Info Note

A rough estimate of the proportion of global emissions from agriculture due to smallholders

Sonja Vermeulen, Eva Wollenberg

APRIL 2017

Key messages

- Smallholders in developing countries produce, on a very rough estimate, 5% of total global greenhouse gas emissions. This figure includes emissions due to both agriculture and land use change for agriculture.
- Mitigation actions in smallholder agriculture now could support farm livelihoods and more sustainable agriculture in the long run, but should only be introduced where they have the potential to advance rather than constrain rural development outcomes.

Introduction

Globally, nearly a quarter of annual greenhouse gas emissions come from agriculture, forestry and other land use, in the region of ~10-12 $GtCO_2eq$ per year (Smith et al. 2014). As reducing greenhouse gas emissions becomes a greater consideration in every sector, a major policy question is whether climate change mitigation should be a priority in smallholder farms in low-income and middle-income countries, where poverty, food insecurity and vulnerability to climate change may already be threats to farmers' livelihoods. To answer this, we need to first know how much smallholder emissions matter. What proportion do smallholder farms contribute relative to all agricultural emissions, and to total global emissions from all sectors?

Providing an accurate estimate is not easy. Data on smallholder numbers and production systems are poor to nonexistent compared to large-scale commercial farmers. Definitions of smallholders vary by country and the data are based on these definitions, so comparisons among countries are difficult. It is also difficult to know from landholdings alone whether a smallholder is poor or a successful intensive farmer. Poverty can be used as a proxy, but these data reflect only numbers of households, rather than land sizes. Emissions are also problematic to estimate. Current data on emissions from land use and agriculture do not allow disaggregation by farm size, nor by poverty level, to identify smallholders. Meaningful quantification is difficult due to almost no emissions factors for smallholder systems in tropical agro-ecosystems and because most smallholders use multiple practices that can have mixed effects on emissions. Emissions estimates usually focus on a dominant source of emissions rather than whole farms. The activity data needed to estimate emissions are also lacking, as is knowledge on differences in activities between large-scale and small-scale farms. Finally, smallholders' contributions to deforestation and land use change are difficult to assess, as it is often interrelated with the contributions of larger farmers.

An estimate of total emissions associated with smallholder agriculture

We estimate that, in approximate terms, smallholder farming contributes agriculture sector emissions of about 1.7 $GtCO_2e$ per year. This is a rough estimate using 2010 data. Smallholder emissions thus contribute up to 32% to global agriculture sector emissions and 42% to the agriculture sector emissions from developing countries (Table 1). This is about 3.5% of all emissions globally – four times more per year than the agriculture sector emissions of the EU or US.

If net deforestation due to conversion for smallholder farming is added to the agriculture sector, smallholder farming results in a total of about 2.5 $GtCO_2e$ per year of emissions. This is 31% of global emissions due to both agriculture and land use change for agriculture, 47% in developing countries specifically, or 5.1% of total global emissions. Again, these are rough rather than precise estimates, as explained in the methods section below.

The agriculture sector estimate is likely higher than the true value, as it reflects a country's average emissions per hectare. Depending on levels of inputs, density of cropland and livestock, and efficiencies of practices, smallholder systems may in some cases have lower emissions per hectare than on larger farms (Box 1). A lower-end conservative estimate would be that smallholder agriculture generates only half the calculated amount, with emissions of 0.85 GtCO2e/yr, approximately the annual agricultural emissions from China, where smallholdings represent 98% of the land area. This would still represent two times more emissions per year than the agriculture sector emissions of the EU or US. Even with highly conservative estimates, smallholder farming is a significant source of emissions, just based on on-farm emissions.

These numbers describe emissions from on-farm production and net deforestation only; they do not include other life cycle emissions from, for example, processing, transport, or the production of fertilizer or feed. They also do not reflect carbon sequestration due to the planting of trees, pasture or organic matter input to the soil. The estimates are very rough due to poor availability of data on smallholder numbers and practices. Details on methods are given below.

Table 1. Contribution of smallholder farming to greenhouse gas emissions

Emissions source	Total emissions $GtCO_2e/yr$	% total emissions from smallholders in developing countries
Global emissions	49	3.4% [b] 5.1% [c]
Agriculture sector	5.240	32%
Developed countries	1.205	-
Developing countries	4.035	41%
Land use change sector (net forest removals attributed to agriculture)[a]	2.726	29%
Developed countries	0.160	-
Developing countries	2.566	29%

Emissions data: FAOSTAT 2015
a 73% of emissions from net forest removals (3.735 $GtCO_2e/yr$)
b counting only smallholders' agricultural emissions
c counting smallholders' agricultural emissions and land use change emissions due to agriculture

Methods and observed differences among countries

Agricultural emissions are a product of agricultural practices, for example, management of crops, soils, livestock and manure, and environmental conditions. To estimate agriculture and land use change emissions, we used FAOSTAT 2010 estimates for all 154 countries. The FAOSTAT estimates are based on country reports of the extent of farming practices.[1] As presented in Table 2, the proportion of the emissions attributable to smallholder farming can be calculated as the percentage of agricultural land managed by smallholders, defined commonly as farmers with less than 2 ha of farmland.[2] Smallholders are not necessarily poor or resource-poor; however we did a check of poverty rates against proportions of smallholder farmers across the set of countries and found the numbers broadly similar.[3]

Data on the proportion of land under smallholder farming was found for 61 countries, which represented 83% of agricultural emissions globally. As these countries contributed four-fifths of global emissions, we did not undertake detailed analyses for the remaining 93 countries, which had very low emissions. Only five countries in this latter group had emissions larger than 0.023 $GtCO_2e/yr$: Sudan, Vietnam, Philippines, Angola and Mali. We assumed 25% land under smallholders for these countries.

Data on the proportion of land under smallholdings needed to be compiled from different sources and was often old, ranging from 1993 to 2011. It is highly likely that the proportions of smallholders have changed in countries with data from more than a decade ago, so these numbers need to be treated with caution.

The proportion of national emissions attributable to smallholders can be calculated in terms of the percentage of farmers that are smallholders (i.e. what proportion of individual landholdings fall below a certain size threshold) or the percentage of agricultural land under smallholders. Both methods involve problematic assumptions: the first that all farms produce the same emissions regardless of farm size and the second that all farms produce the same emissions per area, without any differences in practices between large and small farms, nor economies or diseconomies of scale. We found that divergences between the two methods are higher in countries with less equitable land distribution. Additionally, both systems have data limitations, for example difficulty counting individual landholdings in countries where smallholders do not hold private title. On balance, the per-hectare estimate is preferable to the per-farmer estimate.

Smallholder farming emissions in the agriculture sector are concentrated in Asia, mostly due to large populations.

[1] FAOSTAT data are based on Tier 1 default values for emissions factors. These data do not allow distinct emissions factors for different agro-ecological contexts, but are consistent in activity reporting which enables comparison across countries.
[2] In selected Latin American countries where grazing cattle requires large land areas, we used 50 ha as the threshold to represent vulnerable, low-income farmers.
[3] IFAD data on poverty levels and smallholder landholdings were used to verify smallholder numbers in the selected countries and to provide figures for the proportion of landholdings under smallholders for Vietnam, Nigeria and Mali.

The majority of smallholder agricultural emissions – 71% – come from only three countries: China, India and Indonesia. But not all major emitters are in Asia. Ethiopia, Tanzania and Sudan's smallholder farms are major emitters in Africa, as are Colombia and probably Mexico in Latin America. Also, while absolute emissions are highest in Asia, the emissions per smallholder farm are not necessarily higher. For example, GHG emissions per smallholder farm in Ethiopia (.0057 GtCO_2e/yr) are higher than in China (.0043) and Tanzania's emissions per farm (.0035 GtCO_2e/yr), are higher than those in Bangladesh (.0003 GtCO_2e/yr).

Table 2. Agriculture sector emissions by smallholder agriculture in 20 top emitting developing countries

Country (ranked by emissions from smallholder agriculture)	Agricultural emissions Mt CO2e/yr	% land under smallholders	Smallholder agricultural emissions Mt CO2e/yr
China	818	98%	804
India	647	44%	287
Indonesia	156	55%	86
Ethiopia	89	60%	54
Bangladesh	75	69%	51
Tanzania	44	88%	39
Pakistan	134	15%	21
Egypt	28	58%	16
Colombia*	59	28%	16
Nepal	21	69%	14
Philippines	51	25%	13
Myanmar	64	19%	12
Sum of top 12	2186		1413
Sum for sector	4035		1658
% sector	54%		85%

*Country in which a smallholding is defined as <50ha; for all other countries defined as <2ha

Emissions due to net deforestation associated with smallholder agriculture

Agriculture is the major driver of forest loss, estimated to account for 70-80% of net emissions from deforestation (Hosonuma et al. 2012). These emissions are accounted for in the land use change sector. Here, to complement the agriculture sector data, the 20 developing countries with highest net deforestation emissions associated with smallholder agriculture are selected. Using 2010 data, these 20 countries account for 1.9 GtCO_2e per year, which is 70% of all reported global emissions associated with net forest cover change in 2010.

The method for calculating the proportion of these indirect emissions due to smallholders is based on the work of Hosonuma et al. (2012), which analyses the drivers of net forest change across tropical and sub-tropical developing countries, distinguishing large-scale and smallholder farming. We calculate that smallholders account for 0.8 GtCO_2e per year, 42% of all agriculture-driven emissions associated with net forest cover change in those 20 countries (Table 3). This is likely to decrease in future, as analyses of drivers and trends show that the contribution of smallholders to deforestation is declining globally (Rudel et al 2009; Hosonuma et al. 2012). Differences among countries reflect phases in forest transition (Hosonuma et al. 2012). For example, Congo DRC is in a pre-transition phase, with high forest cover and a low deforestation rate, while Nigeria is a late-transition country in which a smaller remaining forest cover is changing at a slower rate, and smallholders are less important as drivers of change.

Table 3. Indirect agricultural emissions by smallholders in 20 top emitting developing countries

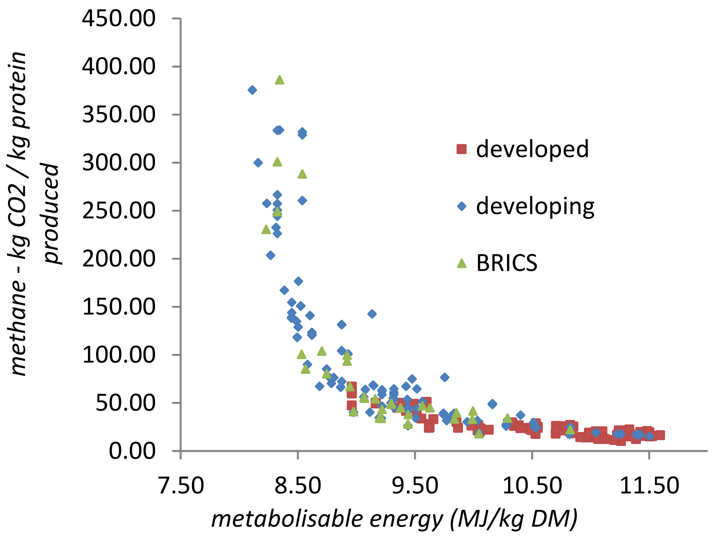
Country (ranked by land use change emissions due to smallholder agriculture)	Land use change emissions due to all agriculture	% due to smallholder agriculture	Land use change emissions due to smallholder agriculture
Brazil	559.1	36	202.7
Indonesia	227.7	49	112.1
Congo DRC	59.7	80	48.1
Cameroon	80.8	57	45.9
Venezuela	117.4	36	42.6
Tanzania	66.4	57	37.7
Myanmar	43.1	84	36
Argentina	86.8	39	33.9
Bolivia	79.7	36	28.9
Ecuador	78	36	28.3
Paraguay	70.8	36	25.7
Malaysia	50.2	49	24.7
Peru	52	46	23.7
Nigeria	149.9	12	18.3
Madagascar	28.8	57	16.4
Zimbabwe	27.9	57	15.8
Mozam-bique	25.8	57	14.6
Angola	25.4	57	14.4
Papua New Guinea	27.2	49	13.4
Zambia	22.1	57	12.6
Sum of top 20	1878.8		795.8
% sector	70%		29%

Box 1: Understanding differences in emissions between large and smallholder farming

Emissions tend to be higher per hectare in farming systems with higher inputs, which is why resource-poor smallholder farms with lower inputs would normally be expected to produce lower emissions. For typical practices in developing countries, smallholder farming can have, for example, up to 15% lower emissions per hectare where no nitrogen fertilizer is used compared to farming with high levels of fertilizer, or 50% lower emissions where less productive or unhealthy livestock predominate. Dryland rice, practiced on about 10% of rice land, reduces or even eliminates methane emissions. However, it is not always the case that smaller farms use lower levels of inputs. For example, in China, the most significant source of smallholder emissions, there is a sharp decline in per-hectare fertilizer use with farm size (Ju et al. 2016), while a nationwide study in Kenya found no relationship between farm size and fertilizer rates (Ariga et al. 2007).

Emissions depend on much more than the level of inputs. Differences in the methane emissions from enteric fermentation in livestock depend on the details of the production system, including herd management, quality of feed, breed and health of the animals, and agro-ecological conditions. For example, dairy cattle in Brazil are estimated to produce 1.97 tCO_2e/head/yr compared to 1.45 tCO_2e/head/yr for beef cattle (Vosti et al. 2011). Emissions can vary hugely by region because of such differences. Similarly for deforestation, practices and governance in smallholders systems may override other factors. In Brazil, smallholder cattle ranchers raising calves are reportedly driving more deforestation than larger finishing farms, as the latter are more easily held accountable to deforestation laws.

Also, emissions per kilogram (kg) of food produced ("emissions intensity") on small versus large land holdings may differ from the emissions per hectare. Low production intensity systems such as traditional pastoralism in East Africa, emit about 25 times more greenhouse gases than high intensity production in the EU or US on a per kg protein basis (figure below), even though the absolute emissions of the traditional system are lower due to far lower numbers of animals. Trade-offs often occur between per-area and per-product emissions. For example, as land prices increase in Brazil, wealthier farmers with larger landholdings often manage their pastures to improve feed quality, which allows them to increase the stocking density and productivity of cattle per hectare. In these systems, emissions decrease per animal and per kilogram of meat or milk, but increase per hectare.



Emissions intensities from livestock based on quality of feed

Source: Herrero et al. 2013

Arguments for and against reducing future emissions in smallholder agriculture

On the plus side, there is much in favour of low-emissions development in smallholder agriculture aside from its significant contribution to global GHG emissions. Early adoption of low-emissions agricultural development in developing countries provides an opportunity for more efficient use of land, fertilizer, energy, feed and water. Incorporating mitigation actions from the start enables favourable practices to be intrinsic to agriculture, rather than having to provide incentives for change in high-emissions systems. A small increment of change could have large impact due to the large numbers of smallholders and the large proportion of deforestation associated with smallholder agriculture. Some low-emissions practices may provide immediate economic benefits for smallholders. Examples include more efficient application of nitrogen fertilizers in high-use contexts, or savings in energy costs from reduced water use in rice paddies.

On the other hand, there are multiple arguments against low-emissions agricultural development among smallholders, particularly under any mandatory basis. While the contribution of smallholder emissions at the global level is material, this does not mean that reductions in smallholder emissions in developing countries are necessary or inevitable. Similar to any investment in sustainability measures, the extra effort and cost to shift to low emissions practices may improve long-term global public goods outcomes but reduce options or in some case increase costs of practices. Shifting to new practices may create disproportionally higher risks and costs for smallholders, who are disproportionately poor, at risk from food insecurity and vulnerable to climate change. Carbon sequestration in smallholder systems may face impermanence and reversibility issues, with smallholders doubly vulnerable if they are blamed for deforesting or cultivating soils during times of hardship.

Low-emissions development projects would need substantial investment to provide financial services to smallholder households to adopt new technologies. Similar constraints to investment may limit transitions to low-emissions development at the national level. Policy targets may be difficult to reach and transactions costs high given large numbers of diverse and dispersed smallholders with weak institutions for collective action. There are also practical problems in monitoring and rewarding mitigation benefits. Measuring efficiency and activity data would be an enormous task, requiring targeting.

Regardless of the options in smallholder agriculture, emissions from larger farms are nonetheless more significant. Therefore larger farms therefore are arguably the initial priority for low-emissions policies in agriculture, especially in places where other production risks are minimal. Further analysis and improved scenarios are needed to determine whether mitigation in large farms would be sufficient to achieve the targets needed in the agricultural sector, as determined by an economically efficient allocation of mitigation across all sectors.

Conclusion: Mitigation in smallholder agriculture?

Emissions from smallholder farming in developing countries are roughly estimated as contributing to one-third of agricultural emissions and one-third of the emissions from deforestation due to agriculture globally. This is a rough interim figure ahead of more detailed information and analysis on agricultural emissions by farm size. Even if the true value were only half this amount, smallholder emissions would be significant and material to public sector and private sector decisions. If society is serious about meeting targets for reducing climate change, reducing future emissions from smallholder agriculture needs to be considered an option.

Just like any other option though, smallholder farming should be evaluated against other mitigation options in terms of costs, feasibility and impacts. Likewise, agricultural practices need to be evaluated against other development options for their impacts on reducing hunger and poverty and increasing adaptation, equity and sustainability. Any decision to seek climate change mitigation in smallholder systems needs to make sense for both mitigation and development. Low-emissions development is thus a necessary framing for approaches in developing country smallholder contexts. It implies that improvements for development need to be identified first, and mitigation opportunities examined in these contexts.

Low-emissions development that is designed first to reduce hunger and poverty, and second to deliver mitigation as a co-benefit, will make more sense in some places than others. Farmers on development pathways towards increasing market integration, who are transitioning to new farming practices and have access to technical support and some surplus, can better afford investment in the shift to improved management practices than highly vulnerable farmers regularly suffering crop loss or chronic hunger.

If smallholders are to seize opportunities for low-emissions development, improving our collective knowledge is paramount. Since much remains unknown about low-emissions agriculture in practice, farmers and researchers need to experiment with portfolios of technical and institutional options. Better information about local farming systems and emissions factors in developing country smallholder conditions will improve priority setting. Working together to improve our understanding of the costs, feasibility and impacts of low-emissions agriculture among smallholders can turn those priorities into practice. Bringing favourable practice to scale has the potential to deliver durable gains for farmers – while making a meaningful dent in the 5% of global emissions due to smallholder agriculture.

Acknowledgements

We thank Elwyn Grainger-Jones for suggesting this study, and Laura Schreeg for assistance with data management and analysis.

References

- Ariga, J., Jayne, T.S., Kibaara, B. & Nyoro, J.K. 2008. Trends and patterns in fertilizer use by smallholder farmers in Kenya 1997-2007. Working Paper 28, Tegemeo Institute of Agricultural Policy and Development.
- Cerri, C.C., Maia, S.M.F., Galdos, M.V., Cerri, C.E.P., Feigl, B.J. & Bernoux, M. 2009. Brazilian greenhouse gas emissions: the importance of agriculture and livestock. Scientia Agricola 66 (6): 831-843.
- Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. 2013. Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome.
- Herrero, M., Havlík, P., Valin, H., Notenbaert, A., Rufino, M.C., Thornton, P.K., Blümmel, M., Weiss, F., Grace, D. & Obersteiner, M. 2013. Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. PNAS 110 (52): 20888-20893. doi:10.1073/pnas.1308149110
- Hosonuma, N., Herold, M., De Sy, V., De Fries, R.S., Brockhaus, M., Verchot, L., Angelsen, A. & Romijn, E. 2012. An assessment of deforestation and forest degradation drivers in developing countries. Environmental Research Letters 7. doi:10.1088/1748-9326/7/4/044009
- Xiaotang Ju, Baojing Gu, Yiyun Wu & Galloway, J.N. 2016. Reducing China's fertilizer use by increasing farm size. Global Environmental Change 41: 26–32
- Rudel, T.K., Defries, R., Asner, G.P. & Laurance. W.F. 2009. Changing drivers of deforestation and new opportunities for conservation. Conservation Biology 23(6): 1396-405. doi: 10.1111/j.1523-1739.2009.01332.x.
- Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E.A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N.H. Ravindranath, C.W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling & F. Tubiello, 2014: Agriculture, Forestry and Other Land Use (AFOLU). In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel & J.C. Minx (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, USA.
- University of Aberdeen & CCAFS 2016. Mitigation Options Tool. https://ccafs.cgiar.org/mitigation-option-tool-agriculture
- Vosti, S., Msangi, S., Lima, E., Quiroga, R., Batka, M. & Zanocco, C. 2011. Agricultural Greenhouse Gas Emissions in Latin America and the Caribbean: Current Situation, Future Trends and One Policy Experiment. Inter-American Development Bank Discussion Paper IDB-DP-167

Sonja Vermeulen *(s.vermeulen@cgiar.org) is CCAFS Head of Research.*

Eva Wollenberg *(ewollenb@uvm.edu) is the Flagship Program Leader for the CCAFS Flagship Program on Low Emissions Development, the goal of which is to test the feasibility of reducing agricultural GHG emissions at large scales while ensuring food security in developing countries.*