Chapter 14

Climate-smart agriculture

Will higher yields lead to lower deforestation?

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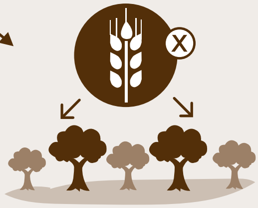
Key messages

- Sustainable intensification of agricultural production, a key component of climate-smart agriculture, can potentially conserve forests. However, higher yields may provide incentives to expand agricultural land into forests, so policies need to incorporate forest-specific measures to ensure land-sparing outcomes.
- Sustainable intensification policies aimed at supporting forest conservation must take into consideration the characteristics of the commodity, farm practices and context, including capital intensities, market conditions, scale of adoption, target location, and accompanying forest governance and conservation policies.
- National REDD+ strategies promoting forest conservation can benefit from promoting sustainable intensification, but thus far few countries combine the two approaches.

Climate-smart agriculture and deforestation in a nutshell

Competition for land is arising from increasing populations, income growth and dietary preferences, requiring increased agricultural production, and potentially new land. This land is also required for forest protection and restoration through initiatives such as REDD+.

A number of factors determine whether higher yields from sustainable intensification will spare land or stimulate expansion.



Farmers must have the capacity, labour and inputs to intensify agriculture, while not using these resources to expand agricultural land.

Whether yield increases stimulate expansion, depends on links to larger national or international markets.

The scale of adoption influences land-sparing outcomes: large-scale interventions keep prices low, which can spare forests.

Location matters: yield increase in forest-poor lowland regions can limit expansion in forest-rich upland areas.

Forest governance and conservation policies, and their coordination with agricultural policies (including removal of competing subsidies), can stimulate sustainable intensification of agriculture and land-sparing outcomes.

14.1 Introduction

Agricultural systems in the developing world are under pressure. Population and income growth, combined with changes in dietary preferences, have raised the global demand for food, feedstock and fibre. Projections suggest that production has to increase by 60% to meet food demand by 2050, and most of this increase should come from yield improvements (Alexandratos and Bruinsma 2012). Other scenarios suggest lower increases could suffice, if more equitable distribution and less waste of food is achieved (FAO 2017).

Over the past 50 years, most of the increase in global production has been from yield growth rather than area expansion, with sub-Saharan Africa being the notable exception (Jones and Franks 2015; Figure 14.1). Yet, agricultural expansion into forests is estimated to account for about 80% of deforestation worldwide (FAO 2017), and forest loss accounts for about a tenth of global greenhouse gas (GHG) emissions (IPCC 2013). Direct agricultural emissions contribute a similar share, of which 35% occur in developing countries (Wollenberg *et al.* 2016).

At the same time, climate change will negatively and disproportionately affect farming systems and poor smallholders in the developing world (Rosenzweig *et al.* 2014). The large yield gaps of these systems suggest they have the most potential to increase productivity, but climate change is reducing this prospect. Closing yield gaps requires formidable effort from producers, including buying improved seed varieties, adding more inputs such as fertilisers and irrigation, and improving efficiencies of inputs through better crop husbandry and agronomic practices (van Ittersum *et al.* 2016).

Climate-smart agriculture (CSA) aims to meet the triple challenge of raising agricultural productivity and farm incomes, enhancing adaptation and resilience to climate change, and reducing GHG emissions from agriculture (FAO 2013). That last mitigation-focused objective relates to whether CSA contributes to lowering both *on-site* emissions (i.e., on the farm itself) and *off-site* emissions (i.e., by preventing agricultural expansion into carbon-rich habitats such as natural forests). Carbon accounting for CSA commonly ignores the latter effect.

CSA is best defined in terms of its objectives (Campbell *et al.* 2014), rather than as a specific set of agricultural practices or policies. It seeks to identify which practices are appropriate to meet CSA objectives, given the particular local conditions. As such, the question of whether CSA delivers reduced emissions (including from agricultural expansion) is circular – if it does not, then it is not climate-smart. The more pressing question is whether CSA as currently practised contributes to lowering both on-site and off-site emissions.

According to Campbell *et al.* (2014, 41), "sustainable intensification is a cornerstone of CSA". As commonly defined, it refers to "producing more output from the same

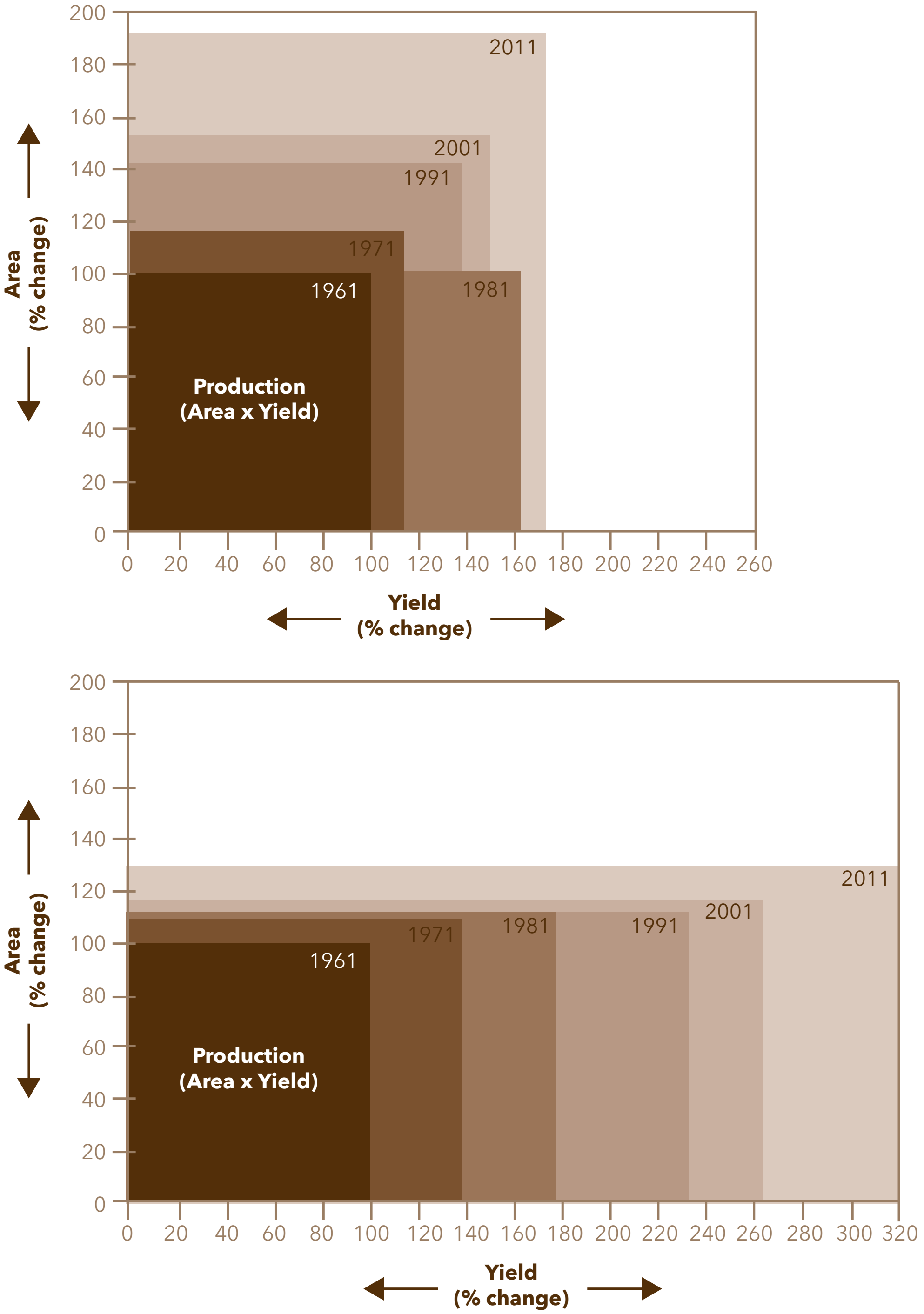


Figure 14.1 Area and yield changes to cereal production in sub-Saharan Africa (upper) and Asia (lower), starting from a baseline of 1961 = 100%

Source: Jones and Franks (2015)

Box 14.1 Examples of climate-smart agriculture and their impact on forests

CSA is defined by its objectives – raising productivity and farm incomes, climate change adaptation and resilience, and reducing GHG emissions from agriculture. As such, depending on location, CSA can include a number of elements to meet these goals: integrated crop, livestock, aquaculture and agroforestry systems; improved pest, water and nutrient management; improved grassland and forestry management; reduced (minimum) tillage and use of diverse varieties and breeds; integrating trees into agricultural systems; restoring degraded lands; improving the efficiency of water and nitrogen fertiliser use; and manure management, including the use of anaerobic bio-digesters (Lipper *et al.* 2014).

In addition to achieving the three goals of CSA and the forest impacts that might be achieved by intensification, some technologies also directly benefit forest conservation. Agroforestry systems can reduce harvest from natural forests of timber, fuelwood, charcoal, fodder and other products that agroforestry trees provide (Minang *et al.* 2011). When implemented in buffer zones around the forest margins, these can be particularly effective. Incentives for farmers to implement agroforestry can include carbon payments, in some countries directly through REDD+ (depending on the forest definition), or under different mechanisms.

area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services" (Pretty *et al.* 2011, 7). To be sustainable, agricultural production systems need to have high productivity (output–input ratio), reduce unnecessary use of external inputs (e.g., inorganic fertilisers), use agroecological processes such as nutrient cycling, and reduce practices that have negative environmental and health risks (Pretty *et al.* 2011; Box 14.1). Likewise, higher yields can, following the dominant CSA logic, avoid "the risk that land is cleared for agricultural production elsewhere to compensate for locally lower yields" (Garnett *et al.* 2013, 33).

This land-sparing effect cannot, however, be taken for granted. This chapter examines the factors which make land-sparing following sustainable intensification more likely to occur, and also suggests policies and interventions that favour win-win outcomes.

14.2 Critical factors linking agricultural yields and forests

14.2.1 A framework: Borlaug vs. Jevons

The debate on how higher agricultural yields can benefit forests reflects two very different paradigms. The Borlaug hypothesis is based on the global food equation:

*food production area * average yield = food consumption per person * population*

For a given total production (consumption), an increase in average yield reduces the agricultural area – by definition – and thus spares forests. This is also referred to as the land-sparing hypothesis, or – in the micro-level version applied at household level – the subsistence hypothesis (Angelsen and Kaimowitz 2001c).

In contrast, the Jevons hypothesis (or Jevons paradox) postulates that higher yields make farming more profitable, which incentivises farmers to expand their land – potentially into forests. More profitable practices will also attract labour and capital to the area (and limit outmigration), putting even more pressure on natural forests. The Jevons paradox is also referred to as the rebound effect: greater efficiency of an input (e.g., land) increases its use.

One notable difference between the Borlaug and Jevons hypotheses is that the former refers specifically to food, while Jevons is applicable to all farm products, as it refers to income rather than food production and demand.

So, do higher yields spare land (Borlaug) or stimulate expansion (Jevons)? The basic economics to analyse this question are well established (e.g., Angelsen *et al.* 2001; Choi *et al.* 2011; Villoria *et al.* 2014). Typically, one first analyses the effects at farm (household) level, focusing on farm preferences and constraints. For example, do farmers have the capacity and access to inputs (labour and capital) to adopt new technologies or intensify production, and to expand their agricultural land? Next, aggregate (general equilibrium) effects are analysed, in particular for output markets (will higher output lead to lower prices?) and labour markets (how will labour demand change, and will it lead to changes in wages and migration?). Using this framework, we review critical factors that co-determine the forest outcome.

Many studies refer to *yield increases*, either through *technological progress* (more output with the same or a lower level of inputs) or through *intensification* (more output due to more inputs per hectare). Villoria *et al.* (2014) point to the need to clearly distinguish between these in empirical analyses. Studies on technological progress and intensification are both relevant for CSA, in part because many technologies represent both technological progress and intensification, and in part because few studies directly assess the impacts of common CSA technologies and practices on deforestation.

14.2.2 Climate-smart farm technologies may need more cash and labour

Some new technologies or farmer management practices are costly or increase the amount of labour needed on the farm. For farmers who are constrained by a lack of labour and/or capital, adopting intensive technologies tends to limit expansion. For example, minimum tillage (MT) can increase water retention and soil fertility by restricting tillage to planting stations, but it requires more labour among smallholders to reopen the planting stations and to control weeds, especially for those without access to herbicides.

In a study from Zambia, Ngoma and Angelsen (2018) found that adopting MT had no significant impact on whether farmers expanded cropland into forests or not. However, MT adoption reduced the area of expansion among those who had already expanded, perhaps because MT is more labour-intensive than conventional practices and absorbs any excess family labour that might otherwise be used to expand cropland into forests (Ngoma and Angelsen 2018). Among farmers who did not expand their cropland, the majority (68%) cited lack of resources (labour and/or cash) as the main reason. Looking beyond individual farms, the adoption of labour-intensive practices can also drive up rural wages, and dampen agricultural profitability and expansion (Angelsen and Kaimowitz 2001a).

Because of labour constraints, farmers will also be reluctant to adopt labour-intensive technologies in the first place, unless their profitability or other characteristics make them more attractive than current practices. The labour intensity of MT in smallholder farming systems – which typically feature hand-hoe or animal draft power and limited herbicide and mechanisation – may also partly explain the relatively low uptake of this practice in Zambia (Ngoma *et al.* 2016). Thus a paradox arises, since farmers "will only be willing to adopt such land-saving practices when land has become scarce and most of the forest is gone" (Kaimowitz and Angelsen 2008, 6).

More labour-saving MT technologies exist: using tractors with rippers reduces the time spent preparing fields for planting. If farmers can afford them, these technologies may be more attractive for the farmers to adopt but are less likely to be land-sparing.

14.2.3 Market size makes a difference

Yield increases boost food supply, and thus lower food prices. This will dampen the incentive to expand agricultural land. The size of the price effect depends on two factors: (i) demand elasticity in the market, i.e., how much demand changes in response to price variation; and (ii) the market share of the sector experiencing technological progress (Angelsen 2007; Hertel 2012). Farmers selling products on national or global markets are less likely to face downward pressure on prices when they increase their supply because their contribution to aggregate supply is low.

The expansionary effect is also likely to differ across regions. Technological progress at global level is likely to take pressure off forests, yet low-yield, land-abundant regions are likely to experience further land expansion (Villoria *et al.* 2014). Globalisation has improved market access for farmers across the world, and will further integrate agricultural markets. In this context, an 'African green revolution' – which has been called for – is likely to lead to a significant increase in crop area in Africa, although crop area is likely to decline by almost the same amount across the rest of the world (Hertel *et al.* 2014).

Farmers prefer to expand production for markets where they will not experience a downward pressure on prices. Such cases of market-driven intensification are more likely to result in negative forest outcomes, as exemplified throughout history by a series of commodity booms and rapid deforestation (e.g., Ruf 2001). Cocoa is one of those global commodities, responsible for much of crop land expansion into the forests of sub-Saharan Africa, but cocoa agroforestry shows some promises (Box 14.2). Technology-driven intensification, conversely, is more likely to dampen cropland expansion (Byerlee *et al.* 2014).

Box 14.2 Cocoa agroforestry at the heart of REDD+ in sub-Saharan Africa

Denis J Sonwa

Cocoa plays an important role in how agricultural land interfaces with forests in sub-Saharan Africa (SSA). In a recent study of commodity crop-related deforestation, cocoa production in SSA was found to contribute the most to cocoa expansion in the tropics since 2000 (57% of all expansion from 2000 to 2013), with land area allocated to coca cultivation in Africa occupying 67% (equivalent to 6.3 million ha) of all cocoa agricultural land in 2013. During this period, 132,000 ha was converted to cocoa each year across SSA, where certain countries showed substantial increases of land converted to cocoa: 313% in the Republic of the Congo, 150% in Liberia and 80% in Cameroon (Ordway *et al.* 2017). Like other post-conflict countries in the region, the Democratic Republic of the Congo has also seen an increase in cocoa cultivation (De Beule *et al.* 2014).

However, not all research points to bad news; agroforestry appears to increase both the productive and ecosystem function outputs of the cocoa farming system. Recent studies in Ghana show that low-to-intermediate-shade cocoa agroforests in West Africa have no negative impacts on production, instead creating benefits for climate adaptation, climate mitigation and biodiversity (Blaser *et al.* 2018). In fact, cocoa agroforests with around 30% shade tree cover could optimise the trade-offs between production, climate and sustainability at low-to-intermediate levels of cover.

Researchers found that cocoa, a shade tree, grows under restructuring forest canopy (Sonwa *et al.* 2017a), and that a complex timber and non-timber cocoa agroforest can store 2–3 times the carbon stock of other systems, e.g., cocoa with no/low shade, and cocoa with banana and oil palm (Sonwa *et al.* 2017b). Since 1960, cocoa farming in West Africa has tended to use no/low shade, whereas some cocoa agroforests have emerged in Central Africa. Between 1988 and 2007, 21,000 km^2 of deforested and degraded forestland could have been saved if earlier research findings on cocoa intensification had been applied, with a subsequent carbon saving of 1.4 GtCO$_2$ (Gockowski and Sonwa 2010). To avoid further deforestation and forest degradation, the needs of farmers and markets must be prioritised in decisions about the types of trees promoted for smallholder agroforestry systems (Sonwa *et al.* 2014).

In an effort to reverse the cocoa-deforestation trend, the two main cocoa-producing countries in SSA have given cocoa a central role in their NDCs and REDD+ strategies. As a result, many companies committed to a deforestation-free supply chain have chosen to work with them (Kroeger *et al.* 2017; Chapter 13). On the ground, an integrated approach to agroforestry that considers the entire cocoa value chain will be central to these REDD+ efforts.

14.2.4 The scale of adoption influences land-sparing outcomes

The scale at which agricultural technologies and intensification are adopted – and indeed analysed – is critical. The more widespread the adoption, the larger the supply increase and the downward pressure on output prices. Thus, "situations that are win-lose [production – forest conservation] at the local level may be win-win at the global level" (Angelsen and Kaimowitz 2001b, 400). The Green Revolution is one example of this; output markets kept food prices low and thus have, according to some calculations, spared millions of hectares of forests (e.g., Burney *et al.* 2010).

Yet, this apparent positive conclusion comes with a series of caveats. Stevenson *et al.* (2013) estimated that in developing countries, the Green Revolution saved 2 million ha of forest over a period of 40 years (1965–2004), or 50,000 ha per year. By contrast, annual gross tropical forest loss was 8 million ha in the 1990s and 7.6 million ha in the 2000s (Achard *et al.* 2014). In other words, the Green Revolution reduced absolute annual forest loss by 0.6–0.7%; put differently, the annual deforestation rate of 0.490% (Achard *et al.* 2014) would be 0.493% without the Green Revolution. Stevenson *et al.* thus concluded that their estimates are "orders of magnitude lower than predicted by the simple global food equation that does not take account of feedback loops through prices of products, consumption demand, and land-use decisions" (Stevenson *et al.* 2013, 8365). Similarly, econometric studies using national data by Ewers *et al.* (2009) and Rudel *et al.* (2009b) found insignificant or only weakly negative correlations between agricultural yield and deforestation.

14.2.5 Location, location, location

Within a country, yield increases in lowland (forest-poor) regions may put downward pressure on output prices, limiting expansion in upland (forest-rich) regions. Intensified lowland rice production also pulled labour out of upland rice cultivation in the Philippines, thus increasing the effect (Shively and Pagiola 2004). There are exceptions to this. In Sulawesi, Indonesia, Ruf (2001) found that Green Revolution technologies were linked with more forest clearing in the uplands for cocoa planting, because: (i) they mechanised lowland rice production by introducing hand tractors, freeing up labour; and (ii) the increased profitability provided funds for investing in cocoa production in the uplands. Maertens *et al.* (2006) found similar effects in their study, also from Sulawesi.

In order to reduce emissions from deforestation, agricultural policies should therefore be place-specific, a point also argued by the World Bank (2007). For example, policies that promote agricultural intensification in peri-urban and rural regions close to cities can effectively spare forests (Rudel 2009b). In Rondônia, Brazil, pasture intensification in farms located closer to markets was more likely to spare forestlands (Fontes and Palmer 2018). Farmers close to markets were also more likely to adopt land-sparing cattle production practices.

Finally, the location and specific ecosystem into which agriculture expands can make a major difference in terms of carbon emissions. Cerri *et al.* (2018) reported that carbon emissions associated with clearing for new pastures and cropland are 4–5.5 times greater in the Amazon than in the Cerrado. Focusing agricultural development on locations where emissions are lower can bring net gains in overall emission reductions.

14.2.6 Forest governance and conservation policies can bring about win-win outcomes

A final factor shaping the yield-forest link is that of forest policies and governance. In South America, agricultural intensification was associated with land expansion in areas with high general governance structures in place (Ceddia *et al.* 2014), possibly because it created more favourable business opportunities. However, when looking specifically at *environmental governance*, good governance led to a spatial contraction of agriculture, and a sustainable intensification process. Thus, "agricultural intensification needs to be accompanied by policies that specifically focus on the environmental aspects of governance" (Ceddia *et al.* 2014, 5).

Forest governance not only influences the outcomes for forests, but can in itself incentivise agricultural intensification. In Mato Grosso, Brazil, Garrett *et al.* (2017) found that cattle intensification was, in part, spurred by better deforestation monitoring, penalties and enforcement. This relates well to the classical insight by Boserup (1965) that farmers tend to exploit the extensive margin before the intensive margin, if spare land is available. Good forest governance and conservation policies restrict the space available for expansion, and thus spur intensification.

14.3 Integrating forest and agricultural policies

Raising both agricultural production and income is needed to meet food security and poverty reduction goals. At the same time, preserving forests is needed to meet climate, biodiversity and local livelihood goals. Synergies between forests and agriculture may support these goals; for example, forests provide ecosystem services, which benefit agriculture. To achieve these multiple goals, forest conservation and agriculture need to be integrated in national policies through coordination across sectors (Salvini *et al.* 2016; Bastos Lima *et al.* 2017b; Chapter 7). In particular, competing policies – i.e., policies in one sector that undermine objectives in the other sector – should be examined. For example, subsidies to four key forest-risk commodities (beef and soy in Brazil, palm oil and timber in Indonesia) amount to USD 40 billion per year (McFarland *et al.* 2015).

REDD+ offers opportunities to better integrate forests and agriculture, as examples from Zambia, Brazil and Mexico show. Zambia's National REDD+ Strategy identifies CSA elements such as conservation agriculture and agroforestry as important land management practices that can support REDD+ implementation (Box 14.3).

Box 14.3 Integration of climate-smart agriculture and forestry policies in Zambia

Deforestation in Zambia – which is estimated between 167,000 and 300,000 ha annually and is driven in part by agricultural expansion into forestland – remains a major threat to the country's forests and biodiversity. Cognisant of this fact, the Zambian government has put in place policy measures to address both food security objectives and forest conservation, by promoting the adoption of CSA practices and sustainable forest management.

Zambia's National Policy on Climate Change (NPCC) (2016) aims to coordinate responses to climate change and mainstream it into national programmes, in order to enable the country to attain climate-resilient and low-emissions rural development pathways. The NPCC advocates for both sustainable forest management and CSA (mainly conservation agriculture and agroforestry) as means to reduce GHG from land use, land-use change and forestry. One of the objectives of Zambia's Second National Agriculture Policy (2016–2020) is "to promote the sustainable management and use of natural resources" through sustainable land management technologies such as conservation agriculture, afforestation and community woodlots, and agroforestry. While recognising that agricultural expansion is among the leading causes of deforestation, the National Forest Policy (2014) is rather silent on specifics, except to call for the use of appropriate farming practices.

Zambia's National REDD+ Strategy (2015) is more upfront: "[C]onservation agriculture as a practice, if successful, could contribute significantly to creating permanent agriculture for small-scale farmers thus reducing the need to convert forests and woodlands to agricultural use while at the same time contributing to climate change mitigation and adaptation from the agriculture sector" (Matakala *et al.* 2015, 12). The promotion of CSA is a priority intervention within the agriculture sector, as much as sustainable forest management is in the forestry sector. Successfully integrating CSA and sustainable forest management holds promise for win-win outcomes in terms of food security and forest conservation, but this will require more coordination than currently exists between the agriculture and forest sectors in Zambia.

Sources: GRZ (2014); Matakala (2015); GRZ (2016a, 2016b)

Jurisdictional commitments from the agricultural sector itself, such as zero deforestation commitments, can also be implemented into REDD+ and show promise in terms of benefiting agricultural production and forests (Chapter 13).

Brazil has made a clear connection between the national REDD+ and CSA strategies, particularly for the Amazon and Cerrado biomes (ENREDD+ 2016). The CSA strategy is outlined in the Low-Carbon Agriculture programme (ABC Plan; MAPA/ACS 2012). It provides low-interest loans to farmers who want to implement sustainable agriculture practices. To what extent this large-scale sustainable agricultural intensification (SAI) can reduce deforestation is yet to be seen. De Oliveira Silva *et al*. (2018, 111) state: "Brazil's NDC is a bold statement of its scientific and institutional commitment to reconciling key sustainability challenges via SAI. Our analysis points to the feasibility of the approach pending the role of complementary policies on deforestation and farm support".

Mexico's National REDD+ Strategy (ENAREDD+) offers another example (CONAFOR 2016). ENAREDD+ is based on the national REDD+ vision (CONAFOR 2010) and it: (i) targets sustainable rural development as its main goal, rather than directly targeting forests; (ii) focuses on both adaptation and mitigation; (iii) relies on a landscape perspective with multiple functions and cuts across sectors instead of focusing on individual activities only in the land sector; and (iv) develops national guidelines for internal coherence but builds upon subnational/state REDD+ strategies.

While examples of CSA within REDD+ strategies are not abundant, trees and forests are commonly included in CSA frameworks.[1] However, natural forests are not necessarily targeted by these CSA initiatives; instead commercial tree species as well as commercial agroforests frequently play large roles. Agroforestry and silvopastoral systems are two classical CSA activities connected to forest conservation (Box 14.1). These CSAs help to reduce demand for trees from *natural* forests, for fuel, fodder and other uses (Desquilbet *et al.* 2017; Duguma *et al.* 2017), which in turn has the potential to reduce deforestation and forest degradation.

14.4 The way forward

Agricultural yield increases can result in mixed outcomes on forest cover. These outcomes depend on the characteristics of the commodity, farm practices and context, including labour and capital intensities, market conditions, scale of adoption, target location, and accompanying forest governance and conservation policies. The predicament of this potential for diverse outcomes is increasingly being recognised. In a recent report on trends and challenges impacting the future of food and agriculture, FAO noted; "there is a risk that agricultural intensification may lead to more cropland expansion rather than less" (FAO 2017, 36).

Yet forest outcomes are not completely at the mercy of fate. Research suggests that the likelihood of win-win outcomes can be enhanced through supporting forest protection policies. As Byerlee *et al.* (2014, 92) warn, "technology-driven intensification by itself is unlikely to arrest deforestation unless accompanied by stronger governance of natural resources". To provide adequate forest protection, policies need to include land-use zoning, economic instruments, strategic deployment of infrastructure, certification, and sustainability standards (Phalan *et al.* 2016; Chapters 9 and 13).

While recognising that sustainable intensification of agriculture alone does not necessarily lead to forest conservation, it is a first step towards achieving the triple objectives of improved food security, climate change mitigation, and adaptation/resilience (Carter *et al.* 2018; Lipper and Zilberman 2018). As yet there are few, if

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[1] See country CSA profiles that include mitigation plans http://sdwebx.worldbank.org/climateportal/index.cfm?page=climate_agriculture_profiles

any, examples of agricultural and forestry policies having been jointly designed with the explicit intention of promoting a land-sparing outcome. Designing and testing the success of such measures should be a key focus of agricultural programmes aiming for zero deforestation (Chapter 13) and forest restoration (Chapter 15).

Given limited resources, countries should prioritise areas where the likelihood for win-win outcomes for CSA is highest. Carter *et al.* (2015) developed a procedure to identify such opportunities, taking into account three variables: (i) *the potential to mitigate*: areas with large agriculture-driven deforestation, and a potential to intensify agriculture (as expressed by a large yield gap); (ii) *an enabling environment:* high score on the governance index (World Bank 2014), and REDD+ engagement; and (iii) *the needs and risk*: a low score on the global food security index (EU 2013). The logic is that high yield gaps imply that CSA can make a difference in farm production and income, good governance will ensure that CSA activities are adopted widely, and active REDD+ policies can help prevent negative forest outcomes.