

Forest Fires: influences of climate change and human activity

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Forest fires (or wildfires) are increasing across the globe. Recently, there have been intense fires in the tropics, but also in Greece, Western US, Canada, Australia¹. These fires have high economic and human health costs, and also biodiversity costs.

A) Forest Ecosystems, Humans and Fire

Whilst fires are a natural part of many forest ecosystem types, including the Boreal and the American West, and tropical (or dry) seasonal forest, many fires today are initiated by humans. There is concern that these fires, or “wildfires” are increasing in frequency and severity. In other ecosystems, e.g. moist tropical forest, some temperate broadleaf forests, fire is a very rare occurrence naturally², but here too, fires appear to be increasing.

There are many reasons why forest fires are increasing and there is a complex web of interactions. These factors include:

1) People living nearer flammable forest. Notably in the developed world, suburban areas are expanding into forests. This is especially true in the Western US and Australia. This increases the human and economic cost of such fires.

2) Human presence in forests

In many forest systems (e.g. the Amazon, Russian and Boreal forests), fires are often associated with human ignition sources³. These may be accidental (e.g. a spark from a cooking fire or barbecue), or deliberately started but then going out of control (e.g. burning to clear a forest or remnant crops or burning a car)⁴, or deliberately started as a wildfire (e.g. to circumvent planning laws).

3) Fire suppression strategies. Historically, fire suppression has been used in some areas, such as Western US and Australia. These often have limited impact and can enhance the flammability of vegetation resulting in larger, more intense wildfires that threaten human settlements and forest ecology.

¹ See, e.g. <http://news.bbc.co.uk/1/hi/world/americas/6090116.stm>;
<http://news.bbc.co.uk/1/hi/world/europe/6252676.stm>; <http://news.bbc.co.uk/1/hi/world/americas/97132.stm>;
<http://news.bbc.co.uk/1/hi/england/hampshire/5263488.stm>

See also http://en.wikipedia.org/wiki/List_of_wildfires

² Cochrane, M. 2003. Fire science for rainforests. *Nature* 421: 913-919.

³ Mollicone, D., Eva, H.D. & Achard, F. 2006. Human role in Russian wild fires. *Nature* 440:436.

⁴ News stories of suspected arson in Australia

<http://www.cnn.com/2009/WORLD/asiapcf/02/09/australia.wildfires/index.html>; Greece

<http://news.bbc.co.uk/1/hi/world/europe/6964519.stm>

4) Tropical deforestation, logging and fires

Deforestation, even selective logging⁵, increases fire risk in tropical forests, even moist (rain) forest. The edges of forests, and thinned canopies dry out more than undisturbed forest, and this leaves them more vulnerable to fire^{6,7}. The intactness of the Amazon forest is seen as key to its survival (i.e. to prevent the forest reaching a tipping point and becoming savannah) under the increased drought predicted by climate change⁸

In the tropics, fire is often used to clear degraded forests prior to using the land for agriculture. Such fires themselves emit carbon. It has been estimated that fires associated with land clearance contribute approximately half the carbon emissions from deforestation, or about 0.65 Pg C yr⁻¹⁹. Such fires may get out of control and unintentionally burn the surrounding forests and there may be unintended fires following deforestation. For example, in Indonesia, peat fires have been increasing over the past 50 years¹⁰, as a direct consequence of increased deforestation and drainage.

Fires in the Amazon

There are **interactions between deforestation, agriculture, climate change and fire** in the Amazon region. Forest fire frequency is related to¹¹:

- **Drought** – longer droughts occur during El Niño years, which are expected to increase with climate change. Prolonged drought increases the flammability of the forest.
- **Distance from roads and pasture** – forest nearer roads and pasture tends to be affected by drying out (edge effects from forest fragmentation) and there are increased sources of ignition from humans. For example, fire is used to maintain pastures and these fires can get out of control
- **Logging** - Even selective logging caused the forest to become degraded (less dense and hence drier). Roads are also created.
- **Deforestation rate**: as forest is lost, the amount of rainfall decreases as trees cause less water to be evaporated to the atmosphere to form rain. Therefore, the forest becomes drier as deforestation continues.
- **Type of forest** – the more humid (wetter) forest in the core of the Amazon forest is less vulnerable to fire than the drier forest nearer the outer zone of the Amazon forest

B) Climate change will increase forest fires in some areas

Forest fires are expected to increase in some areas with climate change and decrease in others. Although some forest areas (such as the Amazon, Mediterranean and temperate US) are predicted to be much drier, and therefore more vulnerable to fire, other areas, such as tropical Africa, may be

⁵ Cochrane, M. 2003. Fire science for rainforests. *Nature* 421: 913-919.

⁶ Cochrane, M. 2003. Fire science for rainforests. *Nature* 421: 913-919.

⁷ Nepstad, D.C., Stickler, C.M., Soares-Filho, B. & Merry, F. 2008. Interactions among Amazon land use, forests and climate: prospects for a near-term forest tipping point. *Philosophical Transactions of the Royal Society B* 363: 1737-1746.

⁸ Malhi, Y., Aragão, L.E.O.C., Galbraith, D., Huntingford, C., Fisher, R., Zelazowski, P., Sitch, S., McSweeney, C. & Meir, P. 2009. Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. *Proceedings of the National Academy of Sciences* doi: 10.1073/pnas.0804619106

Nepstad, D.C., Stickler, C.M., Soares-Filho, B. & Merry, F. (2008) Interactions among Amazon land use, forests and climate: prospects for a near-term forest tipping point. *Philosophical Transactions of the Royal Society B* 363: 1737-1746.

⁹ Bowman, D.M.J.S. et al., 2009. Fire in the Earth System. *Science* 324: 481-484.

¹⁰ Field, R.D., van der Werf, G.R. & Shen, S.S.P. 2009. Human amplification of drought-induced biomass burning in Indonesia since 1960. *Nature Geoscience* doi: 10.1038/NGEO443

¹¹ Cardoso, M.F., Hurt, G.C., Moore III, B., Nobre, C.A., Prins, E.M. 2003. Predicting future fire activity in Amazonia. *Global Change Biology* 9: 656-669.

wetter and less vulnerable to fire¹². However, climate variability is expected to increase across the globe¹³ and this will increase periods of drought, making forests more flammable.

A modeling study of the impacts of warming found that reduced fire frequency, reflecting wetter conditions, was predicted for parts of the boreal region, but increased tree cover in some other parts (especially eastern Canada) promoted fire. Most semi-arid regions, including the Sahel, central Australia, central Asia, southern Africa, and the western U.S., show a high probability of increased wildfires including in grassland ecosystems, especially for $>3^{\circ}\text{C}$, reflecting increased biomass growth. Increased fire risk was also predicted for the southeastern U.S. and at high elevations (notably the Tibetan plateau). More frequent wildfires were found to be likely ($>60\%$ for $>3^{\circ}\text{C}$) in much of South America.¹⁴

There are already questions over whether climate change is already causing an increase in forest fires (e.g. Boreal). Many studies come from the Western US, showing that climate is a major factor influencing fires and that intensified wildfire regimes do appear to be driven at least partially by 20th century climate change in North America¹⁵, despite the influence of historic fire-suppression. Climate is an important driver of fire in the Western US¹⁶ and changes in the climate to earlier springs and warmer springs and summers have lead to increased forest wildfire activity¹⁷.

In particular, climate change may give rise to more El Niño-type episodes, which have marked effects on drought in many parts of the world. El Niño events increase the risk of forest fires in regimes in fire-prone regions such as Australia, the Mediterranean region Indonesia and Alaska but also introduce fire into regions where it was previously absent (e.g., the Swiss Alps)¹⁸.

Forest fires are particularly important for the Boreal forest and are influenced by El Niño¹⁹, which is associated (at least partly) with prolonged and severe droughts. Under these conditions, large fire years become common, and fire frequency increases. If climate change results in the drier conditions predicted, forest fires would cause a reduction in the mean age of the forest and changes in species composition of the North American boreal forest²⁰. Intensified fire regimes are likely to impact boreal forests at least as much as climate change itself and may accelerate transitions, e.g.,

¹² Scholze, M., Knorr, W., Arnell, N.W. & Prentice, C. 2006. A climate-change risk analysis for world ecosystems. *Proceedings of the National Academy of Sciences* 103: 13116–13120.

¹³ IPCC WGII 2007. *Climate Change 2007: Chapter 4: Impacts, adaptation and vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

¹⁴ Scholze, M., Knorr, W., Arnell, N.W. & Prentice, C. 2006. A climate-change risk analysis for world ecosystems. *Proceedings of the National Academy of Sciences* 103: 13116–13120.

¹⁵ IPCC WGII (2007) *Climate Change 2007: Chapter 4: Impacts, adaptation and vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

Littell, J.S., Mckenzie, D., Peterson, D.L., Westerling, A.L. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916–2003. *Ecological Applications* 19: 1003-1021.

Westerling, A.L., Hidalgo, H.G., Cayan, D.R. & Swetnam, T.W. , 2006. Warming and earlier spring increase Western US. forest wildfire activity. *Science* 313: 940-943.

¹⁶ Littell, J.S., Mckenzie, D., Peterson, D.L., Westerling, A.L. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916–2003. *Ecological Applications* 19: 1003-1021.

¹⁷ Westerling, A.L., Hidalgo, H.G., Cayan, D.R. & Swetnam, T.W. 2006. Warming and earlier spring increase Western US. forest wildfire activity. *Science* 313: 940-943.

¹⁸ IPCC WGII 2007. *Climate Change 2007: Chapter 4 Impacts, adaptation and vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

¹⁹ Fauria, M.M. & Johnson, E.A. 2009. Climate and wildfires in the North American boreal forest. *Philosophical Transactions the Royal Society B* 363: 2317-2329.

²⁰ Fauria, M.M. & Johnson, E.A. 2009. Climate and wildfires in the North American boreal forest. *Philosophical Transactions the Royal Society B* 363: 2317-2329.

between taiga and tundra, through facilitating the invasion of pioneering trees and shrubs into tundra (IPCC).

In the tropics, however, it is the interaction of deforestation, logging and drought caused by climate change that is expected to facilitate the spread of human-caused fires. *"Drought acts as the trigger for fire occurrence, but it is humans who ignite the fires."*²¹

C) Forest fires effects on future climate change

Forest fires emit large amounts of carbon to the atmosphere. Globally, forest fires' contribution to carbon emissions is highly variable, estimated to be between 1 and 1.8 Pg C yr⁻¹²². Fires from the Amazon emit an estimated 0.024-0.165 Pg C²³ and those from Indonesia, PNG and Malaysia associated with 0.13 Pg (comparable to fossil fuel emissions in this area)²⁴.

Forest fires create a "positive feedback loop". That is, fires emit carbon dioxide to the atmosphere, which in turn creates more global warming, which is expected to increase forest fires, causing more carbon dioxide to enter into the atmosphere²⁵. Fire itself also makes forests more vulnerable (as does logging and deforestation) by creating fragments and edges, which are drier than other parts of the forest. However, for tropical forests at least, humans also influence this feedback loop as they start most fires *"One unique feature of the carbon-climate feedback described here is the human component; because humans set most fires, this mechanism would not exist or would be considerably smaller in the absence of increased human settlement, agricultural expansion, and logging in the region."*²⁶ Many of these fires are started to clear land for agricultural products such as cattle or palm oil.

This raises the spectre of runaway climate change, where carbon emissions from forest fires create so much global warming that forests (and other terrestrial ecosystems) stop taking more carbon out of than emitting to the atmosphere and, instead, through drought and fire, become overall sources of carbon to the atmosphere²⁷.

*"These deforestation-related fires contribute substantially to the global burden of greenhouse gases, and the associated global warming that they will cause is projected to increase extreme fire weather, leading to further spikes of carbon emissions."*²⁸

²¹Field, R.D., van der Werf, G.R. & Shen, S.S.P. 2009. Human amplification of drought-induced biomass burning in Indonesia since 1960. *Nature Geoscience* doi: 10.1038/NCEO443

²²van der Werf, G.R., Randerson, J.T., Giglio, L., Collatz, G.J., Kasibhatla, P.S. & Arellano, Jr. A.F. 2006. Interannual variability in global biomass burning emissions from 1997 to 2004. *Atmospheric Chemistry and Physics* 6: 3423–3441.

²³Bowman, D.M.J.S. et al., 2009. Fire in the Earth System. *Science* 324: 481-484.

²⁴Van Der Werf, G.R. Dempewolf, J., Trigg, S.N., Randerson, J.T., Kasibhatla, P.S., Giglio, L., Murdiyarso, D., Peters, W., Morton, D.C., Collatz, G.J., Dolman, A.J. & DeFries R.S. 2008. Climate regulation of fire emissions and deforestation in equatorial Asia. *Proceedings of the National Academy of Sciences* 105: 20350-20355.

²⁵Bonan G.B. 2008. Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science* 320: 1444-1449.

²⁶Van Der Werf, G.R. Dempewolf, J., Trigg, S.N., Randerson, J.T., Kasibhatla, P.S., Giglio, L., Murdiyarso, D., Peters, W., Morton, D.C., Collatz, G.J., Dolman, A.J. & DeFries R.S. 2008. Climate regulation of fire emissions and deforestation in equatorial Asia. *Proceedings of the National Academy of Sciences* 105: 20350-20355.

²⁷ Bowman, D.M.J.S. et al., 2009. Fire in the Earth System. *Science* 324: 481-484. IPCC WGII (2007) Climate Change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

Bonan G.B. (2008) Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science* 320: 1444-1449.

²⁸ Bowman, D.M.J.S. et al., 2009. Fire in the Earth System. *Science* 324: 481-484.

Conclusion

Forest fires are apparently increasing, but the reasons are complex – a mixture of human activity and climate change. Climate change is expected to increase forest fire risk in some parts of the world, including the Amazon, but this risk is exacerbated by logging activities (including selective logging) and human presence in the forest. Importantly, forest fires create a “positive feedback loop”, where the carbon emissions from fire create further climate change, increasing the risk of forest fires still further.