



WORKING PAPER

**JOINT
ADAPTATION
AND
MITIGATION
IN
AGRICULTURE
AND FORESTRY**

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LIST OF ABBREVIATIONS

CDM	Clean Development Mechanism
CO₂	Carbon dioxide
GHG	Greenhouse gas
INDC	Intended Nationally Determined Contribution
JAM	Joint Adaptation and Mitigation
NAMA	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Plans of Action
PES	Payment for Environmental Services
REDD+	Reducing Emissions from Deforestation and forest Degradation, including the role of sustainable forest management and enhancement of carbon stocks
SDG	Sustainable Development Goal
UNFCCC	United Nations Framework Convention on Climate Change

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1. INTRODUCTION

Adaptation and mitigation are both processes aimed at reducing the risks and impacts of climate change, although this can happen across different temporal and spatial scales (Felgenhauer and Webster, 2014; Locatelli et al., 2015; Watkiss et al., 2015). Put simply, mitigation reduces the risk of climate change from a mostly global and long-term perspective (Watkiss et al., 2015), whereas climate change adaptation contributes by reducing vulnerability and increasing resilience, often at the local scale and in a near-term perspective (Landauer et al., 2015; Tol, 2005; Watkiss et al., 2015) (see Table 1). A broad overview of

the general differences between climate change adaptation and mitigation is given in Table 1, but these broad differences are increasingly being challenged, as adaptation can occur at the broader level for relatively longer term perspectives and vice versa. Furthermore, the co-occurrence of adaptation and mitigation is evident in sectors that would traditionally involve one or the other but not both. For example, adaptation in transport is increasing, with new design standards being developed to minimise the risk of flooding to metro stations in Copenhagen, Denmark (EEA, 2014).

TABLE 1. GENERAL DIFFERENCES BETWEEN ADAPTATION AND MITIGATION (ADAPTED FROM LOCATELLI, 2011).

	MITIGATION	ADAPTATION
Spatial scale	Primarily global	Primarily local
Time scale	Long term	Short term
Metric	GHG emissions (CO ₂ equivalent)	Various, according to intervention
Main sectoral focus	Energy supply, transport, industry, waste and wastewater management	Water, health, coastal zones
	Forestry and agriculture	

Several characteristics of mitigation and adaptation create opportunities and challenges for implementing both processes simultaneously and with displaced benefits both temporally and spatially. First, in many sectors mitigation and adaptation are inextricably linked, as the amount of adaptation needed depends on the success of international mitigation efforts and vice versa to some extent (Watkiss et al., 2015). Second, mitigation has had little impact in the short term, whereas adaptation could play a greater role. Third, the scale of implementation often differs, which has a bearing on how the costs and benefits of adaptation and mitigation are distributed. Mitigation is a public good, and its benefits are enjoyed at the global level. For adaptation, the costs and benefits are local, with potential contributions to improvements globally (Harvey et al., 2014; Moser, 2012; Watkiss et al., 2015). This simple spatial division is not without exceptions, however, since adaptation might have global consequences (e.g. more resistant crops are grown globally), and mitigation actions might have local consequences (e.g. less air pol-

lution locally by closing coal-fired power plants, or the effect of biofuels on local food security; Swart and Raes, 2007, Moser, 2012). Fourth, income generation from mitigation initiatives can be used to achieve adaptation benefits, a field that is largely underfunded (Matocha et al., 2012).

Even though adaptation and mitigation share the ultimate goal of reducing the unwanted effects of climate change, they have been addressed differently by scholars, institutions and politicians (Ayers and Huq, 2009). Mitigation has been promoted as especially relevant to developed countries, adaptation as imperative to developing countries (Ayers and Huq, 2009; Somorin et al., 2012). Joint Adaptation and Mitigation (JAM) is currently receiving increased interest from scientific scholars (Duguma et al., 2014; Landauer et al., 2015; Watkiss et al., 2015), who are producing examples of the complementary and synergetic effects of adaptation and mitigation globally, nationally and locally and their integration at the landscape level.

In 2015 several international milestones were achieved, each with a bearing on climate change action, and highlighting the need to link climate change adaptation and mitigation action: countries have formulated their Intended Nationally Determined Contributions (INDC) towards climate action; the global goal for adaptation in the Paris Agreement, adopted in November 2015, directly links to the target for mitigation to staying below two degrees Celsius (Magnan, 2016); and the new UN Sustainable Development Goals were also adopted (UN, 2016). Indeed, adaptation and mitigation share several common elements that

advance the sustainable development agenda, including poverty reduction and ecosystem resilience locally (Somorin et al., 2012).

To this end, some are arguing that there is a window of opportunity for the development of policies to promote both mitigation and adaptation as complementary rather than direct substitutes. – where adaptation is cost effective, and mitigation contributes to avoiding threatening climate change (Watkiss et al., 2015) – and that mitigation and adaptation should be pursued equally (Felgenhauer and Webster, 2013; Laukkonen et al., 2009; Warren et al., 2012).

1.1 SCOPE AND OBJECTIVE

Land use is one of the key sectors with great potential for creating synergies between mitigation and adaptation actions, potentially achieving both objectives at little or no extra cost. Other key sectors include waste management, construction, planning and infrastructure (Illman et al., 2012). In this working paper, we focus on land use and discuss agroforestry, climate-smart agriculture, ecosystem-based adaptation and reduced emissions from deforestation and forest degradation (REDD+) as some of the important approaches to capturing both climate change adaptation and mitigation. These approaches are often aligned with sustainable development objectives, with significant co-benefits for local communities (Locatelli et al., 2015; Matocha et al., 2012; Watkiss et al., 2015).

While JAM shows potential in terms of cost-effectiveness, the existing evidence and knowledge of the measurement, operationalisation and implementation of JAM need to be enhanced in order to provide input to improving the design of synergetic projects (Locatelli et al., 2015). The aim of this working paper is therefore to gather knowledge of and insights into the current use of JAM both as a concept and in practice. The paper is based on a literature review, using a snowballing process to identify publications used and cited by others. This approach was chosen especially as a result of the lack of keywords that can capture the complex connections between climate change adaptation and mitigation. The literature search was conducted between December 2015 and March 2016.

This working paper starts by providing an overview of the underlying concepts of joint adaptation and mitigation (JAM) and captures how the literature has defined the concept as benefits, synergies, integration, interlinkages, interrelationships and linkages between climate change adaptation and mitigation. This is illustrated by current examples and practices in agriculture and forestry in developing countries that are creating benefits for adaptation and mitigation. Specifically, the paper highlights current barriers within agriculture and forestry to pursuing JAM by providing insights as to where efforts can be focused to ensure the further development of JAM activities. The remainder of this working paper is organised under the following headings: overview and importance of JAM in climate action, outline of basic JAM concepts, sectoral overviews linking mitigation to deriving adaptation and adaptation to deriving mitigation, as well as integrated and synergetic practices and activities in the sectors of agriculture and forestry, barriers and solutions to joint activities in the two sectors, and the conclusion to the working paper.

1.2 REVIEW OF JOINT ADAPTATION AND MITIGATION CONCEPTS

One way of categorising JAM was suggested by Locatelli et al. (2015), who used a deductive approach involving 274 cases. JAM activities were put into three broad groups (see Figure 1). First, joint outcome activities are activities with non-climatic primary objectives (e.g. development or recreation) that deliver joint outcomes for adaptation or mitigation. Secondly, activities with unintended side effects are characterised as activities that are aimed at only one climate

objective – either adaptation or mitigation – but also affect the other objective. Finally, activities with joint objectives are activities with combined adaptation and mitigation objectives that in turn may lead to interactions strengthening or weakening outcomes, that is, synergies or trade-offs. It is this final group of activities that we define as JAM in this working paper (see Landauer et al., 2015 for a further review of the concepts used in the literature).

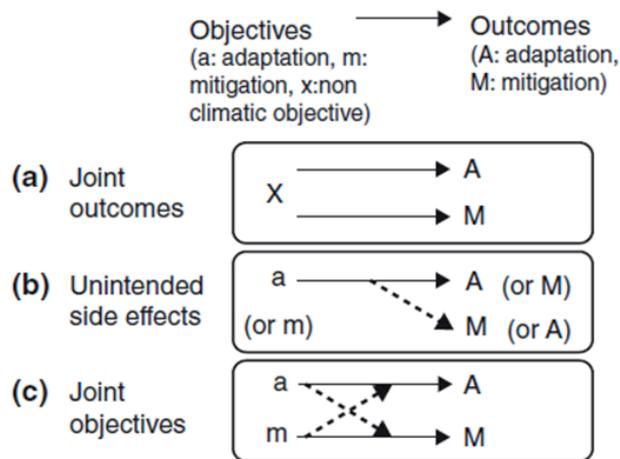


FIGURE 1. RELATIONSHIPS BETWEEN ADAPTATION AND MITIGATION CONCEPTUALISED IN THREE MAIN CATEGORIES (LOCATELLI ET AL., 2015).

This followed on from earlier classifications by the IPCC Fourth Assessment Report, which included a specific chapter on interactions involving adaptation and mitigation and the potential value-added that joint actions could offer. Klein et al. (2007a) identified four types of JAM, which were further elaborated on by Watkiss et al. (2015). These are described below with some examples.

a. Adaptation actions that have consequences

for mitigation: (i) positive mitigation consequences, for example, when crop residue is returned to the field to improve its water-holding capacity, which also sequesters carbon; or (ii) negative mitigation consequences, for example, increased use of nitrogen fertiliser to prevent falling yields can lead to increased nitrous oxide emissions.

b. Mitigation actions that have consequences

for adaptation: (i) positive adaptation consequences, for example, carbon sequestration

projects can lead to greater access to forest products; or (ii) negative adaptation consequences, for example, when land is taken over for carbon sequestration, thus negatively affecting livelihoods and food security.

c. Decisions that include trade-offs or synergies between adaptation and mitigation:

- **Trade-offs** between adaptation and mitigation, as defined by Klein et al. (2007), represent a way of prioritising or balancing between adaptation and mitigation. However, there are many examples of negative or conflicting trade-offs that need to be avoided, for example, when adaptation leads to increased carbon emissions. Specifically, the pursuit of one objective negatively affects the outcome of the other (Moser, 2012; Landauer et al., 2015).
- **Synergies** between adaptation and mitigation are defined in the IPCC Fourth Assessment Report (Klein et al., 2007a, p. 749) as the ‘interaction of adaptation and

mitigation so that their combined effect is greater than the sum of their effects if implemented separately' (see Box 1). Indeed, the main motives for applying a synergetic approach are to increase effectiveness, minimise costs and ensure continuity of production and/or service provision through adaptation, mitigation or mitigation combination of the two, thereby minimising the risk of failure in fighting climate change (Duguma et al., 2014). This suggests that the benefits of an integrated approach are greater than those of two independent, parallel strategies. Importantly, striving for both adaptation and mitigation may also optimise investments – for example, reducing climate change by reducing the transaction costs of implementing projects separately (Matocha et al., 2012).

d. Processes that have consequences for both adaptation and mitigation, or that contribute with both adaptation and mitigation, for example, trees in an urban setting that provide shade during heat waves and simultaneously contribute with carbon sequestration.

The concepts of substitutability and complementarity are also increasingly being discussed in relation to climate policy development and economic theory from a global perspective¹ (Ingham et al., 2013; Kane and Shogren, 2000; Lecocq and Shalizi, 2007).

Substitutability is the extent to which an agent can replace adaptation by mitigation or vice versa to produce an outcome of equal value. In general, adaptation and mitigation are often substitutes, particularly in the policy field at the global level, where large, long-term investments in mitigation can lead to fewer investments in adaptation and, in theory, reduce the need for adaptation (In-

gham et al., 2013; Kane and Shogren, 2000).

Complementarity occurs when the outcome of one supplements the outcome of the other (Klein et al. 2007a, Watkiss et al. 2015). However, complementarity can also occur when the costs of adaptation may depend on the amount of mitigation (Watkiss et al., 2015). Thus, a mix of adaptation and mitigation is considered the optimal approach, depending on local conditions, values, preferences and uncertainties, and evidence of climate change supports the simultaneous pursuit of such a joint approach (Felgenhauer and Webster, 2013; Warren et al., 2012).

While we may be able to justify the principles of JAM theoretically, the evidence is limited when it comes to concrete estimates of its costs and benefits and to how such joint objective projects can be operationalised; thus, a critical gap has been identified (Duguma et al., 2014; Locatelli et al., 2015; Steenwerth et al., 2014; Watkiss et al., 2015). Moreover, although there are many ways of pursuing JAM, purposefully seeking such synergies may lead to unnecessarily complex projects that are neither cost-effective nor efficient in producing the adaptation and mitigation benefits they seek to harness (Klein et al., 2005). The risks and uncertainties on the level of adaptation and the spatial and temporal scale on which adaptation operates compared to mitigation pose challenges to the design and implementation of synergetic adaptation and mitigation projects. Conceptualising and operationalising JAM is evidently highly complex for these reasons, and there is a critical need for a clear methodology and guidance in the implementation of JAM projects in order to secure the best outcome of any one investment and to avoid pitfalls and barriers (Laukkonen et al., 2009).

¹ The two concepts are discussed especially in relation to Integrated Assessment Models (IAM), estimates of the Social Costs of Carbon (SCC) and the application of these results. IAM offers an 'end to end' modelling of climate change, summarising its positive and negative causes and effects (Nordhaus, 2013). SCC represents the present net value of the impact of an increase or decrease, aggregated over the period until 2200, caused by emitting one more or one less ton of CO₂ (Stern, 2007).

BOX 1. BASIC CONCEPTS IN JAM

Interrelationship, interaction, interlinkage: adaptation that has consequences for mitigation or vice versa, or processes that have consequences for both (Landauer et al., 2015).

Synergy: interaction between adaptation and mitigation, so that their combined effect is greater than the sum of the effects derived from implementing them separately (Klein et al., 2007).

Trade-off: balancing adaptation and mitigation when it is not possible to carry out both activities fully at the same time (Klein et al., 2007), or ‘inadequate conditions, competition among means for implementation and negative consequences of pursuing both simultaneously’ (Moser, 2012).

Substitutability: the extent to which an agent can replace adaptation by mitigation or vice versa to produce an outcome of equal value (Klein et al., 2007).

Complementary: the interrelationship between adaptation and mitigation, whereby the outcome of one supplements or depends on the outcome of the other (Klein et al., 2007).

2. JOINT ADAPTATION AND MITIGATION IN AGRICULTURE

Farmlands or lands used for agricultural production, consisting of cropland, managed grassland and permanent crops (including agroforestry and bioenergy crops), occupy about 40-50 per cent of the earth’s land surface. The IPCC estimates that in 2010 about 24 per cent of the anthropogenic emissions of GHGs came from agriculture, more specifically from fuels, deforestation, shifting cultivation, land-use changes, synthetic fertilizers and animal waste (Smith et al., 2014). 13.7 per cent of global GHGs come directly from agriculture, and 96 per cent of the latter from Africa, the Americas and Asia (Tubiello et al., 2013).

Mitigation in agriculture can be divided into three types of initiative (Harvey et al., 2014; Jarvis et al., 2011): initiatives that increase the carbon stock and sequestration above and below ground, e.g. revegetation of degraded land and agroforestry initiatives (Smith et al., 2014); initiatives that reduce the direct emissions from agriculture, e.g. improved feed and dietary additives for livestock and improved use of fire for sustainable grassland management (Smith et al., 2014); and initiatives that work against the creation of a new type of farmland by causing deforestation and degrading ecosystems. Most countries include agriculture and other land-use sectors in their INDCs to reach the goal of the UNFCCC (UNEP, 2015), and agriculture predominates in the adap-

tation actions taken in Asia and Africa (Ford et al., 2014). Emission reductions and mitigation in the agricultural sector can thus be a meaningful way for countries to contribute to minimising climate impacts.

Agriculture is the human activity that is most vulnerable to climate change (Verchot et al., 2007), meaning that the greatest percentage of livelihoods depend on agriculture and will inevitably be affected by climate change (Steenwerth et al., 2014). The main climate vulnerabilities in the agricultural sector are related to seasonal weather changes, increased precipitation and temperatures, and extreme weather events, leading to decreases in crop yields (Gustafson et al., 2014) and disease and death among livestock (Steenwerth et al., 2014), which indirectly can have an impact on market prices and farmers’ incomes. Farmers are especially vulnerable to recurrent droughts, floods, soil degradation, water shortages, limited availability of inputs and improved seeds, limited technology options, and limited infrastructure and access to markets. A lack of knowledge of the threats of climate change can further increase their vulnerability (Li et al., 2015; Mutabazi et al., 2015; UNEP, 2015).

BOX 2. CLIMATE-SMART AGRICULTURE

Climate-smart agriculture (CSA), or climate-related agriculture, is a term used widely in the academic literature and by multilateral agencies and practitioners who are trying to adapt to the climate-related challenges facing agriculture. This is done by increasing farmers' resilience to climate change and decreasing GHG emissions from agriculture, while at the same time supporting sustainable development of the entire sector from small-scale farmers to large agribusinesses (Steenwerth et al., 2014).

The aim of CSA is to enhance the capacity of agricultural systems to meet the need for food security and poverty alleviation under conditions of a changing climate through science-based actions. It incorporates the need for adaptation and the potential for mitigation into sustainable agricultural development strategies without jeopardising the sustainability of the production process (Harvey et al., 2014; Smith and Olesen, 2010; Steenwerth et al., 2014).

Climate change adaptation in agriculture can potentially increase the resilience and adaptive capacity of farmers. Adaptation activities in the agricultural sector can include crop diversification, intercropping, use of irrigation, water conservation activities, rainwater harvesting, reduced tillage, shifting cultivation, changes in livestock composition and diversification of incomes from kitchen and home gardens. These activities can also occur autonomously – introduced by the farmers themselves – and can include activities such as changes in sowing, planting and harvesting dates, and often several adaptation activities can be tried at the same time (Abid et al., 2015; Li et al., 2015; Rogé et al., 2014; Simelton et al., 2015). Moreover, agricultural extension services and other external supporting initiatives

such as crop and index insurance can be important in supporting farmers' resilience to climate change, but these services are not always available (Abid et al., 2015; Harvey et al., 2014; Nguyen et al., 2013; Steenwerth et al., 2014).

The agricultural sector can combine mitigation and adaptation activities to contribute with synergies, as is evident in the approaches and effects of sustainable agriculture or climate-smart agriculture (see Box 2) (Harvey et al., 2014). Likewise, agroforestry has the opportunity to provide food security and income diversification to increase households' adaptive capacities in cases of climate shocks or impacts, as well as achieve significant potential GHG reductions through the planting of trees (see Box 3; Pandey et al., 2016; Rahn et al., 2014).

BOX 3. AGROFORESTRY

Agroforestry has been defined as a ‘land use system that seeks to deliver sustainable improvements to food security, through integrating trees with other components of agriculture in multifunctional landscapes’ (Mbow et al., 2014). Large areas of agroforestry are found in South America (3.2 million km²), Sub-Saharan Africa (1.9 million km²) and Southeast Asia (1.3 million km²). Europe and North America also have large areas of agroforestry, despite having large commercial agricultural sectors (Zomer et al., 2009). Agroforestry systems in tropical and temporal regions tend to be tree-based production systems, such as the jungle rubber system in Sumatra, Indonesia, the mixed cocoa and fruit tree plantations in Cameroon, the peach palm systems in Peru, the pine-banana-coffee system in Java, Indonesia (Verchot et al., 2007), the shade coffee systems in Nicaragua (Rahn et al., 2014) and the *Grevillea* agroforestry system in Kenya (Lott et al., 2009). However, agroforestry is also found on a smaller scale as tree-based home gardens, contributing to household food security and income diversification (Linger, 2014; Nguyen et al., 2013). Agroforestry as an adaptive practice provides certain benefits. In general, farm profitability can be increased through improvement and diversification of the output per unit area of tree/crop/livestock. This is done through protection against the damaging effects of wind or water flow and by introducing new products, adding to the diversity and flexibility of the farming enterprise (Mbow et al., 2014). Agroforestry also provides households with fuel wood, livestock feed and hydrological services, thus increasing farmers’ and households’ resilience to climate variables (Branca et al., 2013). It can also substantially contribute to climate change mitigation (Smith, 2009; Thorlakson and Neufeldt, 2012; Verchot et al., 2007), as it increases the storage of carbon and carbon sequestration above ground. The positive and negative effects of mitigation and adaptation in agroforestry are shown in the table below (taken from Mbow et al., 2014).

		MITIGATION	
		POSITIVE	NEGATIVE
ADAPTATION	POSITIVE	<ul style="list-style-type: none"> • Soil carbon sequestration • Improving water-holding capacity • Use of animal manure and compost • Mixed agroforestry for commercial products • Income diversification with trees • Fire management 	<ul style="list-style-type: none"> • Dependence on biomass energy • Overuse of ecosystem services • Increased use of mineral fertilisers • Poor management of nitrogen and manure
	NEGATIVE	<ul style="list-style-type: none"> • Limited (use) rights to agroforestry trees • Forest plantation, excluding harvest 	<ul style="list-style-type: none"> • Use of forest fires for pastoral and land management • Tree exclusion on farmland

2.1 AGRICULTURAL MITIGATION ACTIVITIES THAT LEAD TO ADAPTATION BENEFITS

Mitigation in agriculture can include practices such as cropland management, management and improvement of pastureland, management of organic soils, restoration of degraded land, livestock management, manure management and bioenergy (Smith et al., 2007). Many management strategies can also contribute to adaptation benefits, as they can result in better plant nutrient contents and increased water-retention capacities, leading to higher yields and greater resilience (Campbell-Lendrum et al., 2014; Rosenzweig and Tubiello, 2007). However, Arslan et al. (2015) finds that activities such as a minimum of soil disturbance and crop rotation have no significant impact on maize yields. Other examples, including manure management and the avoidance of methane production from biomass deterioration, particularly in rice farming and livestock management, have significant mitigation potential, while also offering adaptation benefits through food security and diversification, enhanced productivity, the reduced risk of droughts and floods and improved livestock-based livelihoods (Klein et al., 2007a; Linger, 2014; Locatelli, 2011; Pandey et al., 2016; Steenwerth et al., 2014). Moreover, households

with tree-based home gardens in Ethiopia have higher species diversification compared to households with non-tree gardens (Linger, 2014). Linger (2014) points out other benefits, such as a reduction in the cost of fertiliser, as well as improved social relationships and reduced hunger among children caused by direct access to fruit in the garden, all of which increases the adaptive capacity of the household. Another example in Brazil involves pasture rotation systems and legume intercropping, which can form part of the mitigation strategy for livestock GHG emissions and can also provide adaptation benefits by increasing farmers' capacity through food security for livestock (Steenwerth et al., 2014). Finally, windbreaks are a well-known example of a mitigation contribution with adaptation benefits, as they are established in the fields to protect crops from dehydration and contribute organic material to the soil, thereby increasing soil fertility (Seck et al., 2005). To sum up, the examples of mitigation activities above contribute adaptation benefits that raise the socio-economic and biophysical adaptive capacity of communities, crops and the environment.

2.2 AGRICULTURAL ADAPTATION ACTIVITIES THAT LEAD TO MITIGATION BENEFITS

For crops like maize, rice and wheat, which are grown in tropical and temperate regions, climate change will mainly have negative impacts on production if temperature increases by two or more degrees Celsius (Porter et al., 2014). This will necessitate farmers adjusting the way they manage crops and livestock to secure the long-term stability of production (Havlik et al., 2014; Porter et al., 2014; Tubiello and Velde, 2011).

Several adaptation practices can positively support carbon sequestration in relation to land management under specific conditions. Specific adaptation activities targeted at crop diversification (such as home gardens with trees, legume intercropping, trees providing shade in tea and coffee plantations) can increase income options and lead to mitigation benefits, such as increased carbon sequestration below and above ground (Ashardiono and Cassim, 2014; Linger, 2014; Rahn et al., 2014). Improving soil fertility through increased inputs of organic matter will

not only improve the nutrient status and water-holding capacity of the soil, it can also reduce soil erosion and sequester carbon (Blanco et al., 2009). Other agricultural practices, such as soil and water conservation, crop diversification and improved or no tillage practices, can also make agricultural systems more resilient to climate change and improve the organic material in the soil, its water-holding capacity, nutrient availability and carbon sequestration (Matocha et al., 2012). For livestock farmers, adaptation strategies can include changing the composition of livestock from cattle to poultry and goats (Jacobi et al., 2015) or from cattle to camels, which are more adapted to periods of water scarcity and can provide milk (Steenwerth et al., 2014). On the other hand, certain adaptation activities may have negative outcomes. For example, increasing irrigation and increased use of cooling and ventilation systems will require more energy, resulting in more emissions, unless the energy comes from non-fossil fuel sources (Klein et al., 2007).

2.3 INTEGRATED AND SYNERGETIC ACTIVITIES

Agriculture has great potential for accomplishing both mitigation and adaptation (Smith and Olesen, 2010), specifically activities such as reducing soil erosion, reducing GHG emissions from agricultural processes, conserving soil moisture (where species and crops are improved through assortment and rotation) and improving microclimate to protect crops from temperature extremes and provide shelter. Other synergetic activities related to land use could be re-cultivating abandoned or exhausted farmland, avoiding cultivating new land, or even preventing the clearing or degradation of forests (Smith and Olesen, 2010). Examples of restoring exhausted soil, increasing food crop yields, household food security and incomes, increasing adaptive capacity and avoiding deforestation and the cultivation of new land can be found in Zambia, Niger and Burkina Faso (Garrity et al., 2010).

Food security is directly linked to the adaptive capacity of farmers and households to bounce back from climate change shocks or impacts. Agricultural activities can be categorised as contributing to high or low food security and a

high or low mitigation potential, which results in four categories of agricultural activities with varying food security and mitigation potentials (Figure 2). Activities with high food security and high mitigation potential include restoring degraded and exhausted land, introducing agroforestry to increase food and income options and increase carbon sequestration, and micro-activities such as establishing tree-based home gardens, mulching and the use of organic fertiliser. Activities with low food security potential and low mitigation potential include the cultivation of fallow and bare land, overgrazing by livestock and ploughing on slopes, which can result in soil degradation and exhaustion. The possible trade-offs between biofuel production and food production should particularly be noted, as often these two compete for land, with increases in retail food prices being linked to increases in biofuel production as a result. Moreover, biofuel production can conflict with food supply and water management specifically in the tropical areas of the world (Steenwerth et al., 2014).

		FOOD SECURITY POTENTIAL	
		HIGH	LOW
MITIGATION POTENTIAL	HIGH	<ul style="list-style-type: none"> Restoring degraded and exhausted land Lowering energy-intensive irrigation Agroforestry and the use of cover crops to increase food and income options, and above- and below-ground carbon sequestration Establishing tree-based home gardens Mulching Using organic fertiliser to increase yields and reduce GHG emissions 	<ul style="list-style-type: none"> Reforestation/afforestation Restoring/maintaining organic soils Expanding biofuel production Agroforestry options with limited impact on yield
	LOW	<ul style="list-style-type: none"> Expanding agriculture to marginal land Expanding energy-intensive irrigation Expanding energy-intensive mechanised systems 	<ul style="list-style-type: none"> Cultivation of fallow and bare land Overgrazing Slope ploughing

FIGURE 2. OVERVIEW OF THE EFFECTS OF AND RELATIONS BETWEEN FOOD SECURITY POTENTIAL AND MITIGATION POTENTIAL (BRANCA ET AL., 2013; LINGER, 2014).

The synergetic effects of JAM are in many ways already evident where sustainable agriculture or CSA is being implemented, because the activities needed for achieving adaptation and mitigation are similar (Harvey et al., 2014). As already men-

tioned, adaptation and mitigation are often pursued separately, especially in agriculture, where there are several examples of how this can lead to negative trade-offs on both the temporal and spatial scales (Rosenzweig and Tubiello, 2007;

Smith and Olesen, 2010). For example, increasing the use of agrochemicals in order to increase agricultural productivity when faced with climate change can increase the crop yields, but it may also increase overall GHG emissions (Kandji et al., 2006). Conversely, increasing the use of fast-growing tree monocultures or using biofuel crops may enhance carbon stocks and have a positive effect on emissions reductions, but it can also reduce water availability downstream and thereby degrade areas appropriate for agriculture (Huettner, 2012; Kongsager et al., 2013).

Some of the trade-offs can very well originate from the fact that climate change adaptation is often a result of the individual farmer's attempt to support his or her family (Mbow et al., 2014), therefore other objectives, such as mitigation and sustainability, are prioritised less or excluded. Short-term objectives such as these may therefore conflict with the longer term perspectives needed when considering sustainable development (Mbow et al., 2014). Nevertheless, initiatives such as payments for environmental services (PES) can be one way to pursue climate resilience and sustainable development. Such payments contribute directly to farmers to help manage risk and at the same time offer incentives to invest in and protect the natural resource base, which in turn contributes to mitigation potential through environmental services such as carbon sequestration and watershed regulation (see Box 4).

BOX 4. WHAT ARE PAYMENTS FOR ENVIRONMENTAL SERVICES?

PES, also known as Payments for Ecosystem Services, was originally defined by Wunder (2005: 3) as (1) a voluntary transaction where (2) a well-defined environmental service (or corresponding land use) (3) is 'bought' by a (minimum of one) buyer (4) from a (minimum of one) provider (5) if and only if environmental service provision is secured (conditionality).

Essentially PES is an approach designed to improve livelihoods and sustainable environmental management in a cost-effective way, rewarding custodians of the land for the provision of ecosystem services, such as watershed protection, soil stabilization and carbon sequestration.

Therefore, the potential synergetic effects of approaching adaptation and mitigation simultaneously, especially at the landscape level, and thus avoiding the trade-offs above, should not be ignored. Approaching JAM at the landscape level can catalyse diversification in the agricultural landscape through crop diversification, agroforestry, the restoration of riparian areas, including natural habitats and forest patches, the introduction of silvopastoral systems, livestock diversification and management, taking into consideration where livestock production can be intensified, and land management, including avoiding fragile areas for cultivation or pasturage (see Box 5). Harvey et al. (2014) specifically mention the potential for adaptation and mitigation at the landscape level in relation to the implementation of Farmer-Managed Natural Regeneration (FMNR) practices (also known as Faidherbia farmland) in several places in Africa. Here farmers encourage the systematic regeneration of existing trees and shrubs by re-growing and managing them from felled stumps, sprouting root systems or self-sown seeds. FMNR is an agroforestry system that involves nitrogen-fixing acacia trees. The trees only grow leaves during dry periods and drop them in wet periods, thus contributing to fertilising the soil. The adaptation benefits for farmers include income diversification, water regulation (improved infiltration), possible protection from landslides, increased fodder production during critical times and fuel wood supply, while the mitigation benefits are enhanced storage of carbon both above and below ground (Harvey et al., 2014). A similar initiative is the Ngitili, a traditional fodder bank system used to conserve pasture for the dry season in Tanzania, where it demonstrates both adaptation and mitigation effects, as it involves the regeneration and conservation of trees on land for cropping and grazing (Pye-Smith, 2010).

Table 2 provides an overview of the different practices and actions in agriculture, outlining the effects in three different columns: **1) Effect on agricultural adaptation**, explaining the positive or negative effects of the practices and actions on agricultural adaptation; **2) Effect on people's adaptation**, explaining the positive or negative effects of the practices and actions on farmers' adaptation, that is, how they help farmers adapt to climate change impacts through agriculture; and **3) Effect on mitigation**, explaining the positive or negative effects of these practices and actions on mitigation.

BOX 5. JAM AT THE LANDSCAPE LEVEL

Integrated landscape management, or climate-smart landscapes, is an effective solution to climate change (Hart et al., 2015; Locatelli et al., 2015; Scherr et al., 2012), being an approach where the landscape is increasingly seen as a multi-functional space specifically supporting food production, ecosystem conservation and rural livelihood across the entire landscape (Scherr et al., 2012). Locatelli et al. (2015) describe JAM at the landscape level as involving social adaptation, ecological adaptation and climate mitigation, thus identifying opportunities between adaptation and mitigation and minimizing the trade-offs between these outcomes.

A holistic approach to JAM at the landscape level, based on the known interactions between adaptation and mitigation (see Figure 1), will reduce the risk of climate change impacts and support ecosystem services, as well as increase biodiversity and carbon stocks at the landscape level. A landscape approach can further prevent fragmentation of the landscape and enable connectivity for floral and faunal migration under climate change (Locatelli et al., 2011). In particular, the restoration of agriculture landscapes is seen as an effective solution to climate change. However, pursuing JAM at the landscape level should not only consider the agriculture landscape, but the entire landscape, including the consideration and benefits of forest and riparian areas, watershed managements and other natural habitats contributing ecosystem services and benefits that exist and co-exist with the agricultural landscape.

Further JAM at landscape level captured at the field, farm or local or even regional levels creates the possibility to nurture a mosaic of habitats and ecosystems. This increases diversity, contributing to climate change resilience, adaptation and mitigation, and reducing the ecological risk otherwise found in homogeneous crop covers in an agricultural landscape (Scherr et al., 2012). Achieving JAM at the landscape level demands changes to current institutional arrangements, policies and funding options designed to support the implementation of climate-smart approaches in agricultural landscapes (Harvey et al., 2014; Locatelli et al., 2015; Mbow et al., 2014). It therefore requires management decisions or strategies to be made at the landscape level, but with appropriate care to ensure that the decision-making authority and influence are not taken away from the individual farmer. Pursuing JAM at the landscape level in a thoughtful manner will also provide the benefits of both adaptation and mitigation initiatives together to local beneficiaries, ensuring that negative trade-offs between different initiatives are minimised, and balancing the level of intervention needed compared to costs and benefits.

Scherr et al. (2012) finds three key benefits from focusing on the landscape approach: (1) through climate-smart practice, increase the benefits at the field level; (2) conservation of ecosystem functions; and (3) increasing climate change mitigation. To achieve the optimal outcome of pursuing JAM at the landscape level, it will be necessary for stakeholders to understand the opportunities they have in introducing a landscape approach, and then to identify, negotiate, prioritise and manage the landscape in that direction (Scherr et al., 2012).

A disadvantage of the landscape approach is that in some cases multi-stakeholder involvement could slow the implementation of initiatives, unnecessarily complicating implementation and creating incentives to pursue joint activities at any cost, thus neglecting fruitful initiatives that deliver only one outcome (Locatelli et al., 2015). Moreover, a lack of empirical knowledge and experience of the effects of JAM at the landscape level and of best practice in overcoming the barriers to implementing JAM at this level can create less-effective outcomes until more experience on implementing activities at this level is acquired.

In summary, this table shows that many of the agricultural practices and actions that are showcased in the literature can have many positive effects on agricultural adaptation and farmers' adaptation as well as mitigation. This points to the need to improve understanding of the bar-

riers to and opportunities for operationalising joint activities in order to evaluate the cost-effectiveness and accelerate the pursuit of joint activities in the future.

TABLE 2. OVERVIEW OF AGRICULTURAL PRACTICES AND ACTIONS WITH ADAPTATION AND MITIGATION BENEFITS

PRACTICES AND ACTIONS	EFFECT ON AGRICULTURAL ADAPTATION	EFFECT ON FARMERS ADAPTATION	EFFECT ON MITIGATION	REFERENCES
CROP MANAGEMENT				
Heat- or drought-resistant seeds Changing sowing, planting and harvesting times Changing crop type or varieties Shifting cultivation	+ Increased capacity and resistance to climate stress	+ Increased yields + Spreading risks through diversified crops, leading to more secure harvests		(Branca et al., 2013) (Li et al., 2015)
Cover crops Inter-cropping	+ Increased fertility and nutrient level in the soil + Enhance biodiversity	+ Increased yield + Income diversification + Food security	+ Increasing carbon sequestration below and above ground	(Branca et al., 2013)
Composting of manure and kitchen waste (vermicompost/vermiculture)	+ Increased fertility and nutrient level in the soil + Increased water retention capacities of the soil	+ Increased yield + Increased income from vermicompost	+ Increasing carbon sequestration below ground	(Sushant, 2013)
Mulching	+ Preserving moisture in the soil	+ Increased yield	+ Protection of existing carbon pool	(Li et al., 2015)
WATER MANAGEMENT				
Water-harvesting and conservation Increase irrigation Groundwater exploration for irrigation	+ Increased capacity and resilience to climate stress - Unsustainable, if groundwater is a finite resource	+ Increased yield	- Increased energy requirements (depending on the energy sources)	(Li et al., 2015)
LANDSCAPE AND LAND MANAGEMENT				
Management of organic soils Restoration of degraded land	+ Better plant nutrient content + Increased water retention capacities of the soil	+ Increased yield + Greater adaptation capacity	+ Protection of existing carbon pool	(Campbell-Lendrum et al., 2014) (Rosenzweig and Tubiello, 2007)
Soil-conservation techniques (organic fertilizer, reduced tillage and deep ploughing)	+ Better plant nutrient content + Increased water-retention capacities of the soil	- Decreased yield in (short term)	+ Increased carbon sequestration below ground	(Branca et al., 2013)

PRACTICES AND ACTIONS	EFFECT ON AGRICULTURAL ADAPTATION	EFFECT ON FARMERS ADAPTATION	EFFECT ON MITIGATION	REFERENCES
Diversification of the agricultural landscape (e.g. crop diversification, agroforestry, tree cover, crop rotation) Including natural habitats and forest patches	+ Risk reduction in relation to climate change impacts + Enhance the availability of ecosystem services + Resilience to pest and diseases among crops and livestock + Enhance biodiversity	+ Income diversification + Food security	+ Increase landscape carbon stock + Increased carbon sequestration above and below ground + Protection of existing carbon pool	(Harvey et al., 2014) (Branca et al., 2013)
Planting of windbreaks and shade trees	+ Protections of crops and livestock from climate stress + Increased soil quality and fertility + Reduce Soil erosion and risk of landslides + Enhance biodiversity	+ Income diversification + Food security + Protect people from climate stress	+ Reduce carbon loss + Increased carbon sequestration above and below ground + Protection of existing carbon pool	(Harvey et al., 2014) (Seck et al., 2005) (Jacobi et al., 2015) (Matocha et al., 2012)
Tree based home garden	+ Protecting of smaller crops in the home garden from climate stress; sun, rain, wind etc. + Enhanced biodiversity	+ Income diversification + Food security + Protect people from climate stress + Reduce hunger among children, because of the direct access to fruit	+ Increased carbon sequestration above and below ground	(Linger, 2014)
LIVESTOCK				
Silvo-pastoral system rotation pasture	+ The natural resources of the landscape are included as a measure of adaptation + Enhanced biodiversity	+ Climate-tolerant legumes can be an alternative fodder source + Food security + Income diversification + Reduction in cost of fertilizer for the fields, because of access to manure	+ Protection of existing carbon pool + Increasing carbon sequestration below ground + Elimination of use of fire in pasture management	(Jarvis et al., 2011) (Linger, 2014) (Steenwerth et al., 2014)

PRACTICES AND ACTIONS	EFFECT ON AGRICULTURAL ADAPTATION	EFFECT ON FARMERS ADAPTATION	EFFECT ON MITIGATION	REFERENCES
Converting livestock to more heat- or drought-tolerant species Diversification of livestock Changing from crops to livestock	+ Increased adaptive capacity to climate stress + increased mobility	+ Food security + Income diversification + Increased mobility for the household if they are forced to move + Faster income reliefs in case of climate shocks	+ Manure management to avoid emissions + Mortality reduction of animals + Reduction of deforestation and pasture burning through PES	(Steenwerth et al., 2014) (Li et al., 2015)
Manure used for fertilizer	+ Increased fertility and nutrient level in the soil + Increased water-holding capacity,	+ Increased crop yield + Cost savings on fertilizer,	+ Increased carbon sequestration below ground	(Steenwerth et al., 2014)
EXTERNAL SUPPORT				
Farmers organisations	+ Increased knowledge and knowledge sharing	+ Social capital + Increased capacity and resilience		(Steenwerth et al., 2014)
Insurance of crops and livestock	+ Create incentives for investment and income diversification - Risk of corruption among insurance verifiers	+ Capital relief	+ Avoid exhausting soils + Avoid deforestation and invasions of new land for agricultural areas + Protection of existing carbon pool	(Jarvis et al., 2011) (Steenwerth et al., 2014)
Subsidies	+ Create incentives for investment and income diversification - Risk of corruption among program implementers	+ Increased adaptive capacity and resilience	+ Avoid exhausting soils + Avoid deforestation and invasions of new land for agriculture + protection of existing carbon pool	(Steenwerth et al., 2014)
Extension services	+ Increased knowledge and knowledge sharing + Create incentives for new initiatives - Risk of corruption among staff implementing the extension services	+ Increased adaptive capacity and resilience + Increased awareness	+ Avoid exhausting soils + Avoid deforestation and invasions of new land for agriculture + protection of existing carbon pool	(Steenwerth et al., 2014)
PES or other income generating carbon schemes	+ Enhanced biodiversity - Risk of corruption among program implementers	+ income diversification + Increased adaptive capacity and resilience	+ Avoid exhausting of soils + Avoid deforestation and invasions of new land for agriculture	(Steenwerth et al., 2014)

3. JOINT ADAPTATION AND MITIGATION IN FORESTRY

Forests cover 31 per cent of the earth's land surface (FAO, 2010), and climate change is likely to have a wide range of impacts on the socio-economic systems that surround forests and the natural ecosystems of forests. In terms of biophysical impacts, forests are likely to experience range shifts, changes in patterns of tree growth, changes in insect and disease susceptibility and distribution, changes in disturbance regimes such as fire, and changes in soil properties (Evans and Perschel, n.d.; Yuan et al., 2011). This will reduce the capacity of natural sinks to absorb carbon and increase natural sources of CO₂. Agriculture, Forestry and Other Land Use (AFOLU) activities have a feedback link to climate change in that these activities can reduce or accelerate climate change, affecting biophysical processes such as evapotranspiration and albedo (Yuan et al., 2011). Studies reviewed by the IPCC show that climate change may increase the frequency and severity of droughts in peatlands in particular and become a source of GHG (Yuan et al., 2011).

In terms of socio-economic impacts, shifts in natural ecosystems will influence how communities use and depend on forests. The potential for forest resources to contribute to rural households is becoming increasingly apparent, as studies of the contribution of forest and wild products to the household income portfolio show that forest products on average represent 22 per cent of household incomes (Angelsen et al., 2014). Indeed, in general forests can fulfil three important roles: (1) support current consumption; (2) provide a safety net in cases of shocks and crises and fill gaps during seasonal shortfalls; and (3) represent a means to accumulate assets and provide a path out of poverty (Angelsen et al., 2014). Furthermore, today the livelihood of millions of people, particularly the rural poor, are inextricably linked to forests (Angelsen and Wunder, 2003; Cammack, 2004). The consequences of shifting ranges and the distribution of forests and their products, as well as other disturbances, can thus leave the forest-dependent poor particularly vulnerable.

The IPCC has calculated that forestry and other land uses accounted for about one third of anthropogenic CO₂ emissions from 1750 to 2011 and for 12 per cent of emissions from 2000 to 2009, with a large proportion of that coming from changes to land use, mainly deforestation (Smith et al., 2014). Forest-related mitigation activities are therefore a relatively quick win in the race to slow down the rate of carbon emissions. However, the socio-economic and biophysical impacts of climate change on forests and vice versa significantly affect forests' ability to function as a carbon sink. According to the latest Emissions Gap Report by the UNEP (2015), forest-related mitigation activities, which include avoiding deforestation and reducing degradation, afforestation and reforestation, have the technical potential to mitigate up to 9 GtCO₂ by 2030 if all forest-related activities that degrade or clear the carbon sink were stopped today.

Several characteristics specific to this sector can also have a bearing on the pursuit of JAM activities in this sector. First, the gestational period of forestry projects from idea to implementation tends to be quite long, and the benefits of mitigation cannot be harvested until many years later. This affects the permanence of carbon stocks, but it also makes it more susceptible to issues of land-tenure security, particularly since forests are often formally owned by states, but managed by local communities (Ravindranath, 2007). As mentioned above, forests are also a source of food, shelter, medicine and income, but returns are often low, and forest-based livelihoods rely heavily on the subsistence use of resources (Elias et al., 2014; Ravindranath, 2007). Hence, although challenging, achieving JAM in this sector is both socially and economically important.

3.1 FOREST-RELATED MITIGATION ACTIVITIES THAT LEAD TO ADAPTATION BENEFITS

Forests play a particularly important role in mitigation, mainly due to their capacity to sequester and store carbon. Deforestation and forest degradation are believed to have contributed 12.5 per cent to global GHG emissions from 1990 to 2010 through tropical deforestation (Houghton et al., 2012). The main mitigation activities within forestry are afforestation, reforestation and avoiding deforestation (IPCC, 2000). Nevertheless, mitigation projects have the potential to facilitate adaptation by reducing pressure, conserving biodiversity (through conservation) and enhancing connectivity (Locatelli et al., 2011).

Forestry mitigation projects, largely in the form of forest conservation, can facilitate the adaptation of forests to climate change by reducing the anthropogenic pressure on forests, enhancing the connectivity between forest areas and conserving biodiversity hotspots (Locatelli, 2011). Forestry mitigation projects can also reduce vulnerability and promote adaptation through forest conservation, protected area management and sustainable forest management, but they can also have consequences for adaptive responses and/or the development objectives of other sectors (for example, expansion of farm land) (Smith et al., 2014). Importantly, forestry mitigation activities, including conservation actions, are relatively more cost-effective, safe and easy than other mitigation actions (in other sectors) and are therefore seen as a critical strategy in reducing emissions (Nabuurs et al., 2007; Ravindranath, 2007; Turner et al., 2009). Given the limited need to rely on technological development, it has

been argued that ecosystem restoration will remain the only realistic large-scale climate change mitigation mechanism for the coming decades (Turner et al., 2009). However, strict conservation alone can also have negative effects, such as restricting access to land and forest resources, as well as encouraging dependence on external funding (Locatelli, 2011). The resilience of a natural diversified forest ecosystem is much greater than that of a monoculture plantation, as the former is more resilient to disturbances and provides important ecosystem services, such as water and microclimate regulation (Turner et al., 2009).

Plantation establishment through afforestation or reforestation can also be an effective way of sequestering carbon and preventing other environmental disasters, such as desertification, just as it can represent a useful source of income. The Carbon Farming Initiative, developed by the Australian government, is a voluntary carbon offset scheme rewarding farmers and landholders through the carbon credits system for actions to store carbon on their land (afforestation or reforestation) or to reduce GHG emissions (Commonwealth of Australia, 2013). However, other concerns related to plantation establishment, such as preserving biodiversity, are only incorporated as safeguarding measures (van Oosterzee, 2012). Indeed, if plantations reduce biological diversity, they may also reduce the capacity of people to adapt to climate change. Furthermore, monocultures are often more vulnerable to climate change than other cultures (Campbell-Lendrum et al., 2014).

3.2 FOREST-RELATED ADAPTATION ACTIVITIES THAT LEAD TO MITIGATION BENEFITS

Forests play an important role in adaptation. 'Adaptation for forests' refers to the adaptation needed for forests to maintain their function (Locatelli et al., 2011). Such adaptation strategies for forests can include the anticipatory planting of species along latitudes and altitudes, assisted natural regeneration, mixed-species forestry, species-mix adapted to different temperature tolerance regimes, fire protection and management practices, thinning, sanitation and the intensive removal of invasive species, surplus seed banking, altering harvesting schedules and other

silvicultural practices. Moreover, it can include the in-situ and ex-situ conservation of genetic diversity, drought and pest resistance in commercial tree species, the adoption of sustainable forest management practices, increasing protected areas and linking them, when possible, to promote the migration of species, forest conservation and reduced forest fragmentation enabling species migration, and finally energy-efficient fuelwood cooking devices to reduce the pressure on forests (Millar et al., 2007)).

Strengthening the resilience of forests also increases the permanence of carbon (Malhi et al., 2009). 'Forests for adaptation' refers to how forests can support households in their adaptation to climate change and in coping with climatic change by acting as safety nets, gap-fillers and providers of local environmental services in response to climate-related fluctuations with lower food availability (Locatelli et al., 2011). Ecosystem-based adaptation is one example of this (see Box 6). Pramova et al. (2012) provide an overview of five cases where forests and trees contribute to adaptation. First, forests and trees can represent goods to local communities facing climate impacts. Second, trees on farms can regulate the soil, water and microclimate, thus facilitating more climate-resilient forms of production. Third, forested watersheds regulate the water and protect the soil. Fourth, mangrove forests can protect coastal areas. Fifth, urban forests can regulate the temperature and water of cities. Rural households are destined to be among those that are most affected by the changing climate, including impacts such as decreased rainfall and

increased storms and damage that threaten resource-based livelihoods, including agriculture. With intensified impacts of climate variability in other sectors such as agriculture, water and energy, forests may come to play an even more important role as safety nets (Angelsen et al., 2014; Nkem et al., 2010). For example, 'trees on farm' systems are used to provide shade, reduce temperatures and lessen the impact of hard rainfall and wind, both for certain crops (agroforestry systems) and livestock (silvipastoral practices) (Verchot et al., 2007). Conversely, climate shocks can enhance people's harvesting of forest products, thereby degrading the forest base, particularly if climate shocks become more frequent and intense (Locatelli, 2011). Adaptation and forestry mitigation projects can be linked by incorporating standards for adaptation into forest carbon certification and strengthening the capacities of project developers to accommodate both components (Kongsager and Corbera, 2015). National and international policies can also create conditions to facilitate the development of JAM activities (Locatelli, 2011).

BOX 6. ECOSYSTEM-BASED ADAPTATION (EbA)

EbA projects are characterised by integrating the use of biodiversity and ecosystem services into an overall strategy to help people adapt to the adverse impacts of climate change, can contribute to mitigation by increasing or maintaining carbon stocks in forests (Colls et al., 2009). Though EbA encompasses many different types of ecosystems, forests play a central role as they are often major providers of ecosystem services (Locatelli et al., 2010). The costs of maintaining ecosystems may be lower and the end results can be more effective than for more sophisticated adaptation measures. Although clearly a human-oriented adaptation strategy, there are clear mitigation benefits of conserving forests and avoiding emissions. Within EbA, mitigation approaches such as REDD+ or PES can also be utilised to ensure that project objectives also focus on mitigation (Rizvi et al., 2015).

EbA can also be used to ensure the provision of particular ecosystem services that are crucial for human adaptation, for example water regulation (Locatelli et al., 2010). For example, sustainable watershed management is recognised as crucial in stabilising water supplies to African cities, which will face water scarcity in the future (Mafuta et al., 2011). At the same time, conservation of forested areas ensures the preservation of carbon stocks. Further examples of EbA can be found in the tsunami-affected areas of South and Southeast Asia, where coastal ecosystems were rehabilitated with mangroves and other coastal vegetation, increasing the carbon storage potential (Wetlands International Report, 2011). Mangroves also dissipate wave energy, rendering the impact of storms and other climatic events less severe for both people and the coastline. Another example is forest fire management in West Arnhem Land in Northern Australia. Mitigation benefits include limiting or preventing wildfire emissions, but the initiative also increases the adaptive capacity of forests to extreme climatic events, which may lead to increased fire frequency and intensity (ProAct, 2008).

3.3 INTEGRATED AND SYNERGETIC ACTIVITIES

Activities contributing to conservation and reduced deforestation can have mitigation benefits through carbon sequestration and carbon storage, as well as a range of adaptation benefits. For example, reduced deforestation can be achieved by reducing the dependence on land-based economic sectors (for example, agriculture and livestock) and by creating environments that facilitate such development (for example, removing the subsidies that encourage aggressive land-clearing). REDD+ aims to reduce carbon emissions from deforestation and forest degradation and covers both sustainable forest management and the enhancement of carbon stocks. It has become an important policy tool that will allow forest-rich countries to offset their carbon emissions. REDD+ has gained increasing traction, but it was only in the recently signed Paris Agreement (2015) that it was recognised as a viable path to reductions in CO₂ emissions. Though REDD+ was originally envisioned as an international PES scheme (see Box 1 for example, Angelsen et al., (2009), it is now apparent that emerging REDD+ initiatives are continuing integrated conservation and development strategies (Sunderlin et al., 2014a). Indeed, less than half of the 23 incipient REDD+ projects reviewed by Sills et al. (2014) were making conditional payments for actions to reduce deforestation and degradation. Nevertheless, adaptation benefits from such payment programmes can contribute to enhancing households' economic resilience, while also achieving mitigation benefits through preserving carbon stocks. In the cases reviewed by (Caplow et al., 2011), positive income and employment benefits were found; particularly in the Noel Kempff Mercado Climate Action Project in Bolivia, mitigation activities have produced positive livelihood impacts through the promotion of livelihood activities supporting conservation and sustainable management. The same project, however, suffered from poor inclusion and project coordination, largely due to the scale of the area involved, similar to the issues that concern conservation and development projects (May et al., 2004). Another example is the Bolsa Floresta programme (also known as the Forest Allowance programme) in the Amazon, which emphasises sustainable livelihood development, while achieving mitigation benefits through forest conservation (Börner et al., 2013).

Expanding or establishing protected areas can also lead to mitigation and adaptation benefits for forests, biodiversity and people. For instance, conservation corridors enable wildlife to migrate between areas for food and shelter. Intact forests lead to increased ecosystem resilience and the provision of regulating environmental services, such as water-cycling and microclimate regulation. Finally, greater ecosystem resilience achieved through conservation can conserve biodiversity and reduce susceptibility to disturbances such as fire. People also benefit from such activities by being less affected by disturbances, having access to a resource base and regulating ecosystem services that can help them adapt to climate change. Indeed, conservation actions are increasingly relevant to forest-dwelling communities, which may rely on forest products to diversify income streams in times of need or on forests for current consumption. Another coping strategy is harvesting of forest products (Fisher et al., 2010), which may serve an important function in the face of the increasingly unstable climate and its impact on food supply. Enhanced soil fertility and soil protection can increase the productivity of small-scale agriculture, which may in turn lead to reduced land-clearing. Nevertheless, overharvesting and forest degradation can become problematic if the severity and frequency of climate shocks increase (Locatelli et al., 2011). On the other hand, designating protected areas and placing restrictions on forest use may limit the consumption of forests and forest products, as well as restrict access to resources that people may depend on (Streck, 2009).

Activities aimed at reducing degradation may focus on sustainable forest management activities or practices that reduce the risk of disturbances such as fires or pests. Sustainable forest management, defined as 'a dynamic and evolving concept aiming to maintain and enhance the economic, social and environmental values of all types of forests for the benefit of present and future generations' (UN, 2008), represents a holistic approach to forest management. The failure to manage forests in a sustainable way drastically reduces their adaptive capacity; this includes benefits such as increasing ecosystem resilience to climate change, soil erosion protection, soil fertility enhancement and even watershed and microclimate regulation, depending on the degree of reforestation (Locatelli et al., 2010). Clearly, a reduc-

tion in forest disturbances will positively benefit people's ability to adapt to climate change and reduce the impact of that on household economy and productivity. Fire management practices can have important adaptation benefits, especially in the hotter and drier climates of fire-prone areas, as well as mitigation benefits, as carbon stocks are preserved or maintained (Matocha et al., 2012). However, some adaptive measures, such as reducing rotation times or suppressing fires, can jeopardise the permanence or decrease carbon stocks in the long run. Sustainable forest management can also be implemented with mitigation as the main objective, for instance, in fire management. While fires are necessary for some ecosystems to maintain their function, in others the results can be devastating, leading to slow regrowth, lost biomass and reduced ecosystem services (Elias et al., 2014). More frequent and intense fires can make systems such as the Amazon rainforest reach a tipping point beyond which the forest cannot bounce back, resulting in a transition to grassy savannah-type environments (Nepstad et al., 2008).

Activities associated with afforestation and reforestation can lead to the direct mitigation benefits of restoring carbon stocks. Adaptation benefits for people include the provision of wood fuel to meet current resource demands and thereby reduce pressure on other natural forest areas. Environmental services such as water regulation, flood and erosion control can result in improved water availability and water regulation, soil conservation and increased arable land (Somorin et al., 2012). This is particularly true of water-abundant regions or areas that experience intense rainfall seasons interspersed with long dry spells (Locatelli et al., 2011). Such soil and water conservation benefits can reduce the impacts on tree growth. For forests, short-rotation species in commercial or industrial forestry or silvicultural practices, for example, sanitation harvests, can reduce susceptibility to pests and disease. However, afforestation and reforestation activities have certain negative effects. In semi-arid and arid regions, the demand for water can be high and will increase in hotter climates, while forestry is more water-demanding than other land uses (FAO, 2008; Klein et al., 2007a). Other concerns are land use and availability. For instance, reforestation plans may conflict with future demands for land for cultivation in the face of climate changes and, thereby, land productivity (arable land). Biodiversity can also be affected

through monocultures in afforestation and reforestation, which promote fast-growing alien species (Klein et al., 2007). To minimise trade-offs, afforestation and reforestation activities can ensure the use of diverse tree species or native tree species (Ravindranath, 2007) or planting in degraded or marginalised lands, thus enhancing sustainable forest management (Duguma et al., 2014).

Overall several synergetic or integrated activities can be achieved within forestry, leading to greater cost and project efficiency (Somorin et al., 2012). An overview of integrated and synergetic practices and actions in forestry that result in mitigation and adaptation benefits is given in Table 3. The three columns note the positive and negative effects of these practices and actions on 1) forest adaptation, that is, how practice contributes to or detracts from building forest resilience to climate change impacts; 2) people's adaptation, that is, how practice contributes to or detracts from building people's resilience to climate change impacts, particularly forest-dependent people; and 3) mitigation.

TABLE 3. OVERVIEW OF PRACTICES AND ACTIONS IN FORESTRY WITH ADAPTATION AND MITIGATION BENEFITS

PRACTICES AND ACTIONS	EFFECT ON FOREST ADAPTATION	EFFECT ON PEOPLE'S ADAPTATION	EFFECT ON MITIGATION	REFERENCE
CONSERVATION AND REDUCED DEFORESTATION				
Avoided/reduced deforestation of forests, e.g. changes in policies, economic growth sectors	+ Increase in ecosystem resilience to climate changes + Soil erosion protection and soil fertility enhancement + Watershed regulation	+ Microclimatic regulation for people, livestock, crops and wildlife + Coastal area protection + Increase in crop resilience	+ Increase and enhance carbon sequestration above and below ground + Protecting against watersheds can benefit hydropower and clear energy	(Locatelli et al., 2015) (Malhi et al., 2009)
Avoided deforestation through REDD+/payments for environmental services	+ Microclimate regulation	+ Payments can contribute to household welfare, improve economic resilience		(Campbell, 2009) (Jarvis et al., 2011)
Expansion or formation of protected areas	+ Linking areas through corridors + Reduced impact logging + Conserving biodiversity + Reducing disturbances, e.g. fire	+ Preserving resource base as household safety net + Preserving ecosystem services, e.g. water regulation + Diversify livelihoods and incomes - Competition for land/ decreased access to land - overuse of forest resources for coping with climate shock, can lead to degradation of the forest		(Brown et al., 2011) (Mustalahti et al., 2012) (Alexander et al., 2011) (Locatelli et al., 2011) (Athanas and McCormick, 2013) (Stromberg et al., 2011)
REDUCED DEGRADATION				

PRACTICES AND ACTIONS	EFFECT ON FOREST ADAPTATION	EFFECT ON PEOPLE'S ADAPTATION	EFFECT ON MITIGATION	REFERENCE
Fire management and protection	<ul style="list-style-type: none"> - Shortened rotation times to adapt to CC can decrease carbon stocks - Fire suppression can jeopardise permanence of carbon stocks + Early warning and improved fire fighting 	<ul style="list-style-type: none"> + Microclimatic regulation for people and crops + Increase in crop resilience + Preserving resource base as household safety net + Preserving ecosystem services, e.g. water regulation + Diversify/uphold livelihoods and incomes 	<ul style="list-style-type: none"> + Decrease in carbon stocks + Permanence of carbon stocks - Reduced/limited GHG emission as a result of reduced intensity 	<ul style="list-style-type: none"> (Couture and Reynaud, 2009) (ProAct, 2008) (Swart and Raes, 2007)
Sustainable forest management, including pest/disease management	<ul style="list-style-type: none"> + Restoring degraded natural forest land through regeneration of native species and natural regeneration of degraded land + Increase in ecosystem resilience to climate change + Reduce disturbances, e.g. through fire-protection regimes + Soil-erosion protection and soil-fertility enhancement + Watershed regulation + Microclimate regulation 		<ul style="list-style-type: none"> + Increase and enhance carbon sequestration, and carbon storage above and below ground 	<ul style="list-style-type: none"> (Ravindranath, 2007) (Duguma et al., 2014)
SEQUESTRATION				
Afforestation	<ul style="list-style-type: none"> + Reduce susceptibility to pest/disease through e.g. short rotation species in commercial or industrial forestry or silvicultural practices, e.g. sanitation harvests + Reduce adverse impacts on tree growth through e.g. soil and water conservation measures 	<ul style="list-style-type: none"> + Meeting current resource demands, e.g. wood fuel + Regulation of environmental services, e.g. water + Stabilise slopes and reduce flooding + Lower vulnerability to heat stress 	<ul style="list-style-type: none"> + Increase and enhance carbon sequestration, and carbon storage above and below ground - Some trees may not be as effective in sequestering carbon 	<ul style="list-style-type: none"> (Ravindranath, 2007) (Duguma et al., 2014) (Dang et al., 2003) (Klein et al., 2007a)
Reforestation	<ul style="list-style-type: none"> - Reduced ecological adaptation (fast-growing monocultures are more vulnerable) 	<ul style="list-style-type: none"> - Decreased food security - Compete for land - Short-term benefits for few - Reduction in water availability in arid regions - Reduced ecosystem resilience resulting from monocultures 		<ul style="list-style-type: none"> (Stringer et al., 2012) (Beymer-Farris and Bassett, 2012) (Schroback et al., 2009) (D'Amato et al., 2011)

4. BARRIERS AND OPPORTUNITIES TO JOINT ACTIVITIES IN AGRICULTURE AND FORESTRY

4.1 INSTITUTIONAL AND POLICY BARRIERS AND OPPORTUNITIES

Institutional and policy barriers and opportunities can both hinder and facilitate the development of JAM activities. At the national level, Locatelli et al. (2011) found that in Latin America national policies are rarely set up to accommodate the integration of adaptation and mitigation activities, the strongest focus still being on mitigation activities. They also found that in CDM projects in Colombia the government recognised the lack of an adaptation requirement in the approval process. At the national level, adaptation and mitigation were managed by separate ministries or institutions, largely due to differences in sectoral focus and geographical scales of implementation. Policies that are uncoordinated and, at times, conflict in the areas of climate change mitigation and adaptation, food security and economic development can generate perverse incentives that can unintentionally lead to the unsustainable use and overuse of resources and conflicting goals, hindering a more all-inclusive approach to joint activities (Campbell et al., 2011; Hoffmann, 2011). For example, the fragmentation of mandates and tasks by different government agencies is one of the main challenges in moving REDD+ projects ahead in Vietnam and Indonesia (Thuy et al., 2014).

At the international level, the story is similar to the country-specific one above. The UNFCCC treats mitigation and adaptation as separate policy measures (Duguma et al., 2014), though recognition of joint adaptation and mitigation measures has been growing. International agree-

ments have had a strong focus on mitigation, for example, setting emissions targets under Kyoto (Locatelli et al., 2010), while adaptation is viewed as a means to achieve mitigation (Duguma et al., 2014). Adaptation and mitigation are addressed through different processes and are discussed in corresponding policy debates that are rarely linked and that can involve different constituencies and funding sources (Harvey et al., 2014; Verchot et al., 2007).

Reasons for this may be because in many cases policy planning is short term, whereas the integration of adaptation and mitigation goals requires long-term planning as a result of their varying time scales for implementation and effect (Harvey et al., 2014). For instance, in some cases policies supporting conventional agricultural practices predominate over those supporting climate-smart agriculture. However, promoting multi-stakeholder planning across local, regional, national and business interests could avoid this barrier by raising awareness among policy-makers and other decision-makers about activities with adaptation and mitigation goals – for instance, (i) developing NAPAs, NAMAS and REDD+ strategies that include JAM practices, or (ii) securing high-level commitments to conservation agriculture, agroforestry and other climate-smart agriculture practices (Harvey et al., 2014), as well as incorporating JAM objectives directly into sector policies (e.g. forestry, Locatelli et al. (2015).

4.2 KNOWLEDGE AND CAPACITY BARRIERS AND OPPORTUNITIES

The fundamental divide between mitigation and adaptation also affects the way project developers think of their projects, as is evident from the large number of projects that can potentially contribute win-win outcomes for both adaptation and mitigation, but fail to do so (Locatelli et al., 2011).

Empirical studies of the synergies in forestry and agriculture are few, and more research is needed to explore these linkages in forests at the levels of landscapes, projects, countries and international agreements (Naidoo et al., 2008). Methods for assessing the magnitude of the ecosystem services that are generated through forest conservation

and reforestation are needed, as are methods for measuring the role of ecosystem services in reducing the vulnerability of communities to climate change (Locatelli et al., 2011; Naidoo et al., 2008). The difficulty associated with documenting and collecting data on the benefits of ecosystem services amongst users often plays a central role (FAO, 2015) (FAO, 2015).

Moreover, at the individual level, farmers may face another level of barriers, namely tradition and the social acceptability of change, which can ultimately affect their willingness to adopt new initiatives. This results in the need for awareness and communication of the need for and benefits of climate change adaptation initiatives (Smith and Olesen, 2010). Related to this, capacity barriers have become increasingly relevant. The failure of extension services in some African countries restricts the ability to upscale innovations in agroforestry for improved land-use systems (Mbow et al., 2014). Specifically, knowledge of advanced cultivation methods and technical support is necessary before farmers can add trees to cropping systems and/or animal production, and it may also promote the swift adoption of agroforestry techniques (Matocha et al., 2012).

There is a technical difference between mitigation and adaptation concerning their physical evaluation, where single-metric GHG emissions exist for mitigation, but not for adaptation (Watkiss et al., 2015). Moreover, there are no metrics for evaluating the synergetic benefits of mitigation and adaptation (Duguma et al., 2014). The synergetic effects have only recently begun to be described, and there is still some scientific uncertainty as to what constitutes the optimal mix of adaptation and mitigation, when the goal is to achieve the best benefits of different kinds of synergies (Klein et al., 2005). Moreover, both adaptation and mitigation suffer from other methodological challenges: there are high levels of uncertainty and large

costs involved in measuring and monitoring emissions reductions, including complications in establishing a baseline. REDD+ projects in particular face significant methodological challenges with regard to linking co-benefits to carbon benefits, as common measures for evaluating biophysical and welfare outcomes still need to be developed (Caplow et al., 2011). At the landscape level it is essential to track and monitor the diversity of farming and the changing impacts and threats facing farming (e.g. of agricultural production, ecosystem services and human welfare) in order to monitor the synergies and trade-offs of different agricultural development scenarios and inform future sustainable agricultural development (Sachs et al., 2010).

To solve the existing technical, knowledge and capacity-building barriers, Harvey et al. (2014) have argued that it is necessary to develop tools for policy-makers and other decision-makers to visualise the potential outcomes of different joint strategies concerning mitigation and adaptation, food production, energy, incomes and other related objectives. More analytical assessments of ongoing JAM initiatives and projects can therefore provide the evidence for when and where pursuing adaptation and mitigation simultaneously is more beneficial and cost-effective than implementing them separately. Also knowing the impact of future climate change on current joint activities is essential, for example, knowing how tree species distributions will change in future climate scenarios, particularly if agroforestry relies on a certain tree species. Importantly, there is a large gap in our knowledge of how mitigation can benefit from adaptation (and vice versa) and of the added value of integrated strategies. Also, certain contextual factors should be in place that can largely determine whether mitigation and adaptation should be pursued separately or combined, but this knowledge also needs to be acquired (Locatelli et al., 2015).

4.3 FUNDING AND OTHER BARRIERS AND OPPORTUNITIES

Funding bodies often look at mitigation and adaptation separately, and current funding of adaptation and mitigation projects rarely takes synergies into account (Duguma et al., 2014; Kongsager et al., 2015). In addition, many mitigation and adaptation projects have been on a small to medium scale; hence, identifying the project-level capacity of JAM can perhaps be achieved by first identifying the adaptation

co-benefits of mitigation projects or vice versa (Illman et al., 2012). Project standards such as the Voluntary Carbon Standard only consider the livelihood impacts of mitigation activities, not of adaptation. However, a concept like PES and payment schemes such as REDD+ and co-investment schemes (Namirembe et al., 2014) show increasing potential when it comes to incorporating adaptation activities. The Climate Gold

Level of the CCB Standards' Third Edition adopts an optional criterion, which can be used to identify and promote projects that provide significant support to communities and/or biodiversity with regard to adapting to anticipated climate change impacts and risks (Namirembe et al., 2014). This is a starting point for the joint funding of JAM activities.

Even though there are indications that certain climate management practices generate savings over their lifecycle, many also involve upfront costs and short-term risks (FAO, 2009; Hoffmann, 2011; McKinsey, 2009). For example, soil and water conservation infrastructures can require large upfront costs in terms of labour and external efforts (FAO, 2009). Although the financial incentives for some mitigation practices may take the form of agricultural carbon credits, and some only benefit smallholders, a number of issues need to be taken into consideration here to enhance the options for carbon incomes to create incentives for adaptation initiatives and thus overcome the barrier of underfunded adaptation initiatives.

The lack of joint coordinated funding streams for adaptation and mitigation is another key constraint (Buchner et al., 2013; FAO, 2013). The private sector and carbon finance represent the

main sources of funding for mitigation activities, whereas public funds, NGOs and donors often prioritize poverty alleviation, food security or disaster relief, which tends to complement adaptation priorities (Lobell et al., 2013; Schalatek et al., 2012). This traditional separation of funding sources (and funding eligibility criteria) has created silos in the implementation of adaptation and mitigation measures on the ground (Schalatek et al., 2012), as well as hindering the adoption of integrated landscape-level approaches (Harvey et al., 2013; FAO, 2013).

In REDD+ projects, tenure security poses a major barrier (Kongsager and Corbera, 2015; Sunderlin et al., 2014a). Without secure tenure and rights to use forest resources, the potential of forests to support local communities and our chances of further developing REDD+ will be limited (Sunderlin et al., 2014a). Recent evidence has shown that transfers of ownership of large areas of forest commons to communities coupled with carbon payments can both contribute to mitigation and introduce livelihood improvements (Chhatre and Agrawal, 2009). Moreover, the twenty to thirty-year time scale of REDD+ projects creates uncertainty when it comes to evaluating whether such projects will indeed have positive outcomes (Caplow et al., 2011).

5. CONCLUSION

The present review of the concepts and practices of joint adaptation and mitigation in agriculture and forestry highlights the complexity and challenges involved in both defining and operationalising joint activities. Issues such as the differences between adaptation and mitigation activities in terms of scale of implementation, time horizon for implementation, availability of funding for mitigation versus adaptation and the metrics to measure mitigation versus adaptation pose significant challenges to the pursuit of joint activities.

Land use is one of the key sectors that has great potential for creating synergies between mitigation and adaptation actions, potentially achieving both objectives at little or no extra cost. Importantly, mitigation and adaptation in two of the major land uses – agriculture and forestry – have interconnected effects on agriculture or forest ecosystems and on society, making the pursuit of joint activities even more complex, but at the same time offering mutual benefits. The positive benefits of adaptation can also be mutually beneficial for development, and often positive development benefits are likely to contribute to positive effects on people's adaptive capacity. Moreover, the positive nature of these benefits, showcased by empirical studies in Tables 2 and 3, emphasises the need to pursue joint activities and further research to understand the barriers and opportunities to operationalisation.

The current coverage of joint adaptation and mitigation in the literature has also been piecemeal, as there is no one definition of a joint adaptation-mitigation activity. At best, scholars have attempted to describe the linkages, interrelationships, complementarity, substitutability, synergies and trade-offs that currently exist in empirical examples in agriculture and forestry, among others. From this we have compiled the major activities that can be categorised into mitigation activities with adaptation benefits, adaptation activities with mitigation benefits, integrated or synergetic activities, and importantly their effects on agriculture or the forest ecosystem and on society.

The paper has also highlighted existing barriers and opportunities within agriculture and forestry in pursuing JAM – this is the first step in highlighting the specific areas that suffer from policy,

financial, knowledge and capacity barriers and opportunities that hinder or facilitate the pursuit of JAM activities. This also provides insights into where efforts can be focussed to ensure the further development of JAM activities and the tools necessary for succeeding. Examples include making funding available for joint adaptation and mitigation activities, encouraging collaboration in order to challenge the current policy division between mitigation and adaptation, and promoting further documented research measuring the impacts of joint activities, their cost-effectiveness and their synergies within the complex setting of risks and uncertainty concerning the magnitude of climate change impacts.

Moving forward, in the pursuit of joint adaptation and mitigation activities, it is important to keep in mind the objectives of pursuing JAM activities simultaneously in order to provide cost-effective, sustainable solutions that capitalise on the mitigation and adaptation effects of a particular activity to the mutual benefit of both. Simply striving for win-win outcomes for the sake of doing so may put at risk other activities which may achieve important adaptation- or mitigation-only benefits, thereby diminishing the effective use of limited climate funding (Klein et al., 2005).

Indeed, identifying an optimal mix of adaptation and mitigation is a slow and tedious process, one that is likely to vary between countries and over time (Klein et al., 2015). Thus, country-specific and context-adapted responses are vital to the design of JAM activities and their eventual success. In particular, the enabling conditions that can facilitate the pursuit of joint activities also need to be understood, enhanced and/or established in order to support the full pursuit of joint activities where relevant and thus complement the fulfilment of national ambitions highlighted in the INDCs, as well as in global targets such as the Sustainable Development Goals and the Paris Agreement, thus ultimately setting the world on track to a low-carbon and climate-resilient future.

6. REFERENCES

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