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Interactive comment on "Mitigation of agriculture emissions in the tropics: comparing forest land-sparing options at the national level" *by* S. Carter et al.

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Response to: Referee comments, Cheikh Mbow, ICRAF, World Agroforestry Center, Nairobi. Article: Mitigation of agriculture-driven deforestation in the tropics: comparing land-sparing options at the national level MS No.: bg-2015-79

The authors thank the reviewer for the detailed and insightful comments. These comments will help us to improve the manuscript. Our responses to specific points from the review are detailed below.

Reviewer: This study addresses the importance and potential of forest sparing as a pathway for significant abatement of greenhouse gases (GHG) from land use change.

The authors suggested a systematic framework as a common entry point to addressing multiple sources and possible sinks for carbon dioxide (CO2) mostly from the agricultural sector. They hypothesized that improving farming such as agroforestry, climate smart agriculture (CSA), sustainable intensification and similar land management systems will spare forested lands from human pressures and henceforth improve carbon sequestration. The paper is very ambitious in scope and geographical coverage (tropical countries) but the method to achieve the goals quite appropriate. They used mostly secondary data and global databases for their calculations and assessment. Some proxies such as risk was based on food security indices, the least that can be done in assessing social vulnerability and likelihood for relying on natural capital for survival. Similarly baselines forest trends was depicted from conservative approach of past deforestation rate. Overall the methodological choices are very robust but the analysis could be seen as partial as the authors did not consider non-CO2 GHG.

Authors: Although our study considered only CO2 emissions due to deforestation, we did consider N2O and CH4 from agricultural emissions but reported CO2 equivalents. This point was clarified in the updated manuscript. Not including non-CO2 gasses in deforestation emissions is a commonly used approach (i.e. Achard et al., (2014)) , but the impact of this on the final results is mentioned in the discussion section (4.2).

Reviewer: The assumption that improved mitigation is related to good governance systems could be scrutinized more in this study. General governance systems does not always reflect those specific to the agriculture and forest sectors. We are in most cases dealing with polycentric governance systems that sometimes oppose various logics and in many instances competing goals. An example is the often cited in the case of inconsistent policy objectives between agricultural development and forest conservation.

Authors: The discussion on this point was be expanded in section 4.5 (second paragraph). The link between good governance (at the national level), and implementation of policies (including at the sub-national level) was included. The complex nature of the

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issue, and potential for conflicts between different levels of government is discussed in the conclusions. In addition, the conclusions were adapted to note that coordination between agencies is required with consideration of competing goals.

Reviewer: Another limit could in the requirements for a full accounting of the carbon equivalent balance. Many authors recognized that full GHG budget is quite difficult to perform in developing countries because of lack of data (Valentini, R. et al. 2014).

Authors: The limitations / reliability of the input datasets, and the impact on results has been addressed and considered by the authors throughout the methods, and in the discussion.

Reviewer: I fully approve the use of the forest transition curve to support selection of criteria and trend in deforestation but in developing countries there are many possibilities for future tipping points on the natural resources demand as population grows and emerging lifestyle emerges with increased urban population. The emerging demographic and economic situation could lead to more pressures on forest resources but in some instance this could lead to improved forest management with emerging demand for healthy life styles.

Authors: The authors agree that there are many limitations to the use of the forest transition curve to predict future deforestation. In this case we did not use the FT curve in the deforestation estimates. The comments also point to some limitations to the selected methodology, however this is already elaborated in the paper (section 4.3).

Reviewer: Finally is important to question how under current and future socio-ecological situation land-sharing with CSA, agroforestry, and sustainable intensification will contribute to overall climate dynamics, and how high subsidies agriculture could lead to more forest sparing but with more ecological and climate footprints. Those aspects could be the subject of another paper.

Authors: This is indeed a good point, but as the reviewer mentions, is beyond the scope

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of this study.

Reviewer: The focal interest of this paper is on land based mitigation. It is important to recall the readers that Agriculture, Forestry and other Land Uses (AFOLU) a now a specific section within IPCC AR5 (Chapter 11 of WG III). The conclusion of the IPCC assessment shows that AFOLU offers many flexible options (Smith, Bustamante et al. 2014) that the other sectors do not have. These options have different abatement rates but also different costs. It is important to address the issue of trade-offs amid strategic land based mitigation option but also between those and other aspects of sustainable livelihood and development needs.

Authors: The relevance of this study to the AFOLU sector is mentioned in the paper, however the need to select the most efficient (based on abatement rate and cost of implementation) option within this sector is not discussed in detail. Although estimates on the cost of avoided deforestation, and on mitigation in the agriculture sector are available, since we do not discuss specific technologies (i.e. technologies for intensification), we decided not to discuss the costs of these interventions.

Reviewer: The authors confirmed that agriculture is the main driver of deforestation in tropical area and yet one of the biggest emission sources. The solution for mitigation should be mostly in agriculture not only emission related to deforestation but also emission nested to agriculture systems themselves and food nets. The paper highlighted that land-sparing interventions can potentially be implemented under REDD+ to mitigate the land related emissions. I am not sure if REDD+ is the “silver bullet” solution for reducing GHG, rather additional efforts in non-forested zones through improvement of tree cover, mostly in farming lands could be central to the global solution for land based mitigation strategies. The challenge in developing countries is to meet GHG reduction needs - in the context of Intended Nationally Determined Contributions (INDCs) - without sacrificing food security or natural ecosystems, a challenge called agricultural intensification. Exploring such sustainable intensification pathways should lead us beyond REDD+ that emulates more the countries with dense forest cover. This

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argument appears in water marks in the paper when the authors stated that deforestation rate as compared to forest cover is higher in non-forested countries (e.g. authors cited Togo, Zimbabwe). Why then too much focus on dense forest countries? (Mbow, C. et al. 2012, Mbow 2014).

Authors: It is true that land sparing interventions may not be best implemented under REDD+ and that other options should be considered. Other interventions include the establishment of protected areas plus implementing the restoration of degraded lands (for example the Global Restoration Initiative) or introducing extension services to promote climate-smart agriculture (or agricultural intensification) are also possible. Agroforestry which achieves the aim of carbon storage through sequestration, but not necessarily the protection of established forests is also promoted through a number of other channels, such as through the work of ICRAF. Initiatives are increasingly driven by producers, and interventions like the Roundtable on Sustainable Palm Oil can also reduce deforestation. The point which should be highlighted is that without active forest protection, any efforts to intensify agriculture or to utilize unused or degraded land may not spare forests. This connection is described more clearly in the paper in section 4.5. The comments on the selection of priority countries by focusing on those countries with dense forest cover (or high levels of carbon stored in forests) is very relevant. Since we consider the mitigation potential of each country in terms of emissions rather than forest area, this is something to be aware of. Deforestation in low density forests in Africa is included in this study provided they meet the FAO forest definition (10% canopy cover etc.), so most of these savanna type systems are included. Togo and Zimbabwe are highlighted as countries with high forest loss due to agriculture in percentage terms. Despite having forests which are relatively less dense, they are still considered priorities for interventions, which shows that our paper uses different criteria than for example REDD+ investors to select countries for interventions. The references provided by reviewers elaborate on this well, and one citation was added to the paper, and a discussion point added to cover this issue in section 4.1, paragraph 1.

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Reviewer: The fundamental and technical challenge is how to implement intensification in existing farming lands to avoid net positive emissions including those related to deforestation and low ecological footprint. How to achieve negative emissions through land management systems? Knowing that high inputs and energy intensive agriculture will lead to more emissions (Smith, Haberl et al. 2013)

Authors: This is indeed the fundamental question, and in this paper we take the assumption that this is indeed possible. The methods (for example which interventions to use where) are not discussed as this is not the objective of the paper, but we do conclude that it is possible to lower the emissions intensity of production. This is also discussed in the Smith et al. (2013) paper, who includes options such as the distribution of inputs from low to high fertilized areas. Although perhaps this example is limited in its application, there are other options available, many discussed by the CSA community.

Reviewer: The merit of this paper not only on the research insights (potential for reducing GHG emission from improved land use) but also on how to close the yield gap. I would wish to add some discussion points on what non-forest lands are used for in developing countries. Not all lands need to be used for agriculture. Some are spared for ecosystem services, and many for grazing. The potential farming lands issue reminds the assumption made by FAO that Africa is among the continent where existing land suitable for agriculture is among the highest. That was an open gate for land grabbing rather than improving agriculture for and limiting deforestation (Mbow and C 2010).

Authors: For clarification, we include grazing as part of agriculture. It is likely be that our definition of land availability is not complete, however, we do discuss the limitations of this dataset in the paper. Land grabbing (which is mainly for agricultural purposes) fits in well with the discussion here, and the availability of land in parts of Africa is shown in our findings. The authors included the suggested reference, and discussion point in section 4.4.

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Reviewer: The paper is very rich in content, well organized and quite inspiring for solution oriented climate decisions. The general observations above is simply to contribute to the debate and highlight the bold value of this paper and why it needs to be read. In few details below I raise some minor aspects that could help orient future thinking or even improve the next paper of this wonderful group.

Scientific questions and specific comments Specific questions arise when reading the paper. One is the perpetual quiz of emission factor. While we know how many 1 kg of carbon will be released by 1 kg of wood, the oxidation processes leading to carbon emission are very diverse and difficult to assess in a GHG budgeting effort. For instance, fires related emission is difficult to estimate because of varying emission factors depending to burning completeness, the fuel models in presence and the fuel moisture during combustion. If we had a good database of emission factors, knowing area affected by deforestation in exact terms is impossible because of method discrepancies and land cover definitional implications.

Authors: The use of emissions factors is by nature a limitation in the study. The decision not to include burning in the deforestation related emissions estimates is due to a lack of available data on this. The fact that burning has been omitted was included in the manuscript in section 4.2.

Reviewer: In this study as in most similar ones, there is not accounting of carbon sequestration through improvement of tree cover in farming lands is important (recovery areas). Maintenance of forest can help avoid emission from deforestation but will not increase substantially carbon sequestration. Trees and soil carbon sequestration can be increased through promotion of trees outside forests.

Authors: This is indeed a good point, and it does highlight the need to include these emissions reductions when considering different options in practice. The mitigation potential may therefore be underestimated in this study, however the bias is present for all countries, so the results would not differ because of this. The lack of a global

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dataset on trees outside forests also presents problems to include this in our study.

Reviewer: Another question is what do we do about “non-regret” options such as national parks and protected forest that spare emission from agricultural encroachments with or without REDD+? REDD+ is not fully addressing agriculture even if that sector explain the great deal of deforestation. There is a paradox that makes agricultural intensification - a way for reduced deforestation - as non-REDD+ strategy. CSA is a good mitigation option if implemented well but cannot be a REDD+ branded activity. Agroforestry can be a good mitigation option but up to now there is now REDD+ project based on agroforestry. . ..? Reducing emissions from land use require more inclusion of such practices. A good recommendation is to include land sparing in REDD+ but not at the expense of food security.

Authors: This comment captures the need to maintain forest cover, while considering food security. CSA and Agroforestry cannot be included as REDD+ activities (in terms of the emissions accounting), but they can be potentially included as supportive interventions – i.e. interventions which mean ensure the success of a REDD+ project.

Reviewer: On the technical side, methods for GHG accounting differ in precision and level of disaggregation of various components and process of carbon budget. Current scientific knowledge shows various disaggregation approaches based on land use/cover types from fine scales (Brink, A.B. et al. 2009) to global biomes based carbon accounting (Quéré, C. et al. 2012). The complexity of the carbon cycle in particular in Africa requires in situ data and up-scaling of these data at regional scale. Until methods and data are improved it will be very hard to accurately (big uncertainties) know when a country has a high potential for mitigation?

Authors: The authors agreed that it is difficult to know where the highest potentials are for mitigation, however in our case mitigation potential is mainly from avoided deforestation, and we confident about the activity data and emissions factors used in this paper for this process.

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Reviewer: Technical corrections The authors use remote sensing based forest-cover change data from Hansen or FRA RSS to derive a ratio of net forest change to forest loss "Net:Loss", and use this factor for estimating gross forest loss from the FAO FRA data. Hansen Data I believe do not use the exact forest definition as FAO did. Also the data work best in pure forest cover biomes. In non-forested lands with trees Hansen maps does not work well (e.g. open savanna or pasture lands). FRA RSS was based on tiles of Landsat data with regular intervals (1 degree interval, 2055 tiles for Africa, 1230 tiles Latin America + Caribbean and 741 tiles South and Southeast Asia). The Sample size is 20 km x 20 km. Then land cover maps and land use maps were based on e-cognition clustering (multi bands, multi years) of small spectral classes using expert knowledge. Regional workshops for validation have been performed to finalize the land and land cover products. The challenge of FRA - 2010 data is the status of LANDSAT acquisition under humid forest with a lot of cloud cover that prevent obtaining cloud free data. A big deal of land use emission come from these area where few optical images can be achieved because of "permanent cloud cover" (Roy, P. et al. 2010). The minimum mapping unit of 5 ha, while most land use process happen at small holders plots below the acre in size.

Authors: These comments are correct, and there are a number of limitations to the remote sensing datasets which are described in the paper. Regarding the accuracy of the datasets, we do not go into detail on this, as a full comparison of the datasets is beyond the scope of this study, but we discuss the use of the data and which datasets best meet the needs of the study. For this purpose we consider it sufficient. It is inevitable that any datasets used have limitations, and the authors feel that they have used the best available datasets for the purpose of this study.

Reviewer: For risk assessment the authors used food security index. Risk is related to 3 pillars: hazard (climate, economic), the vulnerability (poverty, food security) and exposure (how many people, infrastructure etc.). Here only one dimension of risk is taken in relation to food security. I am a bit worrying about the assumption of risk in the

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paper. A part from the general and specific comments made on this paper, I believe the article needed to be written to clarify many issues related to the performance of land based mitigation and context specific feasibility of such options. I was delighted to be appointed as a commentator and well open for subsequent discussions on the issues raised in this short review.

Authors: The authors agree that risk is complex and food insecurity alone does not equal risk from interventions in the farming sector. However there are several reasons why this indicator has been selected. Firstly, because food insecure communities are likely to have less resilience to changes to systems. They are likely to also be income and asset insecure, which also lowers resilience to changes. Where communities are reliant on agriculture for food and/or income, then those who are food insecure are by nature more at risk from potential negative consequences of the intervention in the agriculture sector. Secondly, there are no data on the numbers who would be influenced (exposure) as the interventions are hypothetical. An indicator such as percent of population living in rural areas was considered , but there is no clear link between this and those who would be impacted if interventions in the farming system were implemented. Thirdly, the hazard element of risk in our case, is constant across all countries, since we hypothesize that the intervention will occur, and we assume that there is a potential negative impact. There are a number of other hazards which could have both positive and negative influences on a community (such as climate change) and due to complexities, feedbacks, etc. we cannot account for them all. In our case, we take a simple, but we believe robust approach, and use vulnerability to change (as indicated by food insecurity) as being the measure of risk. The methods have been expanded substantially to reflect the reviewer comment on the components and complexities of risks, to explain which aspect of risk this study considers (section 2.5).

Interactive comment on Biogeosciences Discuss., 12, 5435, 2015.