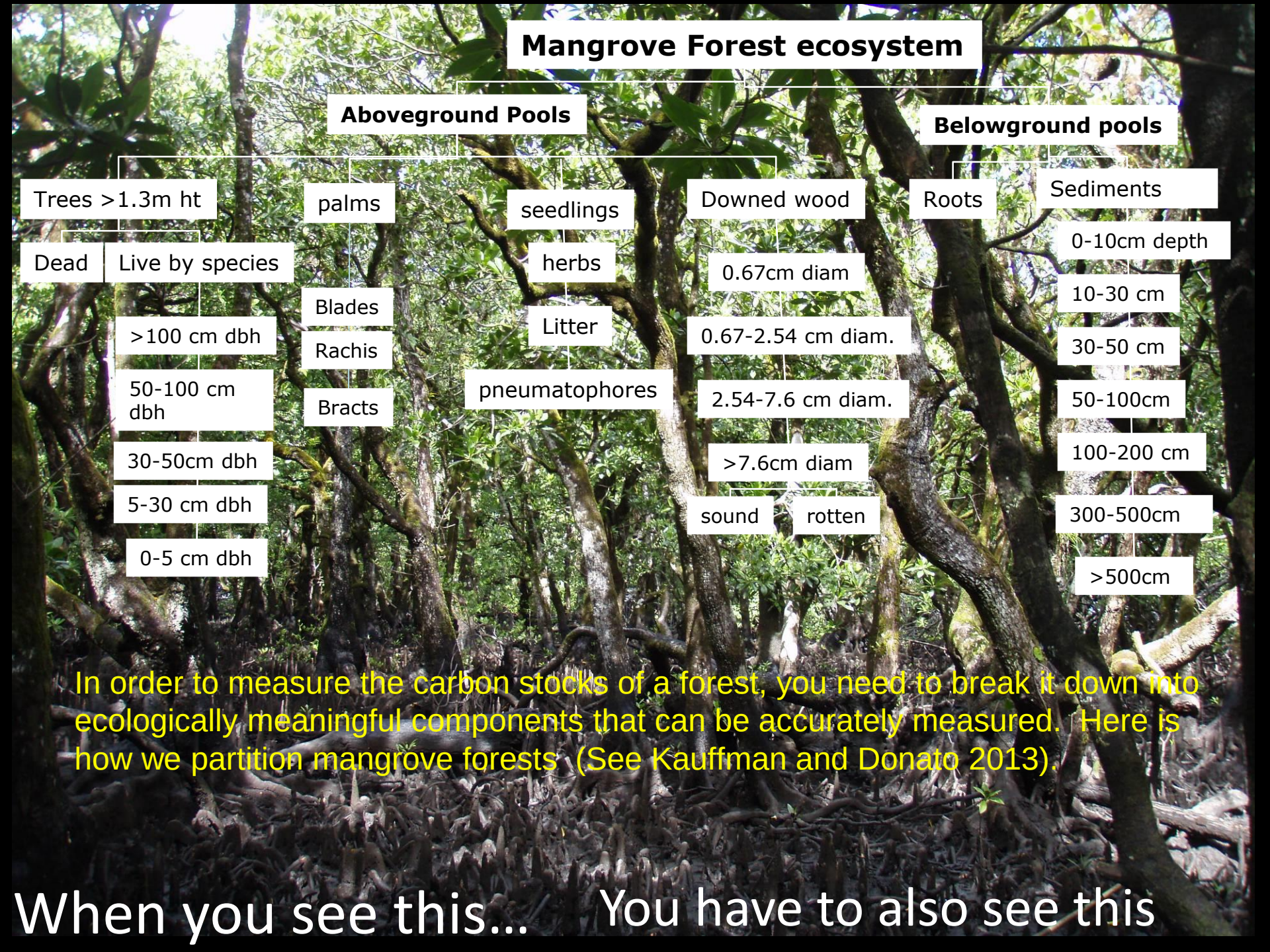
Aquaculture

Agriculture/pasture

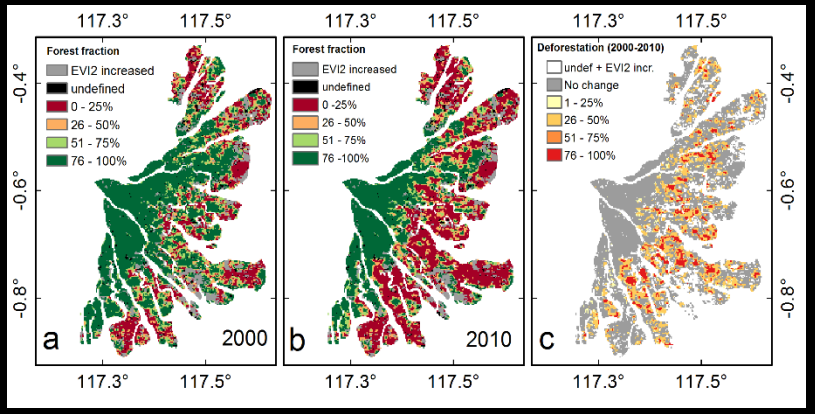
Road development /hydrological disruptions

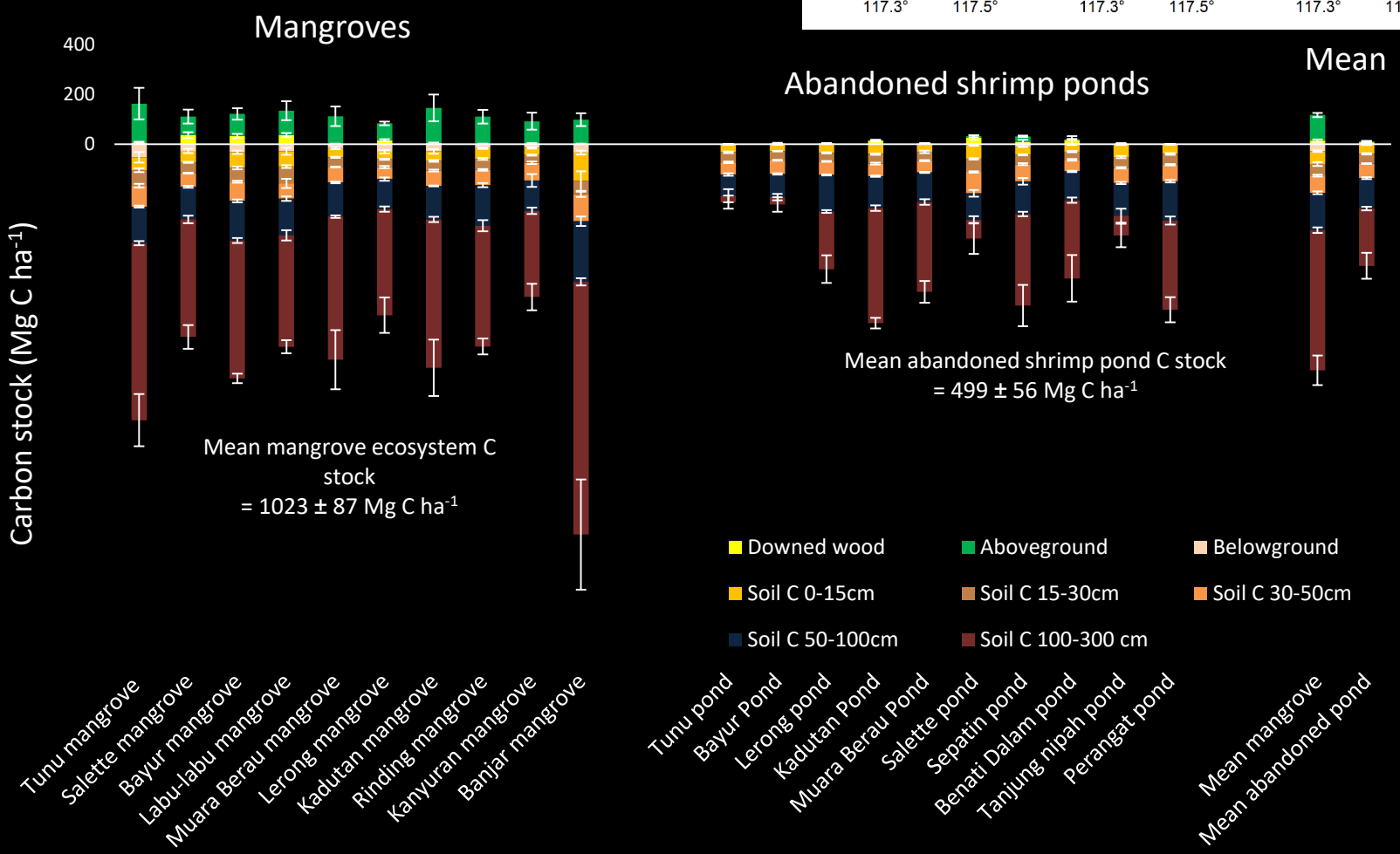
Coastal development

Pendleton et al . (2013)


Mangrove Forest ecosystem
Aboveground Pools
Belowground pools
Trees >1.3m ht
palms
seedlings
Downed wood
Roots
Sediments
Dead
Live by species
herbs
0.67cm diam
0-10cm depth
Blades
10-30 cm
>100 cm dbh
Litter
0.67-2.54 cm diam.
Rachis
30-50 cm
50-100 cm dbh
pneumatophores
2.54-7.6 cm diam.
Bracts
50-100cm
30-50cm dbh
>7.6cm diam
100-200 cm
5-30 cm dbh
sound
rotten
300-500cm
0-5 cm dbh
>500cm
In order to measure the carbon stocks of a forest, you need to break it down into ecologically meaningful components that can be accurately measured. Here is how we partition mangrove forests (See Kauffman and Donato 2013).
When you see this…
You have to also see this

# Ecosystem C Stocks, Mahakam Delta, Indonesia



Tropical evergreen forest (601 Mg CO2e/ha)

What are the emissions from rain forest conversion to cattle pasture?

Slash burn

Cattle pasture, Brazilian Amazon (8 Mg CO2/ha)

**TOTAL Greenhouse gas emissions 632 Mg $CO_2e$/ha**

**Loss of other Ecosystem Services: biodiversity Water quality, etc.**

# What are the emissions from mangrove conversion?


Conversion/Land use

**TOTAL Greenhouse gas emissions 1784 Mg $CO_2$e/ha**

**Loss of Ecosystem Services: Fish/Shellfish Coast Protection Water quality, etc.**

**1321 Mg CO2e/ha; a 57% loss**

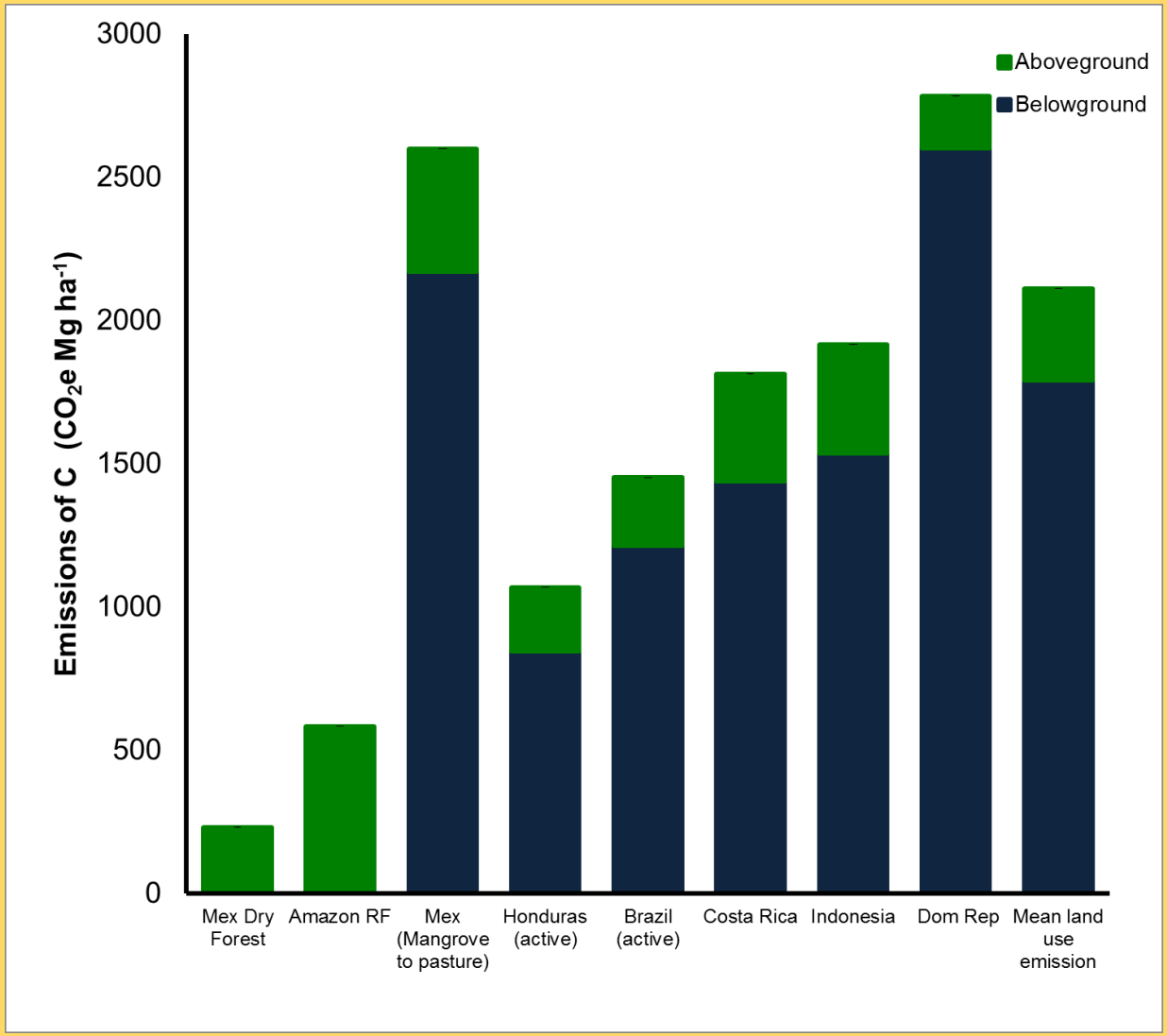
Camaronera abandonado, Monte Cristi, RD

Soil Cores from Mangrove above and a site converted to shrimp ponds, Dom. Rep.

C concentration 11.29% Mangrove; 1.01% Shrimp Pond
N concentration 3.7 mg/g Mangrove; 0.2 mg/g Shrimp Pond

# C emissions from converting mangroves to shrimp ponds and cattle pasture

Mean all sites: 2112 ± 268 Mg $CO_2$ e $ha^{-1}$




Note:

- Oldest sites- highest emissions
- Abandoned sites higher than active

Kauffman et al (2017); (See also Bhomia et al 2016, Kauffman et al. 2014, 2016, 2017)

Tropical deforestation yields emissions of 1.2 Pg C /yr; and from mangroves - 0.12 Pg coming (0.6% of the forest area).

# How much is a Petagram?

(hint: it's a lot!)

Reporting greenhouse gas emissions from deforestation and other land uses at global scales can be difficult to comprehend possibly engendering apathy related to how changes in these ecosystems are contributing to climate change.

In order to present how deforestation and land cover change contribute to global climate change in a comprehensible manner, we change the scale of greenhouse gas emissions from global to personal scales.

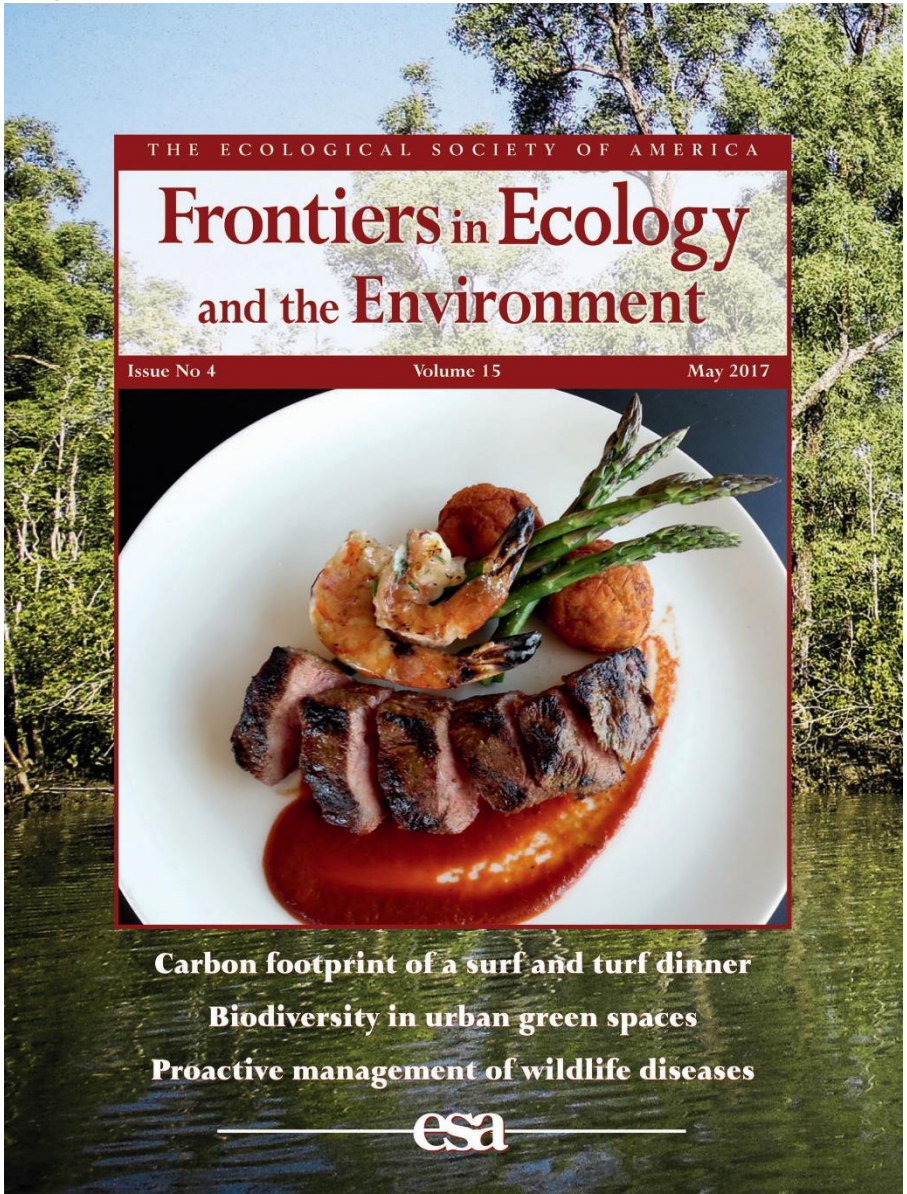
1 gigaton (GT) = $10^{15}$g = 1 petagram (Pg)
(1 billion Mg)

# The Jumbo carbon footprint of a little shrimp

## What is the carbon footprint of a beef steak and shrimp cocktail dinner?

## A wetlands example

Kauffman JB, Arifanti, VB, Hernandez Trejo H, Jesus Garcia M, Norfolk J, Cifuentes M, Hadriyanto D, Murdiyarso D. The jumbo carbon footprint of a shrimp: carbon losses from mangrove deforestation. Frontiers in Ecology and the Environment 2017: 15(4) doi:10.1002/fee.1483



The CARBON FOOTPRINT *is the total amount of carbon dioxide ($CO_2$) and other greenhouse gases emitted over the life cycle of that product or service.*

*But rarely are the carbon costs of deforestation/land cover change included.*

The “Land Use Carbon Footprint” is the carbon emissions that arise from the conversion of an ecosystem to another land cover type in order to provide some commodity.

Logging, Brazilian Amazon

Abandoned shrimp pond Mahakam Delta Indonesia

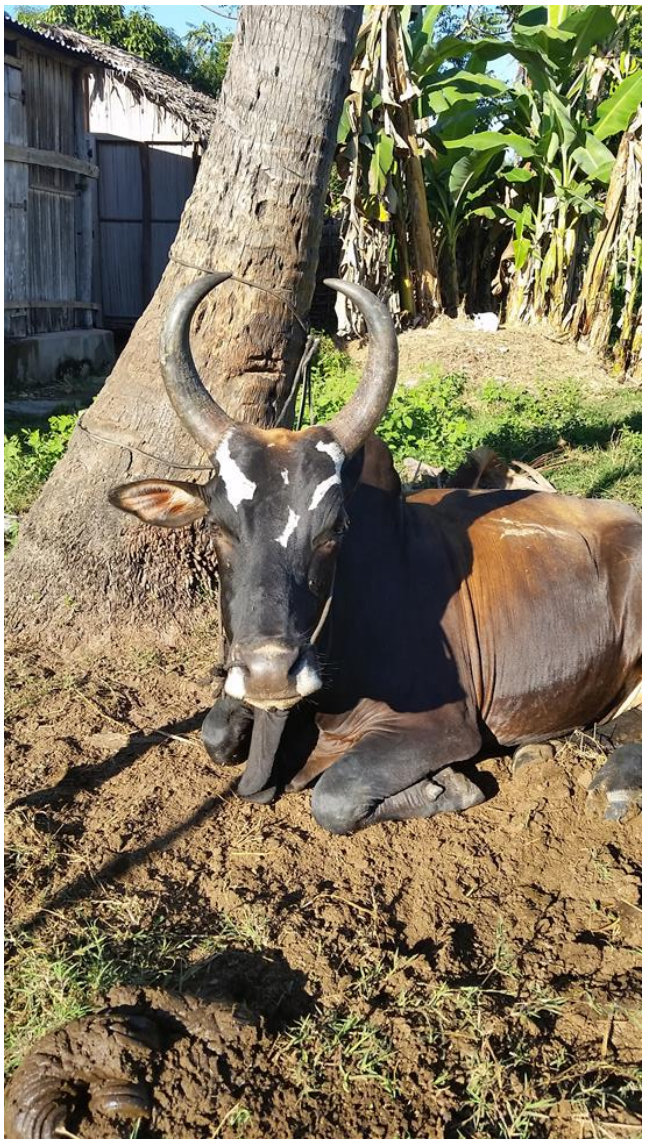
# Cattle pastures from mangroves Pantanos de Centla, MX:

- **Mean emission rate: 2599 Mg $CO_2e$/ha (Kauffman et al 2017).**
- **METHANE EMISSIONS FOR 1.25 HEAD OF CATTLE/ha/YR = 48.4 kg**
- **TOTAL $CH_4$ EMISSIONS OVER A 30 YEAR PERIOD (GWP OF 34) = 49.34 Mg $CO_2e$/ha**
- **$N_2O$ emission from manure = 12.5 Mg $CO_2e$**
- Carbon not sequestered for 30 years = 187.21 **Mg $CO_2e$**
- **Total emission (enteric +carbon loss) =2835 Mg $CO_2e$**
- **CATTLE gain on PASTURES is ABOUT 123.2 kg /ha**
- **MEAT production (50%) of the live weight for 3O Years =1.848 Mg/ha**
- **The land use footprint for a kg of beef is 1534 Kg $CO_2e$.**
- **A 16 oz steak would produce 1534 lb $CO_2e$**

# Why including land use matters

Our estimates of the ecosystem carbon footprints - 449 kg $CO_2e$ per kg meat from rainforests and 1,534 kg $CO_2e$ per kg meat from mangrove conversion dwarf the numbers provided by past studies of carbon footprints from beef production (9 -129 kg $CO_2e$ per kg meat)

These studies did not include land cover change in analyses.



# What is the "land use carbon footprint" of a shrimp cocktail originating from a shrimp farm on converted mangrove?

Original Oil Painting by Precision Realist Mary Ellen Johnson
Big Shrimp Cocktail

# The land use carbon footprint arising from the conversion of forests to shrimp ponds can be determined using the formula:

- $FP_c = C_{conv} + N_2O_e + C_{seq} / P_{prod} \times P_{life} \times Cf_{meat}$
- Where:
- $FP_c$= Ecosystem carbon footprint of the land use.
- $C_{conv}$ = the total loss of ecosystem C (Mg $CO_2e$) due to land cover change.
- $N_2O_e$ = the $N_2O$ emissions during active production phases in shrimp ponds converted to Mg $CO_2e$.
- $P_{prod}$ is the production of shrimp (Mg of shrimp/year).
- $P_{life}$ is the productive life of the land use (years).
- $Cf_{meat\ is}$ the proportion (%) of the shrimp that is meat
- $C_{seq}$= Carbon that would have been sequestered in the absence of deforestation or the difference is C sequestration between the forest and land use.

# Mangroves and farmed raised shrimp


- A dominant cause of the deforestation of mangroves
- 50-60 % of shrimp farms are extensive – low input operations
- Productivity is about 50 to 500 kg shrimp/ha year in extensive shrimp ponds (to 5000 kg in intensive operations)
- Productive life of shrimp ponds are 3 to 9 years
- Percent of shrimp that is meat - 28% cooked/45% raw

Tacon, Albert G. J. (2002) (PDF). *Thematic Review of Feeds and Feed Management Practices in Shrimp Aquaculture*. World Bank/NACA/WWF/FAO Consortium Program on Shrimp Farming and the Environment. Also based upon interviews with shrimp farmers of the Mahakam delta, Indonesia, 2013-14 (Arifanti in prep).

# Land use Carbon footprint

Losses only from mangrove conversion

- Shrimp productivity - about 50 to 500 kg shrimp/ha year. (assume a midpoint – 275 kg)
- Longevity of the shrimp farm 3-9 years. Assume 9 years in this analysis
- Total shrimp productivity – 150 to 4500 Kg – midpoint is 2,475kg (9 yrs @ 275 kg/yr)
- Assuming that the edible meat is 45%, this yields a total productivity of 1,114 kg of shrimp meat $ha^{-1}$.

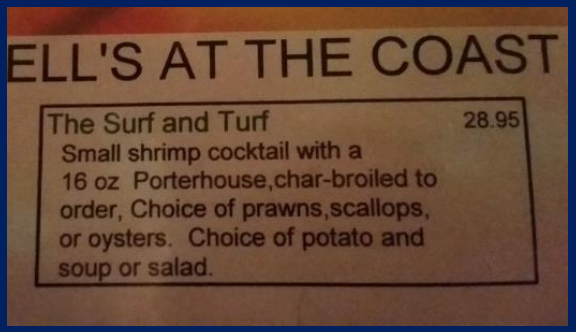
# LUCF of a little shrimp

- The mean loss of C from conversion of a mangrove to shrimp ponds is 1,783 Mg $CO_2e$ $ha^{-1}$
- $N_2O$ emissions would add another 1.2 Mg $CO_2e$ $ha^{-1}$. $N_20$ emissions ($e_{N2O}$) are 1.69g $N_2O$ /kg shrimp produced during active use which is a $CO_2e$ of 503.2 g $CO_2$/kg shrimp produced.
- The LUCF is 1652 kg $CO_2e$ per Kg of shrimp meat produced).


# The land use carbon footprint from a 100g shrimp cocktail is 165 kg $CO_2$ .

- This only includes the effects of habitat destruction of mangroves but does not address the effects of overfishing of other organisms to serve as feed, waste pollution, spread of diseases, and overuse of chemical treatments…social issues.
- This does not include  costs of feeding, establishment, management, fertilizers, medicines, shipping, processing, losses, etc.
- Nor does it cover the loss in ecosystem services or impacts on other ecosystems from the loss of mangroves – fish, storm protection, water quality, other products


# The carbon footprint of a "surf and turf" feast from mangrove ecosystems




- Assume 2 people go to a restaurant for a dinner and both order the "surf and turf " special consisting of a 100g shrimp cocktail and a 16 oz. (454g) beef steak.
- Let's assume the shrimp and the beef come from tropical sites where mangroves were converted for the production of these uses.
- The ecosystem carbon footprint of each would meal burden the atmosphere with about 816kg $CO_2e$; about 655kg $CO_2e$ for the steak and 161kg $CO_2e$ for the shrimp cocktail.
- The mass of the carbon footprint ($CO_2e$) for the 2 meals combined (1,621kg ) could be equivalent or greater than the mass of the car they arrived in the restaurant in (e.g., a Toyota Prius weighs 1,382 kg).
- The ecosystem carbon footprint from this dinner would be equivalent to the emissions from the combustion of 695 liters (182 gals) in an automobile. Driving an automobile from Los Angeles CA to New York City would be lower than the carbon footprint of this meal. (8.9kg $CO_2$/gal)

# CARBON VALUES IN MANGROVE
# Social Costs

Gastos de degradacion y impactos negativos por sociedad

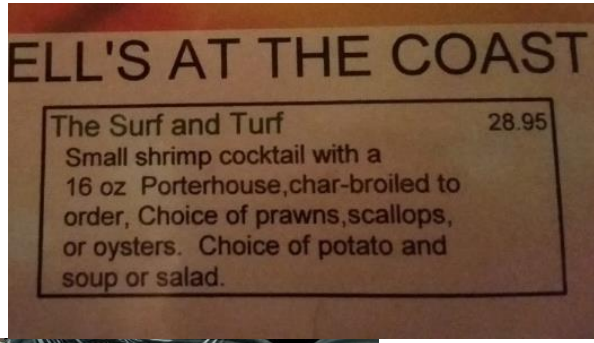
The United States Environmental Protection Agency (EPA) released an updated report in 2016 to estimate the total cost of carbon to society. …**for every tonne of carbon dioxide we emit (2015) into the atmosphere, we sacrifice an average of USD $36 in environmental degradation and negative social impacts**…. In theory, these should be accounted for in the price of a carbon credit (https://www.epa.gov/climatechange/social-cost-carbon).

- *SOCIAL COSTS*
- Mean emissions from mangrove conversion = 2102 Mg $CO_2$ $ha^{-1}$

2102 x $36 = $75,672 $ha^{-1}$ (social costs of mangrove conversion).

# Social Costs of the "Surf and Turf" Special

- The social carbon cost of beef = $55.24/kg
- Social cost of a 1lb Beefsteak is $25.12
- Of a quarter pounder: $6.27
- The social cost = $6.52/cocktail
- Of the surf and turf dinner - $31.39





*Based upon data from Kauffman et al. (2017)* The jumbo carbon footprint of a shrimp: carbon losses from mangrove deforestation. Frontiers in Ecology and the Environment

# Mangroves are considered as high priorities in climate change adaptation and mitigation strategies throughout the world

This is for at least 5 reasons:

1. Wetlands provide a number of ecosystem services that are vital to the sustainability of local communities, livelihoods, and infrastructure.
2. They have exceptionally high carbon stocks – among the highest of any ecosystem on earth;
3. Their rates of land cover change/deforestation are the highest in the tropics; development threats exists in temperate wetlands
4. Their emissions from land cover change far exceed emissions from land conversion of upland forests.
5. Their potential for C sequestration following restoration is among the highest on earth.

# Thanks!

## Conclusión en breve

Oregon State University

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