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Greenhouse gas mitigation in Chinese agriculture: Distinguishing technical and economic potentials

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ABSTRACT

China is now the world's biggest annual emitter of greenhouse gases with 7467 million tons (Mt) carbon dioxide equivalent (CO_2e) in 2005, with agriculture accounting for 11% of this total. As elsewhere, agricultural emissions mitigation policy in China faces a range of challenges due to the biophysical complexity and heterogeneity of farming systems, as well as other socioeconomic barriers. Existing research has contributed to improving our understanding of the technical potential of mitigation measures in this sector (i.e. what works). But for policy purposes it is important to convert these measures into a feasible economic potential, which provides a perspective on whether agricultural emissions reduction (measures) are low cost relative to mitigation measures and overall potential offered by other sectors of the economy. We develop a bottom-up marginal abatement cost curve (MACC) representing the cost of mitigation measures applicable in addition to business-as-usual agricultural practices. The MACC results demonstrate that while the sector offers a maximum technical potential of 402 $MtCO_2e$ in 2020, a reduction of 135 $MtCO_2e$ is potentially available at zero or negative cost (i.e. a cost saving), and 176 $MtCO_2e$ (approximately 44% of the total) can be abated at a cost below a threshold carbon price $\leq$¥ 100 (approximately €12) per tCO_2e. Our findings highlight the relative cost effectiveness of nitrogen fertilizer and manure best management practices, and animal breeding practices. We outline the assumptions underlying MACC construction and discuss some scientific, socioeconomic and institutional barriers to realizing the indicated levels of mitigation.

1. Introduction

Greenhouse gas (GHG) emissions in China reached 7467 million tons (Mt) carbon dioxide equivalent (CO_2e) in 2005 excluding land use, land use change and forestry (NCCC, 2012), and agriculture accounted for 11% of this total, or approximately 820 $MtCO_2e$. Agriculture is responsible for over 70% of national nitrous oxide (N_2O) emissions and approximately 50% of methane (CH_4) emissions, arising mainly from the use of synthetic nitrogen (N) fertilizers, livestock enteric fermentation, rice cultivation and animal waste management. Both in 1994 and 2005, livestock enteric fermentation (37% of 2005 total agriculture emissions) was the largest agricultural source of GHG emissions (only including N_2O and CH_4), followed by cropland (25% of the total) (NCCC, 2004, 2012). Rice cultivation (CH_4) and livestock waste management (N_2O and CH_4) contributed around 20% and 18%, respectively (NCCC, 2012).

In China, national policy aspirations for agricultural mitigation have traditionally been eclipsed by food security goals, with any convergence of production and climate objectives focusing mainly on increasing productivity. But ambitious national mitigation

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aspirations have recently been outlined in the 12th Five-Year Plan, which targets a 17% reduction in carbon intensity (emissions) per unit of Gross Domestic Product. In response, the Ministry of Agriculture (MOA) has initiated programs to mitigate agricultural emissions by improving agricultural productivity by 2015. These include a 3% improvement in fertilizer use efficiency, enhancing irrigation water use efficiency by 6%, accelerating the development of household biodigesters, and improving degraded grasslands. The 12th Five-Year Plan also accommodates a significant increase (+0.45% per year) in scientific research funding.

Existing global reviews (e.g. Oenema et al., 2001; IPCC, 2007; Smith et al., 2008, 2013) suggest that agriculture offers significant technical potential to mitigate climate change through both emissions reduction and carbon sequestration in terrestrial ecosystems. Technically feasible GHG measures identified as applicable in both arable and livestock systems can be broadly grouped into increased N-use efficiency, reduced CH_4 emissions from livestock rumen and rice paddy, sequestering C into cultivated and grassland soils, and energy efficiency to reduce CO_2 emissions. Some reviews (e.g. Wreford et al., 2010) indicate that many mitigation measures can be implemented immediately using current technologies, simultaneously reducing input costs or improving productivity. Beyond such initial win–wins, some agricultural abatement options also afford economic and environmental co-benefits, notably, biodiversity conservation, food security, rural development and poverty alleviation, all of which have high importance in rural China.

Existing research in China has examined and quantified technical abatement potentials for specific agriculture mitigation measures (Lin et al., 2005; Lu et al., 2009; Huang and Tang, 2010; Nayak et al., 2014). These studies provide some insights into how mitigation potentials can be applied across the range of biophysical conditions that characterize Chinese farming systems. Beyond the farm gate, further insights have been provided by life-cycle analysis targeting the N fertilizer production and consumption chain (Zhang et al., 2013). But to date there is no bottom-up estimate of overall technically feasible mitigation potential in agriculture, nor any estimate of the cost-effectiveness of abatement measures in China. Such research would consider the relative abatement cost of implementing each measure and would provide information on how agricultural abatement costs compare with both a benchmark carbon price and abatement elsewhere in the economy. This is significant, since in allocating an emissions budget to a sector, a rational mitigation policy should normally prioritize the cheapest means of abatement first and equalize marginal abatement costs across sectors. Such information is also crucial, for instance, for developing any market-based approach based on offering low cost mitigation credits to any emerging carbon market. While agriculture has been slow to graduate to such market schemes, the inception of emissions trading regimes in China may to lead to an increasing scrutiny of the relative cost of emissions reductions in all sectors of the economy.

This paper considers the extent of biophysical data on agricultural mitigation measures and outlines the stages in moving from a technical potential to an estimate of feasible economic mitigation potential. The methodological approach involves the use of a bottom-up or engineering marginal abatement cost curve (MACC), which allows the aggregation of the mitigation potential arising from the application of a subset of cost-effective measures above a notional baseline level of activity that we denote as business as usual (BAU). This analysis considers measures applicable within the farm gate and the direct cost and benefit implications for farmers. Life-cycle impacts of the measures and energy use related emissions are not within the scope of this MACC exercise. The omission of some system-wide benefits by the current MACC exercise will under-estimate the full gains of certain mitigation options. The paper covers the sections of MACC construction, presentation of key results and a discussion of data. It also reflects on data uncertainties and the behavioral and institutional barriers to the realization of estimated mitigation potentials.

2. MACC construction

Technically feasible mitigation measures will normally be differentiated in terms of their implementation cost to farmers and their wider net environmental impacts borne by society. An economic mitigation potential considers the cost of applying the measures as well as their likely adoption rate relative to a baseline of no additional mitigation activity (BAU scenario), which may be limited by institutional and farm-scale (including behavioral) barriers.

In the first instance it is useful to rank abatement measures in order of decreasing cost-effectiveness; i.e. the implicit cost of each ton (t) of CO_2e mitigated were each measure fully implemented, and then to estimate the annual cumulative potential over a target time horizon offered by all cost-effective measures applied above baseline activity. MACCs offer a rational framework for combining biophysical and economic data to reflect mitigation costs. In this application we adopt the bottom-up or engineering approach to MACC construction that has been used in several previous studies (Beach et al., 2008; Moran et al., 2011; Schulte et al., 2012; Pellerin et al., 2013).

On the right hand side of Fig. 1, each bar represents a feasible abatement measure, differentiated by implementation cost per ton of CO_2e emission reduced (height of bar), and quantity of emissions they can mitigate if the measure is fully applied to its technical potential (width of bar). Measures below the x-axis are cost negative, i.e. removing emissions and saving society costs, those above incur positive cost. Therefore, the biggest financial gains and emission reductions can be seen in the longest and widest bars beneath x-axis, and conversely bars above the x-axis are the costlier measures. Policy therefore needs to focus first on the implementation of the former. An economic potential can be derived by selecting those measures that fall below a cost threshold set by a notional benchmark carbon price (horizontal dashed line). This threshold can be established with reference to traded or non-traded carbon prices and can rule out higher cost measures, and thereby define an economic potential that is less than the full technical potential.

Bottom-up MACCs are best-suited to explore and reflect the complexity and diversity of Chinese agricultural systems, specifically heterogeneity in terms of abatement potential, measure applicability and implementation costs. Overall, the aim is to derive the cost-effectiveness of each individual measure implemented in Chinese average conditions.

The basic steps for bottom-up MACC derivation followed the methodology by Moran et al. (2011):

1. Develop BAU or baseline emissions scenario for the target year 2020.
2. Screen mitigation measures technically applicable in Chinese agriculture.
3. Quantify the abatement rate of selected measures in terms of tCO_2e abated per hectare or per animal head, based on relevant studies or existing meta-analysis results and taking into account measure interactions.
4. Estimate implementation costs/benefits of mitigation measures for farmers as ¥ per hectare (ha^{-1}) or ¥ animal^{-1} in 2020 prices accounting for anticipated future price rise in various agricultural inputs/outputs. Calculate the net present value using a