Greenhouse Gas Mitigation and Carbon Markets in Indian Agriculture

An *Ex Ante* Critical Review

T JAYARAMAN, K APARAJAY, CHARU CHANDRA DEVSHALI, SREEJA JAISWAL

The prospects and implications for continued and possibly rapid extension of the broader effort at greenhouse gas mitigation and the specific effort of carbon markets in India are assessed along four axes: (i) the global experience of mitigation and carbon markets in agriculture in the global North, who are expected to be leaders in such actions; (ii) the theoretical prospects of carbon markets and carbon offsets in agriculture, with special reference to welfare and distributional aspects; (iii) the key initiatives in GHG mitigation and carbon trading related to Indian agriculture; and (iv) considerations of the priority to be assigned to both mitigation and carbon trading in Indian agriculture both in the international and intra-national contexts.

T Jayaraman (*jayaraman@mssrf.res.in*) is senior fellow (climate change), K Aparajay is scientist and Charu Chandra Devshali is research associate with the M S Swaminathan Research Foundation, Chennai. Sreeja Jaiswal is international climate protection postdoc fellow at the University of Heidelberg.

In the 30 years since the Rio Earth Summit, the fate of agriculture in the global climate regime has undergone something of a 180-degree turn. From being positioned as the pre-eminent arena of adaptation, agriculture is now increasingly positioned as the arena of mitigation, or as the arena of both mitigation and adaptation. This positioning is paradoxical, as the enthusiasm for positioning agriculture as the arena of mitigation is not matched by real world policy actions that seek to implement this view. Climate policy experts from the developed world have always focused on agriculture, forest and land use (AFOLU) as potent sources of greenhouse gas (GHG) emissions, especially in the developing countries. However, there has been a notable increase in the stridency of this call for mitigation in agriculture that has now found a much larger constituency, including multilateral institutions.

The shift in emphasis, however, does not merely promote mitigation action in agriculture. Together with mitigation action, carbon markets are seen as the predominant mode of promoting action. Promoting carbon markets is a specific way to introduce carbon prices. A strand in this new emphasis seeks to push for a specific form of carbon markets in agriculture in the form of carbon offsets, arguing that this would be a means of incentivising farmers to undertake mitigation activity, while adding to their income.

India and a substantial part of the global South were successful in resisting the pressures generated for mitigation in agriculture earlier. But increasingly, they appear to be on the defensive on this question. India, since the Paris Agreement, has attempted to meet head-on the challenge of being labelled a naysayer in climate action, achieving a significant degree of success in this regard. Most significantly, the scientific support to India's position that it has considerably lower historical and current responsibility for GHG emissions has significantly been strengthened by the Working Group III Report of the Intergovernmental Panel on Climate Change in its Sixth Assessment Cycle (IPCC 2022). Such an assessment was based on a perspective of fairness and equity, despite the wide variation in what this means in operational terms. Nevertheless, there has also been relentless pressure from several actors in the developed world who have focused on mitigation in agriculture.

In India, mitigation in the agricultural sector is not yet a stated policy. But there are several initiatives that are mitigation-centric or mitigation-oriented as co-benefits to input efficiency or lowering of input costs. This is clearly in keeping with India's overall strategy of "low-carbon development," a general concept that has now been clearly articulated in official submissions to the United Nations Framework Convention on Climate Change (UNFCCC) (MOEF 2021, 2022). In this view, India cannot immediately decarbonise its economy on the grounds of its developmental needs as well as on grounds of equity; yet, it is committed to low-carbon development with a clear sustainability perspective, with the timing and pace dependent on the availability of means of implementation. This low-carbon development will also not involve emissions more than India's equitable share of the global carbon budget.

India's previous carbon trading experiment was with the Clean Development Mechanism (CDM) credits under the Kyoto Protocol. The CDM credits were dominated by non-AFOLU sectors and had little to do with the agricultural sector. After the Paris Agreement, and the push towards mitigation in agriculture, there has been renewed interest in developing carbon markets. A major enabling legislation—the Energy Conservation (Amendment) Bill, 2022—was passed in 2022, that inter alia provides the legal basis for the formation and institution of a carbon market through the issue of carbon credits (MOP 2022).

Under the new policy, sustainable agriculture is included in the Green Credit Programme Implementation Rules, 2023 issued by the Ministry of Environment, Forest and Climate Change in October 2023 (MOEFCC 2023). In these rules, a programme of "green credits" for promoting sustainability is proposed. These rules are to be further developed in detail by a steering committee whose composition was only noted in general terms. What is also not clear is how, and in what manner, these green credits will be traded.

At the same time, there is already a small, voluntary, and unregulated carbon market in agriculture. Typically, these initiatives are celebrated in the business media and business literature, such as in a recent account breathlessly titled "Rise of Carbon Farming in India: World's Large Agrarian Country Expected to Become the Leading Market for Carbon Farming Credits" (Nozaki 2023). While these initiatives are not insignificant, the prospects of a formal carbon trading and carbon pricing scheme in agriculture will depend on the actions and policy signals of Government of India. Studies of such voluntary carbon markets provide important indications of the challenges that might emerge when they are scaled up in the future.

This paper consists of four sections. The first section looks at the state of carbon pricing and carbon trading in agriculture in the developed countries. The second section deals with the existing evidence and theoretical considerations regarding the welfare and distributional consequences of carbon pricing and carbon trading in agriculture. The third section reviews the status of the key initiatives in GHG mitigation related to agriculture in India, mainly from the perspective of government schemes, programmes and initiatives at the central and state level. The fourth section concludes the discussions.

Mitigation and Carbon Markets in Agriculture in the Global North

We begin our discussion with Table 1, which shows the specific mitigation targets in the agricultural sectors of the Organisation for Economic Co-operation and Development (OECD) countries. These account for a major part of the developed countries in the Annex I classification of the UNFCCC, the rest being the so-called "Economies in Transition," namely the former Soviet bloc countries. As the table shows, very few

Table 1: Agriculture Emissions and Emission Trading Systems (ETS) of Select OECD Countries

	Agricultural Emissions and Targets		ETS and Agriculture			
Country/Region	Share of Agricultural Emissions in Total GHG Emissions (with LULUCF) (%)	Mitigation Target (with Base Year/ Level in Parentheses)	ETS	ETS Sectors Covered	ETS Coverage of Agricultural Emissions (Yes /No)	Plans to Include Agricultural Emissions
Austria	10.76	None	Austria ETS	Road transport, buildings (residential/service/public, industry and energy (non-EU ETS)	No	–
Canada	8.31	-30% fertiliser emissions by 2030 (2020)	Canada Federal OBPS	Industry (emission-intensive, >= 50 ktCO_2e per year) and trade exposed sectors	No	–
EU	11.68	No target at the EU level. Targets for member states for 2030 are: BEL: -25% (2005); DNK: -55% (1990); DEU: -31-34% (1990); FRA: -18% (2015); IRL: -22-30% (2018); PRT: -11% (2005)	EU ETS	Domestic aviation, industry, power, maritime	No	Discussions ongoing; no deadline set
Germany	7.37	None	Germany ETS	Transport, buildings	No	–
New Zealand	67.78	-24–47% reduction in biogenic methane by 2050	New Zealand ETS	Forestry, waste, domestic aviation, transport, buildings, industry, power	No	Yes, by 2025
Switzerland	13.63	-40% by 2050 (1990)	Switzerland ETS	Domestic aviation, industry, power	No	–
United Kingdom	10.01	-17–30% by 2030; -24–40% by 2035 (2019)	UK ETS	Domestic aviation, industry, power	No	–
US		None	California cap and trade system; regional greenhouse gas initiative			–

Source: Data compiled from UNFCCC GHG Data Interface; OECD (2022b); ICAP (2023).

OECD countries have set specific mitigation targets for their agricultural sectors. Most countries with agriculture-specific targets are in the European Union (EU).

Emission pricing and trading: Emissions pricing instruments are among the range of policy instruments available at the disposal of governments to mitigate agricultural emissions. Emissions pricing instruments either tax the emissions or establish tradable permits. While emissions taxes have been implemented on certain sectors by some countries, the agricultural sector remains largely exempt. Canada's carbon pollution pricing system, which has been in effect across all provinces since 2019, notably does not include the agricultural sector. Similarly, in Norway, the agricultural sector is mostly excluded from the national carbon tax, except for emissions arising from fossil fuel use in agriculture. Other GHG emissions from agriculture are not subject to taxation in Norway.

Another market-based emission pricing instrument to reduce greenhouse gas (GHG) emissions is the emissions trading system (ETS). The ETS operates on the "cap and trade" principle, where the government sets a maximum on the total emissions within one or more sectors of the economy. Firms and enterprises within these sectors are required to possess one permit for each tonne of emissions. These permits can be obtained through allocation or purchase, and companies have the option to engage in permit trading with other companies. ETS have been implemented across various developed nations, including the EU ETS at the regional-, national-level schemes like the New Zealand ETS and United Kingdom ETS, as well as subregional programmes like the United States's (US) California Cap-and-Trade Program and the Regional Greenhouse Gas Initiative (RGGI).

Nevertheless, it is important to note that, as of now, no ETS in any part of the world covers emissions originating from the agricultural sector. On pricing emissions from agriculture, developed countries are pursuing a cautious and phased approach deploying extensive public consultation, stakeholder engagement, feasibility studies, technological development, and capacity building of farmers.

In terms of sectoral coverage, the New Zealand ETS has the broadest coverage and is the only ETS to include the forestry sector (Neilson 2023). Agriculture contributes more than 50% of New Zealand's gross GHG emissions, representing by far the largest share among the OECD nations. Around 91% of its biogenic methane emissions are from agriculture. Consequently, it is one of the few countries with declared mitigation targets for agricultural emissions. New Zealand's 2019 Zero Carbon Amendment Act, by distinguishing between short- and long-lived gases, aims to reduce gross biogenic methane emissions by 10% below 2017 levels by 2030 and by 24%–47% by 2050. Other GHG emissions are to reach net zero by 2050.

New Zealand also proposes to levy a carbon price on agricultural emissions by 2025, either through the ETS or a separate pricing mechanism. To lay the groundwork, it conducted public consultations on the government's proposed agricultural emissions pricing system in 2022 and published a document on policy directions. The reporting of farm-level emissions will become mandatory by 2024. A final decision on the implementation of farm-level pricing on emissions will depend on the outcome of a government study into its feasibility. This transition period is supposed to allow farmers and government agencies to build capacity on the measurement, reporting and verification (MRV) of farm-level emissions prior to the introduction of carbon pricing (Henderson et al 2021).

However, the National Party, which has emerged as a strong contender to the ruling Labour Party in the October 2023 elections, has asserted that it will delay current plans to price agricultural emissions from 2025 to 2030 and restrict the conversion of farmland to carbon-based forestry purportedly to protect local communities and domestic food production, keep food prices down and ensure that farmers have the tools they need to reduce emissions before charging them for their on-farm emissions (Coughlan 2023; Mcclay 2023).

Similarly, agriculture is an important part of the European economy, and plays a significant role in social and political terms. In the EU, farmlands cover 38% of the EU's total land area, but agriculture accounts for only approximately 1.5% of the total value added. The sector accounts for 11% of the EU's GHG emissions. While the EU ETS has been in operation since 2005, covering industry, power and domestic aviation, there is no plan to extend it to the agricultural sector. According to the European Court of Auditors, EU law does not apply the polluter-pays-principle to agricultural emissions and recommended that the European Commission should "assess the potential of applying the … principle to agricultural emissions, and reward farmers for long-term carbon removals" (European Court of Auditors 2021). In response, the European Commission is exploring options for pricing agricultural GHG emissions along the food value chain as well as for rewarding farmers and other landowners for carbon farming. They have commissioned an exploratory study to investigate ways to put a price on agricultural emissions possibly via a new and separate ETS. There is currently no established timeline for when pricing of agricultural emissions will go into effect.

The EU's attempt to limit agricultural emissions through its Common Agricultural Policy (CAP) has also not been successful. Between 2014 and 2020, the CAP spent €100 billion to encourage farmers to apply climate-friendly practices and techniques through three different mechanisms: the cross-compliance mechanism, which refers to a set of requirements and standards that farmers and landowners must adhere to receive direct payments and other forms of financial assistance; direct payments; and subsidies for rural development.

However, the European Court of Auditors (2021) concluded that CAP had little impact on agricultural emissions. Further, most mitigation measures supported by the CAP have a low potential to mitigate climate change and CAP rarely finances measures with high climate mitigation potential. Livestock emissions represent around half of emissions from agriculture and have been stable since 2010. Emissions from chemical fertilisers and manure increased between 2010 and 2018.

There are several reasons why developed countries are reluctant to price agricultural emissions, include it in an ETS or push non-market measures to reduce agricultural emissions. These range from concerns regarding food production, protecting consumers from food price rises, ensuring trade competitiveness of agricultural products and protecting rural community and rural way of life (Holligan 2022; Kerr nd). Additionally, the complexity of measuring emissions at the farm level poses a significant challenge. Not only are emissions spread across millions of small agents relative to industrial emissions, but farm emissions are also affected by multiple factors like animal diets, tillage practices, soil composition, and fertiliser application methods (Matthews 2023; Verschuuren 2022). Farm-level monitoring and reporting of emissions have very high transaction costs for farmers and authorities. Other factors include capability of farmers to apply recommended farming practices, uncertainty among scientists about the effectiveness, feasibility and cost of mitigation options, and limited current mitigation options within the livestock systems (Matthews 2023; Powlson et al 2014, 2016).

Carbon offsets: While agriculture is not required to reduce GHG emissions under compliance ETS programmes, it is in principle a permitted source of offsets in some of them. However, in practice, the use of agricultural offsets in compliance ETS schemes (compliance schemes are those where participation is mandated by the government with specific mitigation targets) is relatively limited and varies by region. While ETS systems are designed to be flexible, allowing companies to either reduce emissions directly or to purchase permits from others, the inclusion of offsets provide even greater flexibility. Offsets allow emission reductions from outside the scope of the ETS. In the US, some compliance markets accept offsets from reduced or avoided agricultural GHG emissions but do not allow offsets from soil carbon sequestration. For example, California's Cap-and-Trade Program permits the use of offsets to cover 4% of compliance obligations, including livestock manure management, mine methane capture, and US forests. However, the majority of offset credits come from forestry projects in California.

Canada has established the GHG Offset Credit System to incentivise various entities—including businesses, municipalities, Indigenous communities, foresters, and farmers—to undertake projects aimed at reducing GHG emissions or removing GHGs from the atmosphere.[1] Offset credits can be traded and used for compliance as well. Yet, these offset credits do not currently cover sectors like forestry, agriculture, and livestock feed management.

Starting in 2021, offset projects are no longer accepted as a compliance option within the EU ETS programme. Overall, carbon offsets from agricultural activities have played a relatively minor role in compliance carbon markets, with forestry projects having a substantial presence.

Among the reasons for the failure of offsets in agriculture are limited supply of funding to pay agricultural producers for emissions reductions and limited demand for offsets due to the upper limit set up by various compliance ETS schemes (Henderson et al 2021). Agricultural offsets also require strong transparency and integrity standards to ensure additionality (that is, emissions reduction would not have happened without market for offsets) and permanence (that is, sequestered carbon can return to the atmosphere if farming practices change), potentially limiting their scope and effectiveness.

To summarise, developed countries—that practise "industrial agriculture with significant carbon footprint—have shown limited progress both in pricing agricultural emissions and in trying to mitigate agricultural emissions through other measures. We shall discuss the implications of the experience of the global North for India in the concluding section.

Distributional Impacts of Carbon Pricing

There are broadly two forms of carbon pricing—either by allowing trade in emissions with a cap or through an imposition of carbon tax (Steinebach et al 2021). The theoretical foundation of the cap-and-trade systems for emission reduction can be traced back to Coase's Theorem (Coase 1960, 1988). On the other hand, a carbon tax can be theoretically traced back to the Pigouvian Tax, which can be imposed broadly in three ways based on the amount of carbon emitted; on the use of inputs with high carbon content; and on carbon content in the final output (Gandhi and Cuervo 1998).

On cap-and-trade or carbon taxes, most reviews have concentrated on understanding the impact of carbon pricing on efficiency, productivity, carbon emissions, land use change and carbon leakage (Ollikainen et al 2020; Malhi et al 2021; Rosenstock et al 2016; MacLeod et al 2015; Arvanitopoulos 2021). The distributional impact of these economic instruments does not seem to have received as much attention.

Most studies use rational expectations or structural or general equilibrium or partial equilibrium models to understand distributional impacts. Other studies use models accounting for farm-level heterogeneity to study the distributional impacts.

Jansson et al (2023) conducted an *ex ante* analysis of region-wise impacts on food security for 2030 with a baseline without carbon taxes. According to them, if a global carbon tax of EUR 120 per tonne of CO_2 (or CO_2 equivalent) is implemented, food security in certain parts of the world like Ethiopia and Vietnam will be severely hit. Frank et al (2017) estimated that a global carbon tax on agricultural GHG emissions would lead to a significant increase in agricultural commodity prices in regions with inefficient production systems like sub-Saharan Africa, South Asia, and Southeast Asia. However, land-rich developing countries like Brazil may be able to reduce emissions with limited adverse impact on food security. They argued that the implementation of a carbon price can lead to a global average fall in calorie availability in 2050. There will be a decline in calorie availability up to 285 kcal per capita per day in a 1.5°C scenario, which would render 500 million people (up from the current 200 million people now) chronically undernourished in 2050. Havlik et al (2014) suggested that a global carbon price of \$100/t CO_2 equivalent on agricultural and land-use change sectors will lead to a loss of 200 kcal per capita per day. Hasegawa et al (2015) estimated that if global uniform carbon taxes were imposed, India could experience a loss in calories of up to 170 kcal per capita per day.

Ifft et al (2018) argued that a carbon tax on fuel-intensive inputs was regressive for intermediate and commercial-sized farms in the US. The regressivity was statistically significant at a carbon tax of above $10 per tonne of carbon, which is lower than what is considered necessary for mitigation to achieve the Paris targets. On a federal greenhouse gas cap-and-trade (GHG CAT) programme, Jiang and Koo (2010, 2014) estimated the change in cost and net farm income using a simulation model based on surveys of farmers from North Dakota. With the fertiliser industry exempted from GHG cap-and-trade, in the short run, less than 10% of farms in North Dakota would suffer loss. But if the fertiliser industry is subjected to caps, 70% of farms in North Dakota will incur losses with carbon prices up to $65 per metric tonne CO_2 equivalent. The economic loss ranged between $0 and $30 (with the fertiliser industry exempted) and between $0 and $55 (with the fertiliser industry capped).

Gonzalez (2012) analysed the distributional impact of carbon tax on Mexico and US with the assumption that the revenue generated from carbon tax will be recycled through either a manufacturing tax-cut or a food subsidy. The recycling through manufacturing tax would lead to a regressive distribution of costs but recycling through food subsidy would be progressive. For corn, sorghum, soybeans, and wheat, Dumortier and Elobeid (2020) found that even though there were significant regional differences, there would be a decline in median net returns for farmers across different states of the US due to increase in input costs.

Using a large-scale global, comparative-static economic, multi-commodity, agricultural sector model, Felimann et al (2018) estimated that small and less competitive farmers in EU may be pushed out of farming. But those who would remain in farming may potentially benefit, as increase in prices is likely to offset the increase in input costs and decline in output. They, however, caution that their "aggregated EU result hides large differences between the regions in the member states" (p 461).

Partridge et al (2015) undertook an *ex ante* analysis of South Africa's 2016 carbon tax. They found that irrespective of whether agriculture was excluded or included in implementation of carbon tax in South Africa, the domestic agricultural activity output would fall by 7%. In fact, the indirect impact of carbon tax due to a rise in input prices constituted 93% of the overall impact on agriculture. If the tax was imposed on all sectors, including agriculture, total agricultural commodity output would fall. Corong and Strutt (2019) studied the possible impacts of change in fuel and carbon emission prices on agriculture in New Zealand. They found that output and exports of key agricultural sectors—beef, sheep meat and dairy products—would decline even with a moderate increase in carbon prices in New Zealand and would witness further decline with increase in carbon prices and imposition of worldwide carbon taxes. The concerns about loss of jobs and distributional impacts in agriculture have been central to the political debate around carbon pricing in New Zealand (Cooper et al 2013). Lu et al (2010), using a dynamic recursive general equilibrium model, estimated that household consumption demand for all sectors, including agriculture would decline after the imposition of a carbon tax in China. They suggested a reduction in indirect taxes and provision of subsidy to households as measures to cushion the negative impacts and stimulate household consumption demand (Lu et al 2010).

It is worth mentioning here that in the case of India, Chandel and Kumari (2022) found that profit from paddy cultivation, which contributes 27% of farmers' gross income, was "directly elastic to output price … and inversely elastic to variable input prices …" (p 9). *Ceteris paribus*, any tax led to an increase in consumer prices and decline in producer prices. If supply was more elastic than demand, then the decline in producer prices was less than the increase in consumer prices. Agriculture goods, except for meat and dairy products, are generally characterised by low elasticity of demand (Arvanitopoulos et al 2021) and hence there is a higher probability of tax being passed forward (Coxhead et al 2013). Therefore, any imposition of carbon tax, which leads to rise in both output prices as well as input prices, will most likely adversely affect farmers' income in India and higher prices of agricultural goods will adversely impact low-income households (Arvanitopoulos et al 2021).

At the level of the economy, there is clear evidence of the adverse distributional impact of cap-and-trade scheme and carbon tax on the poor (Boyce 2018). Most of the empirical literature suggests that imposition of carbon tax would have a regressive impact on not only farmers but also household consumption. Accordingly, scholars have tried to find an appropriate recycling method to at least neutralise the regressive impact on carbon tax (Combet et al 2010). However, the recycling of revenue generated either through "cap and distribute" or "tax and distribute" to the poor through cash transfers may not lead to the desired results in developing countries (Azad and Chakraborty 2020).

Another problem with recycling the revenue is that transfers to household in cash or other forms may not lead to creation of jobs, especially when there can be job losses due to the impact of carbon pricing (Coxhead et al 2013). Since poor and low-income groups contribute only a small percent of total emissions (Michael and Vakulabharanam 2016), a better move from the point of view of equity would be to avoid imposing carbon taxes on them (Grottera et al 2017). One should also bear in mind that revenues from carbon taxes merely counterbalance the increase in production cost due to imposition of carbon taxes. The revenue generated from carbon tax is not "free money," as the votaries of the double dividend hypothesis would suggest (Fullerton and Metcalf 1997). Alternative proposals of imposing carbon tax only beyond a certain threshold so that resources required to fulfil the basic needs of people do not get taxed, should be also taken seriously (Baranzini et al 2000).

In sum, the over-arching message from the bulk of the literature is that there is no evidence that carbon taxes or cap-and-trade schemes would be of any benefit to farmers. There is much evidence to the contrary, considered at the global scale, that the impact of large-scale carbon trading to promote mitigation in agriculture would result in the tide turning in the fight for global food security.

Mitigation and Carbon Trading in Indian Agriculture

India has always maintained with the UNFCCC that its agricultural emissions are "survival" and not "luxury," given their crucial role in ensuring food and nutritional security. During negotiations on the final drafting of the decision on the "Sharm el-Sheikh joint work on implementation of climate action on agriculture and food security" at COP 27, India opposed the efforts of developed countries to extend the scope of mitigation to agriculture in the developing countries (Carboncopy 2022). Adaptation and adaptation-led mitigation have been the central strategy in India's agricultural sector (Rao et al 2019). Thus, the theme of India's initiatives in agriculture have mainly been on sustainable development in agriculture with a focus on adaptation with co-benefits of mitigation accompanying some of these initiatives (Table 2).

The initiatives in Table 2 are only exploratory in nature, despite the major investment of resources that they represent,

Table 2: Details of Selected Schemes That Focus on Sustainable Agriculture, Government of India

Sl No	Name of the Scheme	Year of Introduction	Scope of the Scheme	Mitigation Benefits/Co-benefits
1	National Mission for Sustainable Agriculture (NMSA)	Established in 2010; Operational in 2014–15	Primary focus is to boost agricultural productivity, particularly in rainfed regions. It plans to increase "water use efficiency," "nutrient management" and "livelihood diversification" by adopting environment-friendly technologies, energy-efficient agricultural equipment, judicious use of inputs and promoting integrated farming (PIB 2018). NMSA has many components, as below:	
1a	Rainfed Area Development	2014–15	Aims to develop an integrated farming system across diverse components like crops, horticulture, livestock, fisheries, and forestry, along with income-generating activities.[1]	Mitigation benefits are to come from sustainable agriculture practices, such as soil health management, land development, resource conservation, and crop selection.
1b	Sub-mission on Agroforestry (SMAF)	Launched in 2016–17 under the National Agroforestry Mission (2014)	Aims to encourage tree planting on farmlands alongside crops.	The programme achieved an estimated emission reduction of 0.1318 $MtCO_2$ in 2017–18 and 2018–19 (MoEFC 2021)
1c	National Bamboo Mission	Launched in 2008–09 and restructured in 2018 under NMSA	Aims to increase bamboo plantations in non-forest areas of the country. The scheme also intervenes in post-harvest processing, skill development and market development (MoEFC 2021).	NBM Dashboard shows that 7,611.15 hectares were planted with bamboo from 1,328 plantations and 0.1873 Mt CO_2 equivalents CO_2 was sequestered in 2018–19[2]
2	Agriculture Demand Side Management (AgDSM)	2015	Aims to reduce power consumption in agriculture by improving energy efficiency of pumps and other demand-side management measures. It seeks to replace old inefficient pumps with BEE star-rated energy-efficient pumps (PIB 2015).	AgDSM dashboard shows that 81,180 pumps were replaced till October 2023, leading to savings of 210.23 million units/year, 1,55,571 t CO_2 emissions reduction/year, and 38,932 kW peak load demand reduction.[3]
3	Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)	National Mission on Micro-irrigation started in 2010, relaunched as PMKSY in 2015–16	Within PMKSY, the Per Drop More Crop (PMKSY- PDMC) component aims to replace traditional flood irrigation in crops with micro-irrigation (drip irrigation and sprinklers). It aims to increase water use efficiency, with the mitigation co-benefit being a reduction in power consumption for irrigation. The scheme also aims to create micro-level water storage and water conservation and management activities (PIB 2023a).	Till 2022–23, a total of 11.02 lakh ha has been brought under micro-irrigation, of which drip irrigation accounted for 5.32 lakh ha and sprinkler irrigation accounted for 5.70 lakh ha. There was an estimated emissions reduction of 22.82 $MtCO_2$ between 2010 and 2016.[4]
4	Crop diversification programme	2014-15	Aims to diversify at least 5% of cultivation away from water-intensive paddy and tobacco through alternate crop demonstrations, farm mechanisation & value addition, site-specific activities and awareness, training, and monitoring (PIB 2020).	Led to emissions reduction of 0.0388 $MtCO_2e$ during 2017–18. A total 81,816 ha of area shifted from paddy to other crops in 2017–18 and 2018–19 (MoEFC 2021).
5	System of Rice Intensification (SRI) and Direct Seeded Rice (DSR) cultivation in paddy	NA	Aims to reduce methane emissions arising from paddy. A reduction in water usage also leads to reduction in energy consumption for irrigation.	In 2017–18 and 2018–19, SRI was introduced in 52,377 ha and 33,487 ha respectively. In 2017–18 and 2018–19, DSR was introduced in 58,438 ha and 41,526 ha (MoEFC 2021).
6	Mission for Integrated Development of Horticulture (MIDH)	2014	Aims to promote cultivation of fruits, vegetables, root and tuber crops, mushrooms, spices, flowers, aromatic plants, coconut, cashews, and cocoa (PIB 2022).	Amount of carbon sequestered was 108.96 MtCO2between 2017–18 and 2018–19.
7	Neem coated urea	2015	Aims to coat all urea with neem oil to reduce the release rate of nitrogen and reduce losses (PIB 2021a).	Total mitigation of 7.529 $MtCO_2$ was achieved between 2017 and 2019 (MoEFC 2021).
8	Agricultural power solarisation under Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM-KUSUM)	2019	Aims to replace diesel-powered water pumps with small solar power pumps up to 2 MW on farmers' barren/fallow/pasture/marshy land (PIB 2021b).	Projected to reduce 32 $MtCO_2$ emissions annually across the country if fully implemented (PIB 2023b; MoEFC 2021).

(1) National Mission for Sustainable Agriculture (https://nmsa.dac.gov.in/frmComponents.aspx).
(2) National Bamboo Mission dashboard (https://nbm.nic.in/Dashboard).
(3) National AgDSM Dashboard (http://agdsm.in/).
(4) PMKSY, Department of Agriculture and Farmers Welfare, GOI website (https://pmksy.gov.in/Default.aspx).
Source: Documents of the Government of India.

as is evident from the acreage covered and the emissions reduction that have been achieved. It is doubtful whether they can, as yet, be considered as scalable opportunities. There is no case, therefore, to regard the current efforts as representing some take-off point for agricultural mitigation in India. Of course, it may be argued in theory that it is only a matter of investing the required resources, whatever be the scale. But unless the overall budget expands, this would mean lesser resources to deal with the urgent development deficits and challenges in agriculture. Without climate finance available in real terms, and not merely as promises or targets, such scaled up mitigation will not be possible.

Another critical issue is that of the price of carbon in a carbon pricing scheme. There are three situations to be considered here. The first is the imposition of a carbon price on agriculture through carbon taxes. Already, through the numerous duties and taxes on fossil fuel use, India has an effective carbon tax, which the OECD estimates at approximately €13 per tonne (OECD 2022b). Farmers' input costs are affected by these taxes, though the level of farm mechanisation may keep this contribution low. But given the overall crisis of farmer incomes in India, a further rise in input costs through a direct carbon tax in any form is hardly in the realm of possibility.

The second possibility is that of a cap-and-trade scheme in Indian agriculture. Given the huge number of landholdings and their relatively low average area, measurement and verification are unlikely to be cost-effective. Attempting to achieve the same through farmer producer organisations or cooperatives will only pass the burden down to the lowest level, which is least equipped to deal with the challenge. Given the considerable efforts that developed countries themselves have had to undertake to enable readiness for measurable and verifiable mitigation activity (that is still to be introduced), there is no urgent need for a cap-and-trade scheme in Indian agriculture.

The third approach is the provision of incentives to farmers for mitigation using carbon offsets. Carbon offsets arise when one party (enterprises or individuals) provides finance to reduce mitigation elsewhere. Such finance may be provided through the selling of certificates of emissions reduction or removal that are initially provided to those undertaking the mitigation action. These are then sold to buyers who may then account for it as their emissions reduction, even though carried out on their behalf by another. These certificates of emission reduction or removal are either provided by a multilateral agency or through certifying agencies set up by private players or non-governmental organisations, as in the case of the voluntary carbon market. This approach is commonly portrayed as a win-win idea that will also add to farmers' incomes.

The draft Green Credit Programme Implementation Rules is an initiative that seeks to set up a voluntary carbon offset mechanism in India. Though the scope of environmentally friendly actions that it covers is much broader (hence "green"), the only structured market available is the carbon market in the foreseeable future. However, questions like whether those receiving the credits must bear the transaction costs are not clarified in the draft rules. As the experience of the Pradhan Mantri Fasal Bima Yojana shows, implementing large-scale monitoring down to the farm level will not be easy, especially since carbon mitigation will be even harder to monitor than losses due to weather extremes.

The more complex issue is that the beneficiaries of incentives would have to accept stringent conditionalities to ensure that the emissions reduction is permanent and lasting. Without such conditionalities, carbon credits would lack credibility leading to a collapse in their price. The issue of the credibility of credits was partly responsible for the collapse of the CDM credits. Recently, the voluntary carbon market, especially in the AFOLU sector, has again come under scrutiny with allegations that the carbon credits issued are not credible in India and other developing countries (Dev and Krishnamurthy 2023; Narain et al 2023; Probst et al 2023). Partly, consequently, the price of voluntary carbon credits fell steeply in 2022–23 (Carboncredits.com 2023). At the same time, such mitigation-centric conditionalities could also have serious negative consequences for farmers' production and incomes by restricting their freedom of farm-level decision-making.

Even if the carbon market is regulated to ensure that the credits are trustworthy, it is not obvious that they would benefit farmers, since their earnings would depend on carbon prices. Especially in developing countries, markets do not benefit the poor, and small and marginal farmers are well known to be vulnerable to price shocks of both inputs and outputs. Nor do farmers, especially small and marginal farmers, get the full benefit of high commodity prices for several reasons. Hence, the expectation that carbon markets will provide stable incomes to the bulk of India's smallholders stands unsubstantiated.

But the more fundamental problem with carbon trading mechanisms is that they are not aligned to the concept of the global carbon budget and the need for countries to equitably have access to these global commons. India has articulated this principle of operationalising equity in terms of equitable and fair access to the global carbon budget in its long-term low-emissions development strategy submitted to the UNFCCC (MoEFCC 2022). Cap-and-trade schemes assume, following the Coase theorem, that there is some distribution of rights to emissions among the emitters before trading commences. The Coase theorem argues that the environmentally viable outcomes are obtained irrespective of how these rights are distributed. However, this does not guarantee equity.

In Conclusion

Mitigation in agriculture is expensive and difficult, including its impact on farmers and the cost of monitoring, and even developed countries are hesitant to launch such initiatives. Mitigation in the agriculture sector in India is a burden that will be borne largely by one of the most vulnerable sections, with little historical responsibility for climate change. Mitigation in Indian agriculture, especially through carbon trading in the cap-and-trade sense or carbon offsets, where developed countries are the predominant buyers, is a means by which they will further enable their appropriation of carbon space. While these arguments apply to all carbon trading, agriculture is a sector whose emissions must be considered a necessary part of ensuring food security for the future. This must be considered so until decarbonisation of agriculture can be achieved without threat to productivity and food security.

There is no case for any rush to develop carbon markets in agriculture. There is also no compelling case for mitigation being part of the main agenda of Indian agriculture. India would be far better off with a focus on adaptation as the key issue in the matter of climate change and agriculture, with mitigation being a co-benefit that radically improves input efficiency in agriculture.

NOTE

1 https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system.html.

REFERENCES

Arvanitopoulos, Theodoros, Grégoire Garsous and Paolo Agnolucci (2021): "Carbon Leakage and Agriculture: A Literature Review on Emissions Mitigation Policies," OECD Food, Agriculture and Fisheries Papers (169).

Azad, R and S Chakraborty (2020): "Green Growth and the Right to Energy in India," *Energy Policy*, Vol 141, 111456.

Baranzini, A, J Goldemberg and S Speck (2000): "A Future for Carbon Taxes," *Ecological Economics*, Vol 32, No 3, pp 395–412.

Boyce, J K (2018): "Carbon Pricing: Effectiveness and Equity," *Ecological Economics*, Vol 150, pp 52–61.

Carboncopy (2022): "Issue of Mitigation in Agriculture Remains a Sticky Subject," 23 November, https://carboncopy.info/issue-of-mitigation-in-agriculture-remains-a-sticky-subject/.

Carboncredits.com (2023): "The Collapse of NGEO Carbon Prices: An In-depth Analysis," 9 July, https://carboncredits.com/the-collapse-of-ngeo-carbon-prices-an-in-depth-analysis/.

Chandel, B S and B Kumari (2022): "How Elastic Is the Profit to Prices of Output and the Variable Inputs? Some Insights from Paddy Cultivation in India," *Agricultural Economics Research Review*, Vol 35(conf), pp 1–10.

Coase, R H (1960): "The Problem of Social Cost," *Journal of Law and Economics*, Vol 3, pp 1–44.

— (1988): *The Firm, the Market, and the Law*, University of Chicago Press.

Combet, E, F Ghersi, J C Hourcade and D Théry (2010): "Carbon Tax and Equity: The Importance of Policy Design."

Cooper, M H, J Boston and J Bright (2013): "Policy Challenges for Livestock Emissions Abatement: Lessons from New Zealand," *Climate Policy*, Vol 13, No 1, pp 110–33.

Corong, E and A Strutt (2019): "Changing Fuel and Carbon Costs: Implications for New Zealand Agriculture," Purdue University, Center for Global Trade Analysis, Global Trade Analysis Project Conference Papers (No 330199).

Coughlan, T (2023): *National's climate Moo-Turn: Agricultural Emissions Pricing Delayed to 2030*, NZ Herald, 12 June, https://www.nzherald.co.nz/nz/politics/national-to-announce-agricultural-emissions-policy/A6HG3JJL-35FULNKPCVO7SELDBY/.

Coxhead, I, A Wattanakuljarus and C V Nguyen (2013): "Are Carbon Taxes Good for the Poor? A General Equilibrium Analysis for Vietnam," *World Development*, Vol 51, pp 119–31.

Dev, Trishant and Rohini Krishnamurthy (2023): "Discredited: The Voluntary Carbon Market in India: Do Climate and People Benefit?" Centre for Science and Environment, https://cdn.downtoearth.org.in/pdf/discredited-the-voluntary-carbon-market-in-india.pdf.

Dumortier, J and A Elobeid (2020): "Assessment of Carbon Tax Policies: Implications on US Agricultural Production and Farm Income," Center for Agricultural and Rural Development (CARD) Publications 20-wp606, Center for Agricultural and Rural Development (CARD) at Iowa State University.

Energyworld (2023): "Credibility of India Carbon Credit Market," *ET Energyworld*, 11 July, https://energy.economictimes.indiatimes.com/news/renewable/credibility-of-india-carbon-credit-market/101666885.

European Court of Auditors (2021): *Common Agricultural Policy and Climate: Half of EU Climate Spending But Farm Emissions are Not Decreasing* (Special Report 16/2021), https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=58913.

Fellmann, T, P Witzke, F Weiss, B Van Doorslaer et al (2018): "Major Challenges of Integrating Agriculture into Climate Change Mitigation Policy Frameworks," *Mitigation and Adaptation Strategies for Global Change*, Vol 23, pp 451–68.

Frank, S, P Havlík, J F Soussana, A Levesque, H Valin et al (2017): "Reducing Greenhouse Gas Emissions in Agriculture without Compromising Food Security? *Environmental Research Letters*, Vol 12, No 10, 105004.

Fullerton, D and G E Metcalf (1997): "Environmental Taxes and the Double-Dividend Hypothesis: Did You Really Expect Something for Nothing," *Chicago-Kent Law Review*, Vol 73, No 1, p 221.

Gandhi, V P and J Cuervo (1998): "Carbon Taxes: Their Macroeconomic Effects and Prospects for Global Adoption: A Survey of the Literature," IMF Working Papers (073).

Gonzalez, F (2012): "Distributional Effects of Carbon Taxes: The Case of Mexico," *Energy Economics*, Vol 34, No 6, pp 2102–15.

Grottera, C, Jr A O Pereira and E L La Rovere (2017): "Impacts of Carbon Pricing on Income Inequality in Brazil," *Climate and Development*, Vol 9, No 1, pp 80–93.

Hasegawa, T, S Fujimori, Y Shin, A Tanaka, K Takahashi and T Masui (2015): "Consequence of Climate Mitigation on the Risk of Hunger," *Environmental Science and Technology*, Vol 49, No 12, pp 7245–53.

Havlík, P, H Valin, M Herrero, M Obersteiner, E Schmid et al (2014): "Climate Change Mitigation Through Livestock System Transitions," *Proceedings of the National Academy of Sciences*, Vol 111, No 10, pp 3709–14.

Henderson, B, S Frank, P Havlik and H Valin (2021): *Policy Strategies and Challenges for Climate Change Mitigation in the Agriculture, Forestry and Other Land Use (AFOLU) Sector*, OECD, https://doi.org/10.1787/47b3493b-en.

Holligan, A (2022): "Why Dutch Farmers Are Protesting over Emissions Cuts," *BBC News*, 29 July, https://www.bbc.com/news/world-europe-62335287.

Hucke, Catalina C, Kaveh Guilanpour and Nathaniel O Keohane et al (2022): "What Does the COP26 Outcome on Article 6 Mean for Non-party Stakeholders?" Centre for Climate and Energy Solutions publication.

ICAP (2023): "Emissions Trading Worldwide: Status Report 2023," International Carbon Action Partnership, Berlin, https://icapcarbonaction.com/system/files/document/ICAP%20Emissions%20Trading%20Worldwide%202023%20Status%20Report_0.pdf.

Ifft, J E, P Spini and S Wilcox (2018): "The Distributional Implications of Carbon Taxation for US Crop Farms," 2018 Annual Meeting, 5–7 August, Washington, DC (No 274423), Agricultural and Applied Economics Association, June.

Jansson, T, N Malmström, H Johansson and H Choi (2023): "Carbon Taxes and Agriculture: The Benefit of a Multilateral Agreement," *Climate Policy*, pp 1–13.

Jiang, Yong and Won W Koo (2010): "Short-term Impact of Cap-And-Trade Climate Policy and Agricultural Adjustment" (No 336-2016-14965, pp 1–5).

Jiang, Y and W W Koo (2014): "The Short-term Impact of a Domestic Cap-and-Trade Climate Policy on Local Agriculture: A Policy Simulation with Producer Behavior," *Environmental and Resource Economics*, Vol 58, pp 511—37.

Kanitkar, T (2021): "Equity in Global Climate Policy and Implications for India's Energy Future," *Economic & Political Weekly*, Vol 56, No 52, pp 68–75.

Kerr, S (nd): "Agricultural Emissions Mitigation in New Zealand: Answers to Questions from the Parliamentary Commisioner for the Environment," Motu Working Paper 16-16, Motu Economic and Public Policy Research Trust.

Lu, C, Q Tong and X Liu (2010): "The Impacts of Carbon Tax and Complementary Policies on Chinese Economy," *Energy Policy*, Vol 38, No 11, pp 7278–85.

MacLeod, M, V Eory, G Gruère and J Lankoski (2015): "Cost-effectiveness of Greenhouse Gas Mitigation Measures for Agriculture: A Literature Review," OECD Food, Agriculture and Fisheries Working Papers (89).

Malhi, G S, M Kaur and P Kaushik (2021): "Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review," *Sustainability*, Vol 13, No 3, p 1318.

Matthews, A (2023): "Agricultural Emissions: A Case of Limited Potential or Limited Ambition?" *Handbook on European Union Climate Change Policy and Politics*, Edward Elgar Publishing, p 275.

Mcclay, T (2023): *National's Plan for Reducing Agricultural Emissions*," New Zealand National Party, 12 June, https://www.national.org.nz/nationals_plan_for_reducing_agricultural_emissions.

Michael, K and V Vakulabharanam (2016): "Class and Climate Change in Post-reform India," *Climate and Development*, Vol 8, No 3, pp 224–33.

MoEFCC (2021): "India: Third Biennial Update Report to the United Nations Framework Convention on Climate Change," Ministry of Environment, Forest and Climate Change, Government of India.

— (2022): "India's Long-term Low-carbon Development Strategy," Ministry of Environment, Forest and Climate Change, https://unfccc.int/sites/default/files/resource/India_LTLEDS.pdf.

— (2023): Gazette Notification, SO 4458, dated 12 October 2023, https://egazette.gov.in/WriteReadData/2023/249377.pdf.

MoP (2022): "Ministry of Power, Gazette Notification No 2702," 28 June, https://beeindia.gov.in/sites/default/files/CCTS.pdf.

Narain, Sunita et al (2023): "Save the Carbon Bubble: India's Voluntary Carbon Market Must Be Regulated and Made to Contribute to Its Climate Goals," *Down to Earth*, 5 October, https://www.downtoearth.org.in/news/climate-change/save-the-carbon-bubble-india-s-voluntary-carbon-market-must-be-regulated-and-made-to-contribute-to-its-climate-goals-92107.

Neilson, Michael (2023): "Climate Change Farming Emissions: Government Reveals Much-anticipated Plan for Pricing by 2025," *NZ Herald*, 26 September, https://www.nzherald.co.nz/

nz/politics/climate-change-farming-emissions-government-reveals-much-anticipated-plan-for-pricing-by-2025/R7UPEXCO7NDNHOFRHRC6IL5DIA/.

Nozaki, Yukiko (2023): "Rise of Carbon Farming in India: World's Large Agrarian Country Expected to Become the Leading Market for Carbon Farming Credits," *Mitsui and Co Global Strategic Studies Institute Monthly Report*, February.

OECD (2022a): *Agricultural Policy Monitoring and Evaluation 2022: Reforming Agricultural Policies for Climate Change Mitigation*, Organisation for Economic Co-operation and Development, https://www.oecd-ilibrary.org/agriculture-and-food/agricultural-policy-monitoring-and-evaluation-2022_7f4542bf-en.

— (2022b): "Carbon Pricing in India," https://www.oecd.org/tax/tax-policy/carbon-pricing-india.pdf.

Ollikainen, M, J Lankoski and S Lötjönen (2020): "Climate Change Mitigation And Agriculture: Measures, Costs and Policies—A Literature Review" *Agricultural and Food Science*, Vol *29*, No 2, pp 110–29.

Partridge, Andrew, L Cloete-Beets and V Barends (2015): "The Real Cost of Going Clean: The Potential Impact of South Africa's 2016 Carbon Tax on Agricultural Production," *Professional Agricultural Workers Journal (PAWJ)*, Vol 3, No 1 (174-2016-2178).

PIB (2015): Ministry of Power, Government of India on Fact Sheet on Agriculture Demand Side Management (AgDSM), https://pib.gov.in/newsite/PrintRelease.aspx?relid=128572.

— (2018): Ministry of Agriculture and Farmers Welfare on National Mission for Sustainable Agriculture, https://pib.gov.in/PressReleasePage.aspx?PRID=1556469#:~:text=National%20Mission%20for%20Sustainable%20Agriculture%20(NMSA)%20has%20been%20made%20operational,soil%20and%20moisture%20conservation%20measures%3B.

— (2023a): Ministry of Jal Shakti on Pradhan Mantri Krishi Sinchayi Yojna, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1946492.

— (2020): Ministry of Agriculture and Farmers Welfare on Crop Diversification, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1605057.

— (2022): Ministry of Agriculture and Farmers Welfare, Implementation of Mission for Integrated Development of Horticulture, https://pib.gov.in/PressReleasePage.aspx?PRID=1842773.

— (2021a): Neem Coated Urea Ministry of Agriculture and Farmers Welfare, https://static.pib.gov.in/WriteReadData/specificdocs/documents/2021/nov/doc202111131.pdf.

— (2021b): Ministry of New and Renewable Energy, Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM), https://pib.gov.in/FactsheetDetails.aspx?Id=148576.

— (2023b): Ministry of New and Renewable Energy, Progress of Implementation of PM-KUSUM Yojana, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1947138.

Powlson, D S, C M Stirling, M L Jat, B G Gerard, C A Palm, P A Sanchez and K G Cassman (2014): "Limited Potential of No-till Agriculture for Climate Change Mitigation," *Nature Climate Change*, Vol 4, No 8, pp 678–83, https://doi.org/10.1038/nclimate2292.

Powlson, D S, C M Stirling, C Thierfelder, R P White and M L Jat (2016): "Does Conservation Agriculture Deliver Climate Change Mitigation Through Soil Carbon Sequestration In Tropical Agro-Ecosystems?" *Agriculture, Ecosystems and Environment*, Vol 220, pp 164–74, https://doi.org/10.1016/j.agee.2016.01.005.

Probst, Benedict et al (2023): "Systematic Review of the Actual Emissions Reductions of Carbon Offset Projects Across All Major Sectors," https://doi.org/10.21203/rs.3.rs-3149652/v1.

Rosenstock, T S, C Lamanna, S Chesterman, P Bell, A Arslan et al (2016): "The Scientific Basis of Climate-Smart Agriculture: A Systematic Review Protocol," CCAFS Working Paper.

Rao, Ch Srinivasa, R S Prasad and T Mohapatra (2019): "Climate Change and Indian Agriculture: Impacts, Coping Strategies, Programmes and Policy," Technical Bulletin/Policy Document 2019, Indian Council of Agricultural Research, Ministry of Agriculture and Farmers' Welfare and Ministry of Environment, Forestry and Climate Change, Government of India, New Delhi, p 25.

Steinebach, Y, X Fernández-i-Marín and C Aschenbrenner (2021): "Who Puts a Price on Carbon, Why and How? A Global Empirical Analysis of Carbon Pricing Policies," *Climate Policy*, Vol 21, No 3, pp 277–89.

Stubbs, M, K Hoover and J L Ramseur (2021): *Agriculture and Forestry Offsets in Carbon Markets: Background and Selected Issues* (R46956), Congressional Research Service.

Thompson, N M, M N Hughes, E K Nuworsu, C J Reeling, S D Armstrong, J R Mintert and K A Foster (2022): "Opportunities and Challenges Associated with "Carbon Farming" for US Row-crop Producers," *Choices*, Vol 37, No 3, pp 1–10.

Tullock, G (1967): "Excess Benefit," *Water Resources Research*, Vol 3, No 2, pp 643–44.

Verschuuren, J (2022): "Achieving Agricultural Greenhouse Gas Emission Reductions in the Eu Post-2030: What Options Do We Have?" *Review of European, Comparative and International Environmental Law*, Vol 31, No 2, pp 246–57, https://doi.org/10.1111/reel.12448.

World Bank (2022): "The Forest Carbon Partnership Facility," https://www.forestcarbonpartnership.org/.

Zhao, M, R Shi, R Du and L Yao (2023): "The Pathway to China's Carbon–Neutral Agriculture: Measures, Potential and Future Strategies," *Chinese Political Science Review*, Vol 8, No 2, pp 304–24.