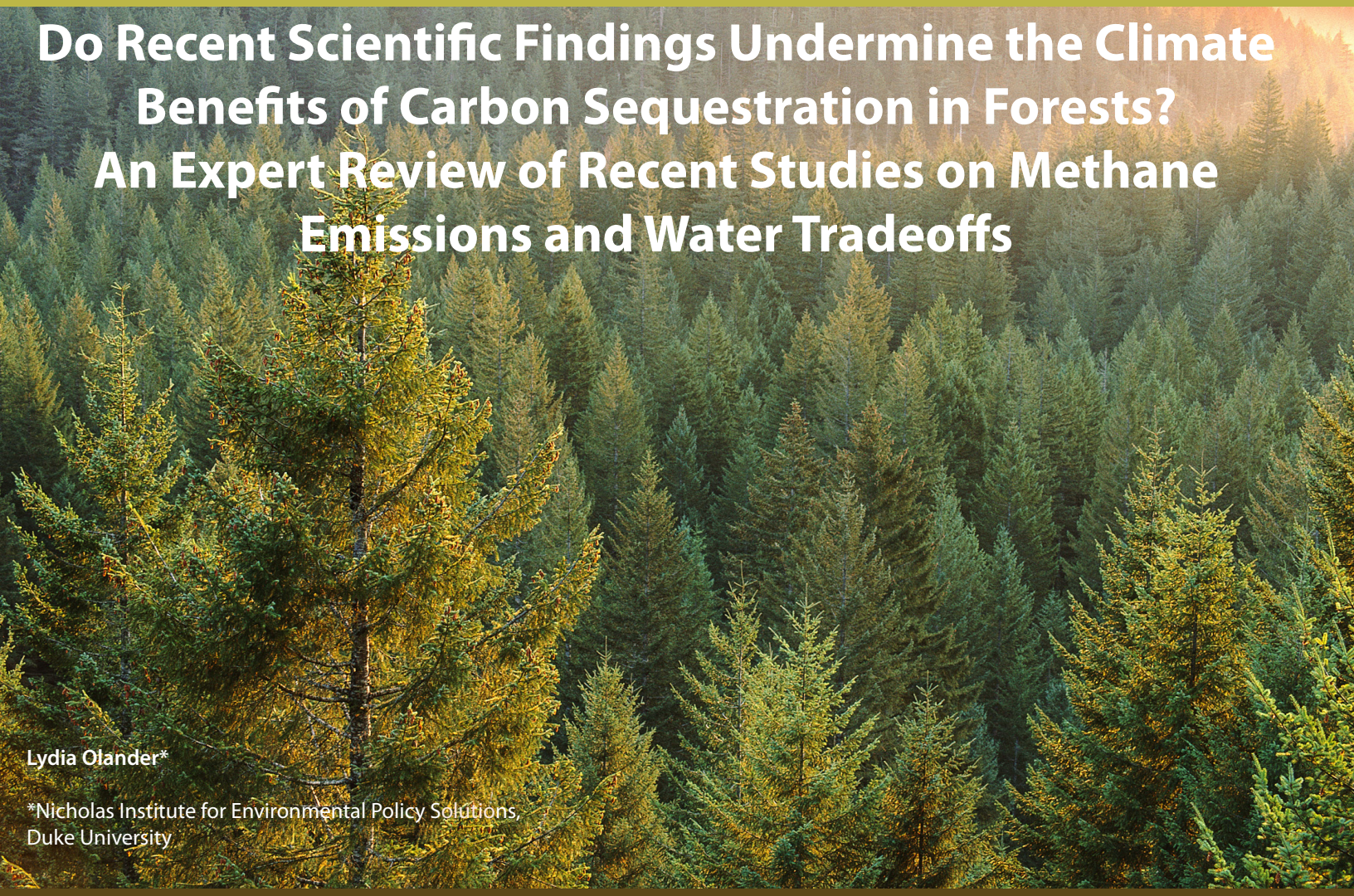
NICHOLAS INSTITUTE REPORT

Do Recent Scientific Findings Undermine the Climate Benefits of Carbon Sequestration in Forests? An Expert Review of Recent Studies on Methane Emissions and Water Tradeoffs



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SUMMARY

A key feature of global warming policy has been the role of carbon sinks in offsetting our greenhouse gas emissions. In practice carbon sinks are forests and agricultural lands that remove carbon dioxide from the atmosphere and sequester it in plant matter and soils. In nearly every policy arena, carbon sinks are used to enhance the economic efficiency of mitigation by providing more flexible compliance options. For instance, the Kyoto Protocol, the international accord on reducing greenhouse gas emissions, allows the use of carbon sinks through afforestation, reforestation, and reduced deforestation to help meet a country's greenhouse gas reduction targets. Carbon sinks play a prominent role in greenhouse gas reduction programs in the U.S., as part of programs such as the DOE's 1605(b) voluntary registry, California Climate Registry, and the Regional

Greenhouse Gas Initiative of the Northeastern states. Two recent papers in the scientific literature have generated speculation regarding the benefits of terrestrial carbon sinks. One paper, led by Frank Keppler from the Max Planck Institute found that plants emit significant amounts of methane, a potent greenhouse gas. Another study, led by Robert Jackson of Duke University found that plantations can reduce stream flow and increase salinization of soils more than previously thought. Some media and interested parties have speculated that this research calls into question the value of carbon sequestration from trees and plants as a climate change mitigation strategy. Others viewed this speculation as far overblown.What did the research say? What do scientific experts think about its significance? And should current policy be altered as a result? To answer these questions a group of experts gathered at Duke University. They assessed the science and its implications and came to the consensus discussed in this document. In sum, the group's conclusions were as follows:

Methane Study (Keppler et al.)

- Plants appear to be a previously undetected source of methane. Using the estimates in the published study, the methane produced by a forest would reduce the carbon sequestration climate benefits by about 4%.
- The group gathered at Duke suggested refinements to the global estimate that would reduce the methane flux by a factor of ten. If future research finds this reduced estimate to be closer to the actual flux, the methane produced by plants would be only a small fraction of the global methane budget.
- More importantly, it is likely that no change in the sequestration climate benefit will be observed. The measurements in the study could not distinguish if the magnitude of methane emissions from trees is any different from that of grasses. Thus, we do not know whether replacing grasslands with forests will increase, decrease, or have no net effect on methane emissions.
- Irrespective of whether the original estimated fluxes are used or those suggested by this consensus group, the impacts on carbon sequestration benefits of forests are quite small. Methodologies typically used to assess the greenhouse gas benefits of carbon sequestration are sufficiently comprehensive and sophisticated to incorporate the impacts of methane emissions.

Water and soil tradeoff study (Jackson et al.)

- The group agreed that plantations in regions previously occupied by non-forest landscapes, such as grasses or shrubs, are likely to cause substantial reductions in stream flow and soil quality, greater than previously realized. In wetter regions reduced stream flow may not be a problem, but in drier regions it can be a substantial problem even stopping flow in some streams.
- The study focuses on plantations and thus did not assess the effects of mixed species and natural reforestation of deforested areas.

- Overall, the study reaffirms the need for careful land-use planning and the need to consider local impacts in the design of plantations for carbon sequestration projects.

Both studies raise important questions for policy design, but do not shift our understanding of carbon sequestration by plants enough to have a profound impact on current offset policies and accounting practices. They do, however, suggest key features to include in the policies. First, as scientific discovery moves forward, sequestration policies and accounting will need to have the flexibility to incorporate updates in scientific understanding. Second, placing a value on one ecosystem service over others can create a win-win situation in some cases, but in others a negative trade-off that needs to be considered to balance competing environmental impacts at the global, national, and local level.

INTRODUCTION

Scientific research papers published in the journal Science in December 2005[1] and Nature in January 2006[2] generated significant press and created quite a stir among the scientific community and those in the policy community who work on the use of forests for sequestering carbon as an offset to greenhouse gas emissions. Members of industry and other entities currently committed to pilot sequestration projects, as well as those involved in the accounting of carbon storage to evaluate and manage projects, have also sought additional information regarding the implications of this research.

The press surrounding these scientific papers may have helped amplify the concern. Sensational sounding titles included: "Can planting trees make global warming worse" –London Daily Mail; "Plants bad for the environment"– Fox News; "Plants gone bad" –Philippine Daily Inquirer; and "'Carbon sinks' drain water" – The Australian. In addition, the science news feature, 'News and Views', in the journal Nature had a particularly provocative statement that was picked up by the media; "We now have the specter that new forests might increase greenhouse warming through methane emissions rather than decrease it by being sinks for carbon dioxide"[3]

In the Nature paper, Frank Keppler and his coauthors report on a previously unmeasured source of methane emissions - living plants and their fallen leaves. Methane is a potent greenhouse gas, with a warming potential 23 times greater than carbon dioxide[4]. At first glance, Keppler's paper suggests the need to reassess the value of biological carbon sinks. If living plants are emitting methane, the benefit gained by planting or replanting forests to sequester carbon could be countered by the release of methane from the trees.

In the Science paper, Robert Jackson and his coauthors documented that plantations can have a large impact on stream flow and soils. The study raises questions about the extent to which the benefit of using plantations to sequester carbon is offset by the reductions in water availability and soil quality.

In response to the publication of these papers and the confusion and questions they and the press surrounding them generated, the Nicholas Institute for Environmental Policy Solutions at Duke University convened a group of experts in climate science, the cycling of methane, and ecosystem hydrology, as well as policy experts that sit at the center of the development of policies on carbon sequestration. We asked this group to evaluate the science of these papers and whether they substantially changed scientists' understanding of methane emissions, the global methane budget, the side-effects of afforestation, and whether any changes in our understanding would or should affect the policies currently in place or those under consideration to value the sequestration of carbon. The participants in the meeting limited their discussion to the science and its implications for policy, and did not range into a discussion of the intricacies of those policies.

None of the experts gathered have any association with the Keppler research and thus provided an independent commentary on this work. However, we did share the consensus document with Dr. Keppler who offered his support for this publication and comments to consider in revision. In contrast, for the Jackson paper, since some of the authors are affiliated with Duke University, we had the opportunity to include them in this meeting. Thus the discussion of the Jackson paper included both those involved and independent experts. This summary document provides a consensus of the experts present at this meeting[5].

Methane – What's the Real Story?

What did this new research by Keppler et al.say?

A crucial underlying fact about this research that was mischaracterized in some of the press coverage is that this source of methane is not a new phenomenon. However, scientists had never identified it, distinguished it from other sources, or included it as an identified source in global methane budgets. Although existing uncertainty in the budget provides room for an unidentified source, that this previously undetected plant-produced source could be as large as calculated by the authors gave rise to skepticism among some scientists. Balancing the sinks and sources of methane, with Keppler et al.'s estimates, would have required that other sources of methane have been overestimated.

Keppler and his coauthors were the first to detect methane emission from a wide variety of plants and their fallen leaves. They were the first to try to quantify this flux from plants and the first to try to understand this new mechanism of methane production. Scientific discovery is an iterative process. While they have taken the very first step and discovered a new phenomenon, much research still needs to be done before we will know enough to incorporate this new methane flux into greenhouse gas mitigation planning and accounting.

What did the press say?

While Keppler and his coauthors used their laboratory findings to calculate global methane estimates from plants and found these estimates to be fairly large, they did not suggest major policy implications for their results. In contrast, the science news and general press made broad generalizations[6], often in the headlines, which led to a misinterpretation of the research suggesting that the benefit of forests for carbon storage could be substantially reduced based on the results of this study. The authors themselves felt this was a misinterpretation of their results and replied with a press release from the Max Plank Institute clarifying their results[7].

What do other scientists say? Is the flux of methane reported by Keppler real?

While the participants accepted that plant methane emissions were likely measured by Keppler and his coauthors, there was a general sense that these results should be replicated and validated through further experimentation.

Other recent scientific research may lend some support to Keppler's findings of methane production from plants. A number of measurements in the Amazon[8] suggest that the concentration of methane that accumulates in the forest canopy and the atmosphere above the Amazon region is too high to be easily explained by the sources usually considered. These studies may provide support for Keppler's observations of methane emissions from plants, but are not detailed enough to help quantify them. Participants in this discussion also noted that Keppler showed no consistent differences in methane emissions from different kinds of plants. Measured methane emissions from grasses and trees were variable and overlapping[9].

The primary focus of the discussion was not so much on the validity of the experimental findings, but rather on the extrapolation to global methane flux, due to the latter's relevance for policy. Keppler and his coauthors used their laboratory measurements to calculate potential global methane emissions from plants. The scientists gathered at the Nicholas Institute suggested that further refinements of this calculation could decrease the estimated emissions by a factor of ten[10]. In particular, they noted refinements that would (a) account for the fact that only the top layer of leaves receive constant sunlight, where Keppler's calculations seem to assume that all of a tree's leaves receive direct sunlight, and (b) account for the fact that Keppler uses total plant biomass growth (about 70% of which is wood in forests) in his calculations, rather than leaf production. Green leaves, appear to generate substantially more methane than the woody parts of plants[11].

A reduction in estimated emissions by a factor of ten would mean that global methane emissions from plants are only 1 to 3% of the total methane emitted annually from all sources, and implies that the reduction in carbon sequestration climate benefit from forests would be, at most, around 0.4%. It would also mean that methane emissions from plants are within the uncertainty bounds of current global estimates.

Uncertainties in these global estimates confirm the need for additional measurements and research, but also tend to suggest that refinements are more likely to reduce the initial estimated flux rather than increase it. In order to develop better estimates, future research needs to assess how plant emissions vary by species and with environmental conditions, and how to measure and model these fluxes to the atmosphere.

Methane – Policy Implications

The answer is no.

Keppler's paper does not add a new methane source; rather it better defines what is in the uncertainty of current global measurements. The reduction in sequestration benefits from methane emissions from plants may be in the range of 0.4%, based on our discussion, or 4% based on the authors' original calculation. In either case, it would likely make little difference in current policy de sign and, based on the precision in accounting methods it would likely have little significance for individual projects. Furthermore, in most terrestrial sequestration projects, trees replace grasses, shrubs, or crops. In Keppler's study they show no clear difference between the emissions from grasses and those from trees. There is no indication that a plantation would emit more methane than the grassland or other land cover that it replaces.

With the development of a carbon market under the Kyoto Protocol (KP) and the potential of a carbon market or carbon policies in non-Kyoto countries like the United States, land-use based sequestration offset policies are being developed around the world. Some of these are internal to a country, for example, Articles 3.3 and 3.4 of the KP and the U.S. voluntary registry; and some exist between countries, such as Joint Implementation and the Clean Development Mechanism (CDM) under the KP. These policies are all still relatively new constructs. Keppler's study, which is a leap forward in our understanding of how plants affect greenhouse gas emissions, underscores the need for flexible policies that allow the incorporation of updates in scientific understanding as they develop.

Soil and Water Trade-offs for Plantations – What's the real story?

What did this new research by Jackson et al. say? And what did other scientists think?

In their research Jackson and his coauthors analyzed paired watershed studies from around the world and found that when previously unforested watersheds were planted with trees, significant reductions in

stream flow occurred[12]. These plantations may also reduce soil fertility and increase salinity in certain settings. The authors found the negative consequences for water availability and soil quality can be quite substantial. The paper highlights the need to consider the full environmental consequences of how we use land management for carbon sequestration, particularly plantations. The authors conclude that afforestation projects in water-limited areas are most likely to suffer from these negative water and soil impacts

Key details from the paper clarify the scope of the study and implications of its results:

1. The plantations assessed in this study are dominantly monocultures of relatively fast growing tree species.
2. These monoculture plantations on landscapes that were previously occupied by shrub-, grass-, and croplands generally reduce stream flow, and the reductions can be substantial, 38% on average. However, reduced stream flow may be primarily a problem in drier regions that experience water limitation.
3. The magnitude of the reduction will depend on the local environment and conditions of the ecosystem (rainfall, soils, water table, etc...).
4. Mixed species reforestation or regeneration of areas that were previously forested and that would natural revert to forest were not assessed in this study. However, in these circumstances planting trees may have positive effects on water and soil conditions.
5. In the watersheds assessed, plantations covered large portions, in most cases 50% or more,of the watershed. Plantations with less watershed coverage would likely show less impact on water; while those with full coverage could have more.
6. In the watershed comparison most plantations were planted with Eucalyptus or pine. These are by far the most commonly planted trees for plantations around the world. While, eucalyptus clearly has a greater effect on water quantity than pine, it is not known how other species would compare.

The group convened by the Nicholas Institute accepted the finding that plantations reduce stream flow and can completely eliminate flow in some locations. While a reduction in stream flow may not be a problem in areas with sufficient water it may be a substantial problem for drier regions. It is also clear that plantations can increase soil acidity and salinity and decrease fertility.

Overlap in the use of the terms afforestation and reforestation is common and may cause confusion about the extent to which the results of this study can be applied. The study used a definition of afforestation that is also used under the Kyoto Protocol, limiting afforestation to forest establishment on lands without forest cover in the last 50 years. Furthermore, the study assessed the impacts of plantations, which in this case involved predominately monoculture growth of typically fast growing trees. This synthesis research did not distinguish whether plantations were grown on lands that would naturally revert to forest if left on their own versus those that would remain grass- or shrub-lands. While one might expect plantations to have less impact on lands that would revert to forest, this was not assessed in this study, due the difficulty of knowing the natural state of lands that have been under land management for hundreds of years.

One exception to these side-effects of plantations which was noted in the paper, but not emphasized, is the replacement of intensive croplands by plantations. In these cases, planting can be beneficial in restoring water availability and soil quality.

What did the press say?

Media coverage of this research highlighted the potential negative consequences of using plantations for carbon sequestration, often avoiding mention of the positive side effects forests can have. That said, the media generally did not misrepresent the results of the study[13]. In Australia, where the government has

recently proposed a tripling of land under plantations to 3 million hectares by 2020, response to this paper was particularly strong. The limitations of the study were not always clearly expressed by the press or understood by its readership which was apparent in letters to the newspapers[14].

Soil and Water Trade-offs for Plantations - Policy Implications

Should the trade-off in water availability and soil quality, as described in Jackson's paper, change current or proposed policies for land use projects designed for the sequestration of carbon?

It is generally known that growing plantations will change water dynamics. What makes the Jackson et al. paper important is that it quantified the impact of plantations across broad regions, and improved our ability to estimate the impact more generally across the globe. This paper reinforces the notion that the water trade-off can be significant and water scarcity needs to enter into decisions regarding carbon sequestration projects.

National and local leaders may have to consider the benefits an afforestation project can bring, through carbon sequestration and wood products, against the availability of water and soil quality that maintaining a landscape dominated by grass or shrubs can provide for the local population. In essence it is a question of national and local priorities and land use planning. If a decision is made to plant forests, key questions like where to put plantations and what kind of trees to plant need to be considered.

Plantations will be an important land-use option for carbon offset policies around the world. Within a country, it would be expected that the potential negative local impacts would be carefully considered along with the positive and profitable aspects, such as carbon and other products. There is greater uncertainty when these projects are between-country agreements. For example, current UN Climate agreement guidelines require that CDM sequestration projects meet sustainability objectives[15]. This policy is designed to avoid trading global solutions for local problems. As a result, the impacts on water from a plantation should already be considered in the requirements for a qualifying CDM project. However, developing countries where CDM projects are located want to maintain autonomy and the right to make decisions about their land use. As a result, no international criteria have been established for sustainability. Instead each individual project is considered by the host country and the country purchasing the sequestration benefits.

Since plantations for carbon benefits and other sequestration projects can be primarily a private good (for private profit), policymakers, when accrediting sequestration projects, must consider the consequences on other ecosystem services (e.g. water) that are often public goods. In particular for carbon trading between countries, the agreement of host and purchasing nations may not be sufficient to limit projects to those that promote sustainability unless policies by either party provide additional restrictions or guidelines.

CONCLUSION

Although these recent scientific papers by Keppler and Jackson, and the press that followed their publication generated many questions about carbon sequestration policy and pilot projects, the negative implications of these studies have been largely overstated.

- Methane is likely produced by plants, but at a magnitude likely insignificant in the account-ing of benefits for carbon sequestration. In fact, the methane flux from plants may be small enough to be within the uncertainty bounds of known methane sources. And furthermore, at this time, there is no indication that forests release anymore methane than the vegetation they would replace in a

sequestration project. Much research still needs to be done to understand the mechanism of methane production and the quantity of methane released to the atmosphere.

- Although carbon benefits from forest sequestration are changed little by the Keppler discovery, the study reveals how important it is for offset policies to have the flexibility to incorporate changes in our understanding of carbon sequestration as scientific discovery continues to advance.
- The value of plantations for carbon sequestration and the impacts they have on other ecosystem services has been an ongoing question in the climate policy community. The
- Jackson study provides an improved basis for predicting where trade-offs in water availability and soil quality are likely and may help improve decisions on what we plant and where. In particular, it focuses attention on the potential problems of growing plantations in drier regions on lands naturally occupied by grasses and shrubs.
- The Jackson paper highlights the need for land-use offset policies to consider the sustainability and local impacts of proposed projects. It also reinforces concerns about providing a market value to a single ecosystem service without providing one to others. Given the understandable desire for local autonomy for land use decisions new ideas are needed for how to promote projects with the greatest mix of benefits for sustainability as well as sequestration.

APPENDIX A

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** Was not able to attend the meeting, but has reviewed this document and supports its conclusion*

ENDNOTES

[1]*R.B. Jackson, E.G. Jobbagy, R. Avissar, S.B. Ray, D.J. Barrett, C.W. Cook, K.A. Farley, D.C. le Maitre, B.A. McCarl, and B.C. Murray. Dec 2005. Trading water for carbon with biological carbon sequestration. Science. 310:1944-1947.*

[2]*F. Keppler, J.T.G. Hamilton, M.Bras, and T. Rockmann. Jan 2006. Methane emissions from terrestrial plants under aerobic conditions. Nature. 439:187-191.*

[3]Daily Mail *(London). January 12, 2006. Can planting more trees make global warming worse? By Julie Wheldon. Pg. 33; Fox News.com. January 12, 2006. Plants bad for the environment? Celebrities causing frogs to croak? By Steven Milloy;* Philippine Daily Inquirer. *February 4, 2006; Plants gone bad. By Massie Santos Ballon; D.* The Australian. *January 1, 2006. Carbon sinks drain water. By Amanda Hodge; and C. Lowe. Jan 2006,. A green source of surprise.* Nature. *439: 148-149.*

[4]*Intergovernmental Panel on Climate Change, Climate Change 2001: The Scientific Basis (Cambridge, UK: Cambridge University Press, 2001)*

[5]*See Appendix A for list of participants*

[6]Daily Mail *(London). January 12, 2006. Can planting more trees make global warming worse? By Julie Wheldon. Pg. 33;* Daily Mail *(London), January 13, 2006. does this prove that global warming's all hot air? By Melanie Phillips. Pg 19; and C. Lowe. Jan 2006,. A green source of surprise. Nature. 439: 148-149.*

[7]*Max Planck Society Press Release. January 18, 2006. Global Warming – the blame is not with the plants. <www.mpg.de>*

[8]*Frankenberg, C. et al. 2005. Assessing methane emissions from global space-borne observations. Science 308, 1010-1014.; Carmo, J. B. do, M. Keller, J. D. Dias, P. B. de Camargo, and P. Crill (2006), A source of methane from upland forests in the Brazilian Amazon, Geophys. Res. Lett., 33, L04809.; and C. Martens (Personal Communication).*

[9]*Keppler et al. 2006. Supplemental materials.*

[10]*Refinements to Keppler's extrapolation were suggested by participants. a) The emissions rates Keppler measured were from leaves in sunlight and it appears that these rates were used in the calculations. However, only 20-50% of leaves, depending on the ecosystem, are on the top of the canopy and exposed to direct sunlight; and b) While Keppler appears to have used whole plant fluxes for the extrapolation, only one of these was a woody plant. The woody plant had the lowest emissions and was likely a young plant with less woody biomass than a mature tree. Apparently most of the emissions are coming from leaves. Keppler's calculation appears to use total plant growth, rather than leaf production to scale the measurements from their experiments Leaf production makes up only 20-50% of total plant growth. It was also noted that the trees likely consume some of the methane they emit, stopping its release to the atmosphere. Initial modeling efforts that incorporate many of these details also suggest an approximate factor of 10 reduction in the global estimate of methane flux from that published by Keppler (A.Guenther, Personal Communication)*

[11]*It was also noted that the average temperature Keppler et al. used to extrapolate methane fluxes (30 degrees Celsius) is appropriate for tropical forests, but not appropriate for temperate forests. It appears that fluxes at this temperature were used in the global extrapolation, despite the temperature sensitivity observed by Keppler et al.. This suggests that lower flux rates in cooler regions may be more appropriate for the extrapolation and lower the global estimates*

[12]*Jackson et al. 2005*

[13]The Press Trust of India, *December 23, 2005. Afforestation has side effects too!;* The Guardian. *December 23, 2005. Tree-planting projects may not be so green. By James Randerson;* Christian Science Monitor. *January 5, 2005. On the horizon. By Peter N. Spotts.;*

[14]The Australian. *January 1, 2006. Carbon sinks drain water. By Amanda Hodge;* The Mercury. *February 3, 2006. Letters to the Editor*

[15]*United Nations. Conference of the Parties to the UN Framework Convention on Climate Change, 3rd session. Report of the conference of the parties on its third session. 1997. Online UNFCCC. Available: http://unfccc.int/cop3/07a01.pdf.20 February 2006*

The Nicholas Institute for Environmental Policy Solutions

The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to help decision makers in government, the private sector, and the nonprofit community address critical environmental challenges. The Nichols Institute responds to the demand for high-quality and timely data and acts as an "honest broker" in policy debates by convening and fostering open, ongoing dialogue between stakeholders on all sides of the issues and providing policy-relevant analysis based on academic research. The Nicholas Institute's leadership and staff leverage the broad expertise of Duke University as well as public and private partners worldwide. Since its inception, the Nicholas Institute has earned a distinguished reputation for its innovative approach to developing multilateral, nonpartisan, and economically viable solutions to pressing environmental challenges.

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