Ecosystem Services in an era of Global Change

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Photo: J Thom
## Millennium Ecosystem Assessment

### Ecosystem Services Provided by or Derived from Wetlands

<table>
<thead>
<tr>
<th>Services</th>
<th>Comments and Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Provisioning</strong></td>
<td></td>
</tr>
<tr>
<td>Food</td>
<td>production of fish, wild game, fruits, and grains</td>
</tr>
<tr>
<td>Fresh water*</td>
<td>storage and retention of water for domestic, industrial, and agricultural use</td>
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<tr>
<td>Fiber and fuel</td>
<td>production of logs, fuelwood, peat, fodder</td>
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<tr>
<td>Biochemical</td>
<td>extraction of medicines and other materials from biota</td>
</tr>
<tr>
<td>Genetic materials</td>
<td>genes for resistance to plant pathogens, ornamental species, and so on</td>
</tr>
<tr>
<td><strong>Regulating</strong></td>
<td></td>
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<tr>
<td>Climate regulation</td>
<td>source of and sink for greenhouse gases; influence local and regional temperature</td>
</tr>
<tr>
<td>Water regulation (hydrological flows)</td>
<td>groundwater recharge/discharge</td>
</tr>
<tr>
<td>Water purification and waste treatment</td>
<td>retention, recovery, and removal of excess nutrients and other pollutants</td>
</tr>
<tr>
<td>Erosion regulation</td>
<td>retention of soils and sediments</td>
</tr>
<tr>
<td>Natural hazard regulation</td>
<td>flood control, storm protection</td>
</tr>
<tr>
<td>Pollination</td>
<td>habitat for pollinators</td>
</tr>
<tr>
<td><strong>Cultural</strong></td>
<td></td>
</tr>
<tr>
<td>Spiritual and inspirational</td>
<td>source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems</td>
</tr>
<tr>
<td>Recreational</td>
<td>opportunities for recreational activities</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>many people find beauty or aesthetic value in aspects of wetland ecosystems</td>
</tr>
<tr>
<td>Educational</td>
<td>opportunities for formal and informal education and training</td>
</tr>
<tr>
<td><strong>Supporting</strong></td>
<td></td>
</tr>
<tr>
<td>Soil formation</td>
<td>sediment retention and accumulation of organic matter</td>
</tr>
<tr>
<td>Nutrient cycling</td>
<td>storage, recycling, processing, and acquisition of nutrients</td>
</tr>
</tbody>
</table>

*While fresh water was treated as a provisioning service within the MA, it is also regarded as a regulating service by various sectors.*
Jakarta court rules in government's favour in case involving pulp company April
Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.
Land-use change was the dominant source of annual CO$_2$ emissions until around 1950

Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; Le Quéré et al 2017; Global Carbon Budget 2017
Total global emissions: 40.8 ± 2.7 GtCO₂ in 2016, 52% over 1990
Percentage land-use change: 42% in 1960, 12% averaged 2007-2016

Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; van der Werf et al. 2017; Le Quéré et al 2017; Global Carbon Budget 2017
Land-use change emissions are highly uncertain. Higher emissions in 2016 are linked to increased fires during dry El Niño conditions in tropical Asia.

Primary forest cover loss in Indonesia over 2000–2012

Belinda Arunarwati Margono1,2*, Peter V. Potapov1, Svetlana Turubanova1, Fred Stolle3 and Matthew C. Hansen1
Atmospheric CO$_2$ records

Trend expected from fossil-fuel burning
Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2007–2016 (GtCO$_2$/yr)

The budget imbalance is the difference between the estimated emissions and sinks.

Source: CDIAC; NOAA-ESRL; Le Quéré et al 2017; Global Carbon Budget 2017
Global carbon budget

Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean. The “imbalance” between total emissions and total sinks reflects the gap in our understanding.

Forests in Flux

A. Surface energy fluxes
- Diffuse solar radiation
- Direct solar radiation
- Reflected solar radiation
- Absorbed solar radiation
- Latent heat flux
- Sensible heat flux
- Emitted longwave radiation
- Longwave radiation
- Momentum flux wind speed

B. Hydrology
- Precipitation
- Interception
- Evaporation
- Transpiration
- Sublimation
- Infiltration
- Throughfall
- Stemflow
- Surface runoff
- Drainage

C. Carbon Cycle
- Photosynthesis
- Autotrophic respiration
- Fire
- Foliage
- Stem
- Litterfall
- Nutrient uptake
- Mineralization
- Root
- Soil carbon
- Heterotrophic respiration

D. Vegetation dynamics
- Competition
- Disturbance
- Growth
- Establishment

E. Land use
- Deforestation
- Farm abandonment
- Urbanization

Bonan 2008
Regional carbon fluxes from an observationally constrained dynamic ecosystem model: Impacts of disturbance, CO$_2$ fertilization, and heterogeneous land cover

Ankur R. Desai,$^{1,2}$ Paul R. Moorcroft,$^3$ Paul V. Bolstad,$^4$ and Kenneth J. Davis$^5$
Assessing Interactions Among Changing Climate, Management, and A M

JUSTIN M.
PAUL A. D
BINFORD,

...
Cross-Sectoral Resource Management: How Forest Management Alternatives Affect the Provision of Biomass and Other Ecosystem Services

Susanne Frank 1,*, Christine Fürst 1 and Frank Pietzsch 2
Infrared gas analyzer
Thermistor, hygrometer, barometer

\[ \text{LE} = \text{Latent Heat flux} \]
\[ \rho w'q' \]

\[ H = \text{Sensible Heat flux} \]
\[ \rho w't' \]

Net radiation = Net solar + net Longwave
Major challenges to EC

- Quality control for violation of EC assumptions (Mauder et al., 2013)
- Gap-filling of quality controlled and missing data for seasonal-annual sums (Desai et al., 2008)
- Systematic bias from unmeasured terms (Metzger, 2017)
- Representation error (Xu et al., 2017)
Full net surface-atmosphere exchange in a box

### Eddy Covariance

\[
w' T'(x_0, y_0, h) = \partial T(x_0, y_0, (z_1 \ldots z_m)) / \partial t
\]

### Assumptions!

**Assumption 1:**

Storage change

\[
\int_0^h \frac{\partial \bar{c}}{\partial t} \, dz \quad \left\langle \quad \int_0^h \left[ \frac{1}{4L^2} \int_{-L}^{+L} \int_{-L}^{+L} \frac{\partial \bar{c}}{\partial t} \, dx \, dy \right] \, dz
\]

**Assumption 2:**

Horizontal transport

\[
0 \quad \left\langle \quad \int_0^h \left[ \frac{1}{4L^2} \int_{-L}^{+L} \int_{-L}^{+L} \left\{ \frac{\partial \bar{u} \bar{c}}{\partial x} + \frac{\partial \bar{u} ' \bar{c}'}{\partial x} + \frac{\partial \bar{v} \bar{c}}{\partial y} + \frac{\partial \bar{v} ' \bar{c}'}{\partial y} \right\} \, dx \, dy \right] \, dz
\]

**Assumption 3:**

Vertical transport

\[
\bar{w'} \bar{c}'(h) \quad \left\langle \quad \int_0^h \left[ \frac{1}{4L^2} \int_{-L}^{+L} \int_{-L}^{+L} \left\{ \frac{\partial \bar{w} \bar{c}}{\partial z} + \frac{\partial \bar{w} ' \bar{c}'}{\partial z} \right\} \, dx \, dy \right] \, dz
\]

*Modified after Finnigan (2004)*

*Assumptions!*

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**Coutesy S. Metzger, NEON**
Land cover and age influences NEE

- NEP (= - NEE)
- 13 flux towers
- One summer
- Stand age matters
- Ecosystem type matters
- Desai et al, 2008, Ag For Met
Scaling (Buffam et al., 2010)
Wetland flux controls: how does interacting water table levels and temperature influence carbon dioxide and methane fluxes in northern Wisconsin?
Impact of hydrological variations on modeling of peatland CO$_2$ fluxes: Results from the North American Carbon Program site synthesis

Benjamin N. Sulman, Ankur R. Desai, Nicole M. Schroeder, Dan Ricciuto, Alan Barr
Figure 4. Network representativeness for all of the FLUXNET2015 sites (164 sites).
Global and regional importance of the tropical peatland carbon pool

SUSAN E. PAGE*, JOHN O. RIELEY† and CHRISTOPHER J. BANKS*†
*Department of Geography, University of Leicester, University Road, Leicester LE1 7RH, UK, †School of Geography, The University of Nottingham, University Park, Nottingham NG7 2RD, UK

• Best estimate of 88.6 Gt (range 81.7–91.9 Gt) equal to 15–19% of the global peat carbon pool. Of this, 68.5 Gt (77%) is in Southeast Asia, equal to 11–14% of global peat carbon. A single country, Indonesia, has the largest share of tropical peat carbon (57.4 Gt, 65%), followed by Malaysia (9.1 Gt, 10%).
Effects of disturbances on the carbon balance of tropical peat swamp forests

TAKASHI HIRANO*, HENDRIK SEGAH†, KITSO KUSIN‡, SUWIDO LIMIN‡, HIDENORI TAKAHASHI§ and MITSURU OSAKI*
Greenhouse gas fluxes from tropical peatlands in south-east Asia

JOHN COUWENBERG, RENÉ DOMMAIN and HANS JOOSTEN
Physical controls on CH$_4$ emissions from a newly flooded subtropical freshwater hydroelectric reservoir: Nam Theun 2

C. Deshmukh$^{1,2,*}$, D. Serça$^1$, C. Delon$^1$, R. Tardif$^3$, M. Demarty$^4$, C. Jarnot$^1$, Y. Meyerfeld$^1$, V. Chanudet$^5$, P. Guédant$^3$, W. Rode$^3$, S. Descloux$^5$, and F. Guérin$^{6,7}$
Land use of drained peatlands: greenhouse gas fluxes, plant production, and economics

Kasimir et al 2017, GCB

1 = Norway spruce
2 = Willow
3 = Reed canary
4 = Peatland

Saving peat and avoiding methane release using fairly wet conditions can significantly reduce GHG emissions, and this strategy should be considered for land use planning and policy-making.
We estimate that on average granting a concession for oil palm, timber, or logging in Indonesia increased site-level deforestation rates by 17–127%, 44–129%, or 3.1–11.1%, respectively.
Carbon quota for a 66% chance to keep below 2° C

The total remaining emissions from 2017 to keep global average temperature below 2° C (800GtCO₂) will be used in around 20 years at current emission rates.

Grey: Total CO₂ quota. Non-CO₂ only quota for 2° C with 66% chance. Green: Removed from CO₂ only quota. Blue: Remaining CO₂ quota.

The remaining quotas are indicative and vary depending on definition and methodology.

Source: Peters et al 2015; Global Carbon Budget 2016
What do you need?

• Making a flux measurement is one thing
• Getting useful science out of it is another
  – Quality control / representation / gap-filling
  – Ancillary data: water table, peat depth, C export, microclimate, vegetation biomass, management history of site, remotely sensed physiology
  – Testable hypotheses, relying on space for time substitution, evaluated with ecosystem models
• Our lab has a track record in much of the above, and students/post-docs in my lab have potential to advance this work
Questions?
Ankur Desai, desai@aos.wisc.edu, @profdedsi

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