Chapter 4

Bridging the gap I: Policies for reducing emissions from agriculture

Lead author: Henry Neufeldt (World Agroforestry Centre, Kenya)

Contributing authors: Tapan K. Adhya (KIIT University, India), Jeanne Y. Coulibaly (AfricaRice, Benin), Gabrielle Kissinger (Lexeme Consulting, Canada), Genxing Pan (Nanjing Agricultural University, China)

4.1 Introduction

Bridging the emissions gap requires a substantial increase in ambition and action, as the previous chapters of this report have illustrated. In 2012, the UNEP Emissions Gap Report (UNEP, 2012) reviewed a number of policies in three sectors – building, transport and forestry – that are proving successful in substantially reducing emissions. In this report we review best-practice policies in agriculture, an often-overlooked emissions-producing sector. The sum of the policies from these different sectors, if replicated and scaled up, shows great potential for narrowing the emissions gap. Moreover, in many cases, these policies can help fulfil important national development objectives beyond climate goals as they can, depending on the policy, boost agricultural productivity, save costs of heating homes, promote eco-tourism, reduce traffic congestion, abate air pollution and associated adverse health effects, or a combination of these.

Here we focus on agriculture because it is among the sectors most affected by climate change, while, at the same time, contributing a significant fraction of the world’s greenhouse gas emissions (IPCC, 2007a). Tubiello et al. (2013) recently estimated that in 2010 direct emissions from agriculture contributed to 10–12 percent of global greenhouse gas emissions, releasing 5.4–5.8 GtCO₂e into the atmosphere. UNEP (2012) gave a best estimate of 11 percent.

According to Bellarby et al. (2008) 38 percent of the emissions can be attributed to nitrous oxide from soils, 32 percent to methane from enteric fermentation in ruminant livestock, 12 percent to biomass burning, 11 percent to rice production and 7 percent to manure management. Direct agricultural emissions, as opposed to indirect ones discussed below, account for 60 percent of global nitrous oxide emissions and 50 percent of global methane emissions (Smith et al., 2008).

Globally, 80 percent of deforestation and forest degradation is believed to be related to agriculture (Kissinger et al., 2012). A more realistic evaluation of emissions related to agriculture should therefore include the emissions released by the conversion of forests and grasslands into agricultural land and the degradation of peat lands. These emissions can be described as indirect emissions from agriculture and, according to Vermeulen et al. (2012), amounted to 2.2–6.6 GtCO₂e in 2008. If agricultural pre- and post-production emissions are also added, the global food system accounts for about 19–29 percent of global greenhouse gas emissions (Vermeulen et al., 2012).²

Between 1990 and 2005, direct agricultural emissions rose by around 0.6 GtCO₂e per year (IPCC, 2007b), reflecting trends in major drivers such as population growth and rising affluence. These trends are expected to continue although their trajectories largely depend on our choices in natural resource management, food systems and consumer behaviour. Scenarios of continued population growth and consumption suggest that, by 2055, global agricultural methane and nitrous oxide emissions might increase by 57 percent and 71 percent, respectively (Popp et al., 2010). Although current trends predict strong growth of agricultural greenhouse gas emissions, there is significant potential to reduce them in the coming decades, particularly if mitigation options are mainstreamed into agricultural policies and incentives. At marginal costs of less than US $50–100 per tonne of carbon-dioxide equivalent, the direct emission reduction potential of agriculture lies in the range of 1.1–4.3 GtCO₂e per year in 2020 (Chapter 6).

About 89 percent of this potential could be realized through improved management practices such as conservation tillage, combined organic/inorganic fertilizer application, adding biochar to the soil, improved water management and reducing flooding and fertilizer use in rice paddies (Smith et al., 2008). Emissions could be further reduced by abating emissions in the broader food sector, for example, by reducing food waste and meat consumption.

² Emissions originate from the global food system during pre-production (fertilizer manufacture, energy use in animal-feed and pesticide production); during production (direct and indirect emissions from producing crops and livestock); and during post-production (primary and secondary food processing, food storage, packaging and transport, food refrigeration, retail of food products, catering and domestic food management, and the disposal of food waste).
The most promising and cheapest mitigation options in agriculture are those that lead to an increase in productivity and income, while the demand for inputs, land or labour rise at a lower rate. It is, however, necessary to minimize environmental externalities to avoid undermining the long-term provisioning capacity of our agro-ecosystems (Garnett et al., 2013; Neufeldt et al., 2013). It should also be noted that climate mitigation in agriculture involves more than reducing emissions. It can also mean increasing the uptake of carbon dioxide from the atmosphere by biomass or soil organic matter. Furthermore, it can also involve avoiding or displacing emissions, either by substituting fossil fuels with biofuels, or forestalling the conversion of natural vegetation into agricultural lands (Smith et al., 2008).

Bringing about change in agricultural management practices, however, for climate or other reasons is not easy. More often than not there are important market- or tenure-related barriers that need to be overcome. Experience also suggests that overcoming these barriers individually is often unsuccessful. It is better that they are addressed in an integrated way, with interventions simultaneously supporting farmers, the governance and market conditions in which they operate, and the science and resources upon which technological change depends. Experience has also shown that the policies successful in overcoming barriers are often the ones that are attuned to local conditions.

In the remainder of this chapter we present examples of concrete agricultural policies that have managed to overcome barriers and have been successful in mitigating climate change while raising income and enhancing food security.

### 4.2 Conversion of tillage to no-tillage practices

#### Drivers and benefits of policy change

Conventional plough-based farming developed largely as a means for farmers to control weeds. However, it leaves soils vulnerable to water and wind erosion, increases agricultural runoff, degrades soil productivity and releases greenhouse gases by disturbing soils and burning fossil fuels for farm machinery. No-till practices—sowing seeds directly under the mulch layer from the previous crop—reverse this process by minimizing mechanical soil disturbance, providing permanent soil cover by organic materials and diversifying crop species grown in sequence and/or association (FAO, 2013a).

The financial benefits of no-till practices can be considerable, but depend on the location. Farmers save between 30–40 percent of time, labour and fossil fuel inputs using no-till practices, compared to conventional tillage (FAO, 2001; Lorenzatti, 2006). In Argentina it was found that one litre of fuel was needed to produce 50 kg of grain under conventional tillage, but it could produce 123 kg under no-till practices (Lorenzatti, 2006).

Climate adaptation benefits can also be significant. While Kazakhstan’s 2012 drought and high temperatures halved wheat yields overall, wheat grown under no-till practices were more resilient, producing yields three times higher than conventionally cultivated crops (FAO, 2012).

Although no-till practices have only a small effect on reducing methane or nitrous-oxide emissions (Smith et al., 2008), a number of studies show the significant potential of no-till cultivation to sequester carbon. The expansion of Brazil’s no-tillage system under its National Plan for Low Carbon Agriculture (ABC Plan), for example, may build up an additional 500 kg per hectare and year of soil organic carbon, offsetting a total of 16–20 MtCO₂ by 2020, equivalent to 1.6–2.0 MtCO₂ per year. Kenya anticipates an increase in carbon uptake of 1.1 MtCO₂ by 2030, equivalent to 0.04 MtCO₂ per year, from no-till farming activities under its Climate Change Action Plan (Stiebert et al., 2012). In China, no-till farming may sequester a total of 2.27 MtCO₂ of soil carbon by 2015, equivalent to 0.5 MtCO₂ per year (Cheng et al., 2013a). These are all estimates of the potential to mitigate greenhouse gas emissions; estimates of what has already been achieved are given in the next section.

#### Policies that work

Governments have traditionally encouraged no-till practices as a measure to curtail soil erosion, and have only recently begun to promote it as a way to mitigate greenhouse gas emissions. However, farmers face difficult challenges during the transition to no-till practices related to high investment costs for machinery, increased dependence on such herbicides as glyphosate, changes in production inputs, and differences in crop and cover-crop management. Thus, support is required for farmers during the transition.

In 2011 Brazil established its ABC Plan, the first national policy promoting no-till cultivation, which includes state-level activities, based upon local and sub-national government plans. It sets implementation goals, anticipating that adoption of no-till practices increase from 31 million hectares to 39 million hectares under the plan. Farmers have access to ABC Plan credit and finance as well as training and extension services if management practices are compliant with the approach.

The adoption of no-till practices in Brazil was brought about by many factors: new knowledge on no-till systems stemming from research by the Brazilian Agricultural Research Corporation; support from farmer associations such as the Brazilian Federation of Direct Planting and Irrigation; backing from agricultural machinery companies who recognize the potential benefits from promoting the technology and expanding their markets; and recognition by farmers that no-till practices bring increased land productivity and reduced production costs (Casão Junior et al., 2012).

Between 1982 and 1997 overall cropland erosion dropped by more than a third in the USA, where policy interventions to promote no-till practices on highly erodible land contributed up to 62 percent of the overall reductions (Claassen, 2012). Classifying soils as highly erodible made it easier to target

---

1 To combat weeds, farmers may resort to an over-use of glyphosate or may rely on genetically modified crops, notably corn or soy. Alternatives are available, but support for farmers is required if those alternatives are to be introduced.

2 Brazil’s ABC Plan also includes: species diversification through rotation of crops, succession or combination of crops in a variety of production systems; permanent soil cover, either as mulch or perennial species; organic matter of sufficient quality and according to the soil’s biological demand; and further conservation agriculture practices, depending on the location.

3 From 3.1 billion tonnes of soil in 1982 to 1.9 billion tonnes in 1997.
specific areas for conversion to no-till cultivation, enabled by financial support from the United States Department of Agriculture. To get this support, farmers on highly erodible lands, approximately 25 percent of all USA cropland, had to devise and have approved a soil conservation plan. As a result, in 2009, 35 percent of USA cropland, mostly producing soy, was under no- or reduced-tillage, although often not permanently, which reduces its effectiveness to sequester carbon.

No-till agriculture increased in Australia from 9 percent of cropland in 1990 to 74 percent in 2010 (Llewellyn and D’Emden, 2010), particularly in grain producing areas. Awareness of soil erosion problems, region-specific information and learning opportunities for farmers, and declines in the price of glyphosate, all contributed to the adoption of no-till practices (D’Emden, et al., 2006; Llewellyn and D’Emden, 2010). Australia’s Landcare Programme, a community-based approach to land management, which is now made up of 6 000 farmer groups across the country, has played a key role in information dissemination and technical support (Department of Agriculture, 2013). The programme provides a refundable tax offset, financed by carbon-tax revenues, of 15 percent of the purchase price of an eligible no-till seeder to participating farmers. More recently, Australia has recognised the greenhouse gas reduction potential of no-till practices by including them in its Carbon Farming Futures programme – part of Australia’s Clean Energy Future Plan, and central to the cropland management component of Australia’s national greenhouse gas-reduction target.

Chinese interventions to increase the use of no-till practices have aimed to reduce soil erosion, treat crop residue, and eliminate their post-harvest burning.\(^5\) Up to now, reducing greenhouse gas emissions has not been a factor. As in much of Asia, smaller farm sizes restricted adoption of no-till practices. In addition, crop residues were commonly used for alternative purposes, such as feed for livestock (Lindwall and Sontag, 2010). China hopes to expand no-till practices to 13.3 million hectares by 2015 (Ministry of Agriculture, 2009), especially by providing subsidies to farmers (Zhao, et al., 2012).

No-till practices have spread across diverse soil types and agricultural production systems around the world over the last 30 years. The MERCOSUR countries of Argentina, Brazil, Paraguay and Uruguay have the highest rates of no-till cultivation, covering 70 percent of total cultivated area, two-thirds of which are under permanent no-till schemes, resulting in significantly increased soil carbon storage (Derpsch et al., 2010). Table 4.1 shows the cumulative mitigation benefits of up to 240 Mt CO\(_2\)e of avoided emissions in selected countries based on annual greenhouse gas mitigation rates in different climatic zones as provided in Smith et al. (2008) and best-available information on the coverage of no-till cultivated areas\(^6\).

Table 4.1 Greenhouse gas mitigation through no-till cultivation, selected countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Climate zone</th>
<th>Base year</th>
<th>Area under no-till in 2007/8 (million hectares)</th>
<th>Best estimate cumulative avoided greenhouse gas emissions by replacing till- with no-till cultivation (between indicated base year and 2007/8) (Mt CO(_2)e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Notes</td>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
<td>(d)</td>
</tr>
<tr>
<td>Australia (e)</td>
<td>warm-dry</td>
<td>1976</td>
<td>17</td>
<td>95.2</td>
</tr>
<tr>
<td>Argentina</td>
<td>warm-moist</td>
<td>1993</td>
<td>19.7</td>
<td>109.4</td>
</tr>
<tr>
<td>Bolivia</td>
<td>warm-moist</td>
<td>1996</td>
<td>0.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Brazil</td>
<td>warm-moist</td>
<td>1992</td>
<td>25.5</td>
<td>145.7</td>
</tr>
<tr>
<td>Canada</td>
<td>cool-moist</td>
<td>1985</td>
<td>13.5</td>
<td>82.3</td>
</tr>
<tr>
<td>China(^5)</td>
<td>cool-dry</td>
<td>2000</td>
<td>2</td>
<td>1.6</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>cool-dry</td>
<td>2006</td>
<td>1.2</td>
<td>0.2</td>
</tr>
<tr>
<td>New Zealand</td>
<td>cool-moist</td>
<td>1993</td>
<td>0.16</td>
<td>0.7</td>
</tr>
<tr>
<td>Uruguay</td>
<td>warm-moist</td>
<td>1999</td>
<td>0.66</td>
<td>2.0</td>
</tr>
<tr>
<td>USA</td>
<td>cool-moist</td>
<td>1974</td>
<td>26.5</td>
<td>241.3</td>
</tr>
</tbody>
</table>

Notes:
(a) Considering the lack of information on where no-till cultivation is being practiced, we assume one climate zone throughout the country, considering, where possible, the regional distribution of no-till agriculture.
(b) The base year is the estimated year in which the area of no-till cultivation began significantly expanding from a small baseline value in the country. The base year was estimated by linearly extending adoption rates from Derpsch et al. (2010), unless otherwise stated.
(c) From Derpsch et al. (2010), unless otherwise stated.
(d) Mitigation here refers mostly to avoided carbon dioxide emissions, with a small amount of avoided nitrous oxide emissions. Mitigation estimates on a per hectare basis are from Smith et al. (2008). These were multiplied by the area covered by no-till cultivation to obtain a value for total avoided emissions in Mt per year in the country for a particular year. To obtain the cumulative emissions in column 5, the annual emissions were summed for each year from 2007/8 back to the base year (in column 3). To compute the area covered by no-till cultivation in each year, it was assumed that the area covered decreased linearly from 2007/8 back to the base year (in column 3). In countries with long histories of no-till agriculture this probably led to an underestimate of the mitigation that was achieved. However, if the use of no-till cultivation began very slowly, then it is also possible that cumulative avoided emissions were overestimated.
(e) The 2007/8 estimate is derived from Derpsch et al. (2010) whereas the base year was established from Llewellyn and D’Emden (2010).
(f) The area stated for China is derived from Liu and Qingdong (2007) and Ministry of Agriculture (2009).

---

\(^5\) Refers to materials left in the field after harvest, such as straw, which can act as mulch if retained until the next crop.

\(^6\) These best estimates have a wide uncertainty range caused by the variation in conditions under which measurements were made, among other factors.
4.3 Improved nutrient and water management in rice systems

Drivers and benefits of policy change

Rice cultivation contributes more than 25 percent of global anthropogenic methane emissions but there are good options for reducing these emissions. Here we focus on three innovative and promising cropping practices that not only reduce methane emissions but also greatly improve the management of water and nutrients in rice cultivation – alternate wetting and drying (AWD), the system of rice intensification, and urea deep placement (UDP).

Alternate wetting and drying is a water management practice for irrigated rice fields through which farmers can achieve 5–30 percent water savings, lower labour costs, no significant yield penalty and profit increases of up to 8 percent (IRRI, 2013). Where it has been used on farms in Bangladesh, yields have risen by more than 10 percent, raising income by US $67–97 per hectare (IRRI, 2013). In Rwanda and Senegal, rice yield increased from 2–3 tonnes per hectare to 6–8 tonnes per hectare due to the similar system of rice intensification (Baldé, 2013; Cissé, 2013).

Another option for reducing emissions, urea deep placement, consists of inserting urea granules into the rice root zone after transplanting. It is reported to reduce fertilizer use by 35 percent while increasing crop yields by about 20 percent (IFDC, 2012). In Nigeria, for example, farmers were able to harvest 2.69 tonnes more rice per hectare using this technology than when broadcasting urea (IFDC, 2012)7.

Although the emission reduction potentials of these nutrient and water conserving techniques are in principle very high, actual reduction figures are sparse. Adoption of alternate wetting and drying has been shown to reduce the emissions of methane by 40 percent per year on China’s rice paddies, compared to continuously flooded rice production (Li et al., 2005). With urea deep placement, large fertilizer users such as China and India could achieve nitrogen fertilizer savings of up to 6.43 Mt and 2.89 Mt per year, respectively (Sutton et al., 2013). At the same time, nitrous oxide emissions would be reduced because of lower leaching and denitrification. In China, for instance, a mitigation potential of 0.08 to 0.36 t CO2-e per tonne of grain yield is possible by reducing nitrogen chemical fertilizer rates along with intermittent flooding in paddy rice cropping systems (Cheng et al., 2013b).

Policies that work

There are many examples of success in adopting alternate wetting and drying, the system of rice intensification and urea deep placement across the world. Governments have helped in many cases by providing the necessary incentives and support.

In Bangladesh, government support and policies, as well as targeted public-private partnerships and research, have led to high adoption rates of both alternate wetting and drying and urea deep placement. As an example of government support, alternate wetting and drying was introduced into the draft of the first National Irrigation Policy of Bangladesh. A key incentive turned out to be the government’s support for appropriate irrigation pipes or the adaptation of existing pipes (Kürschner et al., 2010). The International Rice Research Institute and the Bangladesh Rice Research Institute played key roles in mainstreaming the technique by raising awareness of its benefits and providing technical guidance. The use of TV, radio and newspapers also played an important role in the awareness raising process (Kürschner et al., 2010) – to date more than 100 000 farmers have adopted alternate wetting and drying practices (IRRI, 2012).

As a promoter of the fertilizer deep placement technology, the International Fertilizer Development Center took a leadership role in introducing urea deep placement to Bangladesh in the mid-1980s. Among other actions, the Centre organized demonstrations of urea deep placement techniques. By 2012 more than 2.5 million Bangladeshi farmers were using the technology, and it was expected to be adopted by an additional 1 million farmers across the country (IFDC, 2013).

Alternate wetting and drying and the system of rice intensification (a technique similar to alternate wetting and drying) have also been introduced very successfully to other parts of Asia. According to Uphoff (2012) more than 1 million Vietnamese farmers had adopted the system of rice intensification by 2011; in the Philippines, more than 100 000 farmers had begun using alternate wetting and drying by 2012, and it is expected that 600 000 farmers will have adopted this technology by 2015 (Rejesus et al., 2013; IRRI, 2013).

In Africa, the government of Madagascar supported the diffusion of the system of rice intensification by providing access to microcredit services, particularly in areas with weak coverage by microfinance institutions. The government facilitated the acquisition of farm equipment by liaising with microcredit institutions and by offering incentives to the private sector in production areas (Ministry of Agriculture, 2008). These credits also promoted knowledge and information sharing and thereby helped scale up the technology.

As women play a prominent role in rice production in Madagascar, the government also relied extensively on women’s networks to promote the system of rice intensification. Priority was given to providing women with training in how the system is practiced. Some rural communities relaxed current restrictions on women’s access to land and agricultural equipment, suggesting that women, through government support, have significantly contributed to the increase in usage of the system8. The technique is also being used on a small scale, but with increasing interest, in several other African countries, including Benin, Cameroon and Senegal (Agripace, 2013)9.

As a general lesson, emissions of greenhouse gases from rice cultivation can be substantially reduced through efficient management of fertilizer and water. Here we have

---

7 Broadcasting refers to a uniform distribution of fertilizer on the soil surface. It differs from deep placement in the sense that it requires more fertilizer and also increases leaching and run-off of nitrogen, especially during the rainy season.

8 In many African locations women do not have land ownership rights.

9 The governments of Rwanda and Senegal have helped introduce the system of rice intensification by providing credits to rice cooperatives and through knowledge and information sharing (Cissé, 2013).
talked about three innovative and promising approaches – alternate wetting and drying, urea deep placement and the system of rice intensification. Several steps could be taken to quickly scale up of these useful practices. First, they could be included in national agricultural policies. Second, direct financial support could be provided to farmers. Third, it would be very helpful to coordinate the support coming from the private sector and from organizations involved in research and agricultural extension training. Finally, direct support to women involved in rice cultivation would be very effective in scaling up these practices.

4.4 Agroforestry

Drivers and benefits of policy change

Agroforestry refers to a land management approach involving the simultaneous cultivation of farm crops and trees. In addition to sequestering carbon in the tree biomass, agroforestry generally improves microclimate and water balance, reduces erosion and raises soil fertility, among other ecosystem services. It leads, therefore, to higher crop and livestock productivity and, hence, income (Garrity et al., 2006; Schoeneberger et al., 2012). For instance, Haglund et al. (2011) reported 18–24 percent higher household incomes following the introduction in Niger of a variant of agroforestry called ‘farmer managed natural regeneration’. Garrity et al. (2010) summarized experiences with maize grown in association with a tree called *Faidherbia albida* in several African countries, reporting yield increases of 6–200 percent, depending on the age of the trees (Figure 4.1).

In temperate mechanized agroforestry systems, Dupraz and Talbot (2012) have shown land equivalent ratios reaching 1.2–1.6, suggesting that planting trees and crops together is more efficient than when the two are planted separately. Through diversification of income from fuel, fodder, fruit, timber, and the reduction of labour for firewood collection and the generally strong resilience of trees to climate variability, agroforestry has also shown to provide greater food security under climate shocks than conventional farming (Thorlakson and Neufeldt, 2012).

The mitigation potential of agroforestry systems is theoretically very high, but strongly dependent on the agroecosystem, the species being planted, and on the specific type of agroforestry practice. One estimate is that it could potentially mitigate 2.2 GtCO₂e per year (Verchot et al., 2007). This large figure stems from the fact that agroforestry has the possibility of being applied to 630 million hectares worldwide (Verchot et al., 2007).

The amount of carbon sequestered in agroforestry systems typically ranges from 1.06 tCO₂ per hectare per year to 55.77 tCO₂ per hectare per year for biomass carbon (Nair et al., 2009) and from 0.17 tCO₂e per hectare per year to 1.89 tCO₂e per hectare per year for soil carbon (Smith et al., 2008). Recently Aertsens et al. (2013) estimated that agroforestry could provide 90 percent of the potential of agriculture in Europe to take up additional carbon dioxide from the atmosphere.

Policies that work

Despite agroforestry’s high potential for increasing welfare and providing environmental services, there may be significant opportunity costs associated with establishing such systems and long time-lags before they generate returns (FAO, 2013b). Particularly in smallholder farming, the barriers include lack of access to farm inputs, capital, markets and training; uncertain land tenure situations; weak institutions and governance structures; and poor seed and seedling provisioning systems (Thorlakson and Neufeldt, 2012). Policies are needed to overcome these barriers.

---

10 A land equivalent ratio of 1 suggests that planting crops and trees together requires just as much land as planting them separately. A ratio greater than 1 indicates that it requires less land to produce the same amount of crops and trees.

11 The total technical potential in the EU-27 is estimated to be 1.566 MtCO₂e per year, corresponding to 37 percent of all carbon dioxide equivalent emissions in the EU in 2007. The introduction of agroforestry is the measure with the highest potential – 90 percent of the total potential of the measures studied (Aertsens et al., 2013).

**Figure 4.1** Mature *Faidherbia albida* between maize in Tanzania. One of the characteristics of the species is its reverse phenology: the tree sheds its leaves in the rainy season and goes dormant, reducing competition for light and water while providing valuable nitrogen-rich litter that is also good fodder. (Copyright: ICRAF).
Niger is one example of a country where these barriers have been overcome. Here, a combination of declining traditional governance structures in the 1920s and 1930s and severe droughts and famines in the 1970s and 1980s resulted in the overuse of common lands, which led in turn to a shrinking of natural tree cover by about 90 percent (Sendzemir et al., 2011). Reforestation began in earnest in the 1980s when the practice of ‘farmer managed natural regeneration’, introduced by several non-governmental organizations, was adopted on a large scale because of a change in government policies regarding the use and felling of parkland tree species (Reij et al., 2009). While farmers had previously ripped out germinating trees because they had no claim to ownership over the trees’ products and services, they now let them grow selectively. Within two decades this combination of non-governmental and governmental support led to a re-greening of about 5 million hectares of nearly barren bush savanna (Reij et al., 2009).

Another example is Kenya, where the government has adopted policies to promote farm forestry12. Key actions include the relaxation of restrictions on harvesting and marketing of tree products, tax incentives for growing trees on farms, and the creation of contract farming schemes to enhance trading of tree products between landholders and companies13. Wangari Mathai’s Green Belt Movement has also been instrumental in raising awareness about the importance of trees and for mobilizing thousands of women to plant millions of trees. In western and central Kenya this mix of regulation and incentives has resulted in a 215 000 hectares expansion of agroforestry over the last 30 years (Norton-Griffiths, 2013). Other national policies have promoted tree planting on Kenyan farms (Ajayi and Place, 2012) by supporting the training of extension service staff, establishing tree nurseries countrywide and prohibiting the harvesting of trees from public forests14.

In northern India, beginning in the late 1970s, poplar trees have been rapidly added to irrigated wheat and barley farms and now cover about 280 000 hectares – or 10 percent of irrigated agricultural lands in this region. Poplars provide timber and other benefits to farmers and barely compete with crops for light and water. Meanwhile, the Forest Conservation Amendment Act of 1988 prohibited cutting timber from state forests, and this increased the price of wood and created an economic incentive to plant trees on farms (Ajayi and Place, 2012). Agroforestry was further encouraged through credits for tree planting from the National Bank for Agriculture and Rural Development and through support provided by the timber industry in the form of higher quality planting material, such as seeds, fruit or aggregate fruit; training in agroforestry; and guaranteed timber prices.

In Europe and North America, agroforestry is mainly promoted for the ecosystem services it provides (Dupraz and Liagre, 2008; Current et al., 2009; Jacobson, 2012; Schoeneberger et al., 2012). Yet, despite its long-term economic benefits, agroforestry has not achieved its potential in Europe because of high investment costs and the perceived complexity of introducing annual and perennial plantings into high-input, mechanized agriculture (Papanastasis and Mantzanas, 2012). To encourage the expansion of agroforestry, the European Agroforestry Federation has recently called for reforms of the European Common Agricultural Policy, including greater financial support to farmers and more flexible eligibility rules (EURAF, 2013).

4.5 Lessons learned
To mitigate greenhouse gas emissions effectively while achieving development goals in the agriculture sector, the following factors should be considered:

- **Agricultural mitigation options require a coordinated mix of policy support, private and public sector investment, strengthened research, and capacity building of key stakeholders.** Specific actions are needed to demonstrate the benefits of new technologies to farmers, to coordinate needed investments and to disseminate information about benefits and how to overcome barriers. These actions can be supported by public-private partnerships and by research centres, governments, agricultural extension services, the private sector and non-governmental organizations.

- **Multiple benefits require multiple goals.** At the early policy-development stage it makes sense to articulate a number of environmental, social and other goals rather than one objective alone. This makes it easier to identify synergies between different goals rather than having to resolve trade-offs between them. Multiple goals can lead to multiple benefits of climate change mitigation, improved agricultural productivity and enhanced food security.

- **Financial incentives are needed.** A major barrier to the adoption of emission reduction measures has been the lack of financial incentives for farmers to adopt new technologies and practices. Financial incentives, including tax offsets, subsidies, and credits, are needed to help farmers in both developing and developed countries defray high up-front investment costs. Incentives are also needed because no-till and agroforestry practices can have a several year time-lag before their climate and other benefits are realized. Subsidies and microcredit may be particularly important for poor rice farmers who usually lack access to capital and credit.

- **In order to be successful in mitigating emissions, new technologies must be context-specific to the region or country where they are introduced.** For example, for no-till practices to be successful they must take into account local farm size, crop and soil types, carbon/nitrogen ratio over the crop rotation. Context specific research at landscape scale, as well as learning from past mistakes, is important for making each mitigation option work. In addition, land tenure issues have to be resolved before the needed investments and changes in new agricultural practices can be made.

---

13 Contract farming is agricultural production carried out according to an agreement between a buyer and farmers, which establishes conditions for the production and marketing of a farm product or products (FAO, Rome, 2008).
14 The Forest Policy (Government of Kenya, 1968) and the Rural Afforestation and Extension Services Division, set up in 1971.