



Agricultural Policy Research in Africa

AGRICULTURAL COMMERCIALISATION PATHWAYS

CLIMATE CHANGE AND AGRICULTURE

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ABBREVIATIONS AND ACRONYMS



APRA	Agricultural Policy Research in Africa
CA	Conservation Agriculture
CCAFS	Climate Change, Agriculture and Food Security
CCD	climate-compatible development
CSA	climate-smart agriculture
FAO	Food and Agriculture Organization of the United Nations
IFPRI	International Food Policy Research Institute
INGO	international non-governmental organisation
IPCC	Intergovernmental Panel on Climate Change
MASL	metres above sea level
NGO	non-governmental organisation
SAP	sustainable agri-food system productivity [framework]

SUMMARY OF KEY INSIGHTS

- Climate change is likely to alter the environmental parameters which affect where agricultural commercialisation activity can happen in sub-Saharan Africa, what can be grown and how well it will fare. In other words, it touches upon factors fundamental to the viability of commercialisation pathways.
- Some contemporary forms of agricultural commercialisation – especially industrial agriculture – are an important source of greenhouse gas emissions and as such contribute to the anthropogenic climate change that farmers subsequently have to adapt to. African agriculture contributes very little to global climate emissions, but the climate impact it will face is contingent, at least in part, on the extent of reform of industrial agriculture elsewhere.
- There is a consensus on high-level findings: temperature will rise, precipitation patterns will change, and cereal crop productivity is therefore expected to decrease. Temperature rise will undermine perennial crop performance, most pests/diseases are likely to increase. A number of areas in which high-value crops including tea, coffee, and cocoa are grown are projected to become less suitable for their production. However, the level of uncertainty that continues to exist in climate projections undermines their credibility as a basis for decision-making in the short-to-medium term even at country level, let alone at farm level.
- Climate change will have an impact on all varieties of commercialisation, but we conjecture that it will differentially affect alternate pathways. There is insufficient evidence base to substantiate this proposition as yet, and we see an opportunity to contribute to building it through the life course of the Agricultural Policy Research in Africa (APRA) research agenda.
- Vulnerability and resilience to climate impacts is unevenly distributed across people involved in different commercialisation pathways, and can be broken down according to gender, age, ethnicity and class. It is too simplistic to state that women are more vulnerable to climate impacts than men, in relation to agricultural commercialisation; not least because in the sub-Saharan Africa context, as elsewhere, men are overwhelmingly more involved in commercialisation activities than women. Yet women and men are clearly affected differently by climate impacts. It is therefore key to account for the interactions of these different vulnerability profiles at the household and other levels.
- Whilst agricultural commercialisation activities may be highly sensitive to climate impacts, the vulnerability profiles of the people practising them will depend also on off-farm livelihood activities, which themselves will have their own degree of climate sensitivity (i.e. manual labour in warmer conditions).
- There are differing views over whether the modernising agricultural technologies often associated with agricultural commercialisation increase or reduce vulnerability to climate impacts. The answer to this question has fundamental ramifications for the kinds of commercialisation pathways it will be advisable to invest in if questions of socio-environmental sustainability are to be addressed robustly, along with those of gender empowerment and poverty reduction. Correspondingly, across commercialisation pathways, a key consideration will be around the extent to which changes to farming strategies currently envisaged or taken by those seeking to commercialise, or by those seeking to maintain existing commercialisation activities, strengthen or weaken resilience in the face of climate impacts.
- Policy approaches that aim to foster agricultural commercialisation are not automatically reconcilable with efforts to enhance adaptive capacity in the face of climate impacts. Nevertheless, there are agricultural practices that offer the prospect of increasing resilience to climate impacts and productivity, and these are documented in this paper. The extent to which any of them, or the conceptualisations in which they are based, such as sustainable intensification or climate-smart agriculture, offer prospects for sustainable agricultural commercialisation pathways at scale, is contested. However, using an approach such as Sitko and Jayne's (2017) 'sustainable agri-food system productivity' framework, we can get a clearer sense of which practice or technique is more or less likely to work in specific commercialisation contexts.

1. INTRODUCTION

Rationale and aims

This paper presents a review of recent literature on the implications of climate change for agricultural commercialisation, focusing chiefly on sub-Saharan Africa, and incorporating evidence, where relevant, from around the world. Climate change is one of the crosscutting themes of the Department for International Development (DFID)-funded Agricultural Policy Research in Africa (APRA) consortium.¹ APRA is intended to produce new data and insights into agricultural commercialisation processes, and their impacts and outcomes with regard to rural poverty, empowerment of women and girls, and food and nutrition security. In addition to outlining our rationale and aims, this introduction sets out (a) the approach we have taken to classifying climate impacts upon agricultural commercialisation, and (b) the structure. Time-constrained readers wishing quickly to get a sense of the paper's principal insights and recommendations are directed to the summary on page 6.

Given the highly climate-sensitive character of agricultural production, climate change has obvious and important ramifications for agricultural commercialisation, which in turn have a bearing on poverty, gender empowerment, and food and nutrition security. The nature and extent of climate change implications for agricultural commercialisation will depend on the choices that are made and the resulting commercialisation pathways.

It is therefore important that there are opportunities to build considerations of climate change into the design of the APRA research in the early stages. With this objective in mind, this paper aims not only to give a broad indication of the current state of knowledge on climate change and agricultural commercialisation, but also to indicate how and where this is relevant to the APRA research priorities, and to identify key questions to explore in its data collection activities. As such, we outline the salience of key issues for each of the three work streams that, broadly, comprise the APRA research effort. Additionally, we offer a preliminary exploration of the overlaps and intersections between

the different crosscutting research themes.

Types of climate impacts upon agricultural commercialisation

The implications of climate change for agricultural commercialisation can, for the purposes of analysis, be grouped into two related sets. The first set might be called agro-biophysical: climate change is projected to alter the environmental parameters within which agricultural activity takes place. Higher temperatures, in combination with changes in rainfall quantities and patterns across Africa, may have profound effects on what can grow and where, with potentially fundamental consequences for the types and distributions of cultivation and livestock farming, and even for the viability of these activities. To be sure, the exercise of attempting to predict how climate change will unfold, let alone how it will affect agricultural activities, is fraught with deep uncertainty. It is increasingly clear that climate change projections are not sufficient to form the basis of decision-making about responding to climate change impacts, at least in the short-to-medium term. It is for this reason important to clarify caveats around interpreting and using such information. Yet commercialisation hinges on the most marketable crops, and it is, therefore, important to consider even at a general level the magnitude of the impacts that climate change is currently envisaged to have for some of these. Thus rather than planning for specific climate change scenarios, the focus should be on planning for robustness in the face of a range of possible future climates, and gaining a clear sense as possible of existing adaptive capacity and vulnerability dynamics in the face of historical and contemporary forms of climate variability.

The second set of implications is societal, understood as an umbrella term incorporating social, political and economic dimensions. It is crucial to attempt to understand the implications for vulnerability and resilience to climate change and variability, differentiated chiefly by gender, age, class and ethnicity, for those involved in agricultural commercialisation

activities and pathways. Climate impacts have different consequences for women and men, boys and girls, because women are involved in, or excluded from, commercialisation activities in sometimes strikingly different ways. Yet vulnerability and resilience also need to be understood relationally, both between women and men, and between different social groups. Only in this way can we start to grasp the implications of climate impacts for rural poverty, empowerment of women and girls, as well as food security and nutrition.

However, once these different impacts have been identified, it is then important to examine the interactions between them. Therefore, we seek to understand and outline not only the implications of climate change for agricultural commercialisation, but the implications of agricultural commercialisation for climate change itself. These latter implications potentially change the nature of what we have to adapt to, how able we are to do that, and who is most adversely affected. It is well known that agricultural activity (both commercial and subsistence) contributes substantially to greenhouse gas emissions, but there is an increasing literature which suggests that some forms of commercialisation also weaken social-ecological resilience to climate impacts, even as they offer benefits for poverty reduction and food security. Again, the idea of relational vulnerability is helpful in understanding these dynamics. Additionally, debates around transformation, which are becoming increasingly prevalent not just in relation to climate change but across a broader range of sustainable development issues, are also salient. Agricultural commercialisation is often seen as part of a broader process of structural

may yield insights into directions and forms that commercialisation activities might seek to take.

Structure of this paper

This paper is divided into three main sections. There is a strong focus in the structure towards serving the objectives of the APRA consortium. This is particularly the case with Section 4, but Sections 1–3 do not require prior knowledge of the consortium’s aims. Section 1 has two main aims. First, it introduces the relationship between global agricultural production and climate change, outlining the central conundrum facing those involved in agricultural commercialisation: agriculture is both a key driver of climate change and highly vulnerable to climate impacts. Second, it surveys the implications of climate change for agricultural commercialisation activities across sub-Saharan Africa, both in terms of (a) the implications of climate impacts for the viability of agricultural production and associated value chains, and (b) the implications, gendered and otherwise, for livelihoods resilience. Section 2 considers the extent to which the modern methods of agricultural production which most obviously suggest themselves for commercialisation are climate resilient. This paves the way for a consideration of alternative concepts, methods and techniques for sustainable, resilient commercial agriculture. At this juncture we introduce Sitko and Jayne’s (2017) ‘sustainable agri-food system productivity’ framework, which is useful for assessing the prospects for these different practices and techniques.

Box 1: Four pathways of commercial farming

1. Estate/plantation/large-scale commercial farming – large landholding, typically growing a single cash crop, high level of mechanisation, relies on labour (Smalley 2013).
2. Outgrowing/contract farming – farmers supply produce to a central buyer on a contractual basis (see Oya 2012 for a discussion on various contract farming business models).
3. Medium-scale enterprises – more than 5–100 hectares, often owned by urban-based investors who hire labour to produce (Jayne et al. 2014; Sitko and Jayne 2014).
4. Smallholder farmers – rural, farmed by household members, full-time producers who sell surplus/cash crop.

Source: Dancer and Tsikata (2015); see also Smalley (2013).

transformation in a country’s economic development. Historically speaking, it could be argued, the processes of structural transformation we have witnessed have given rise to forms of large-scale, intensive commercial agriculture which beg rather than answer the climate question. If the future is not to repeat the past, then debates around transformative climate adaptation

All of the issues that we cover in Sections 1 and 2 are relevant across agricultural commercialisation pathways. In Section 3, we examine the implications of climate change which we take to be specific to the particular commercialisation pathways at the heart of the APRA research agenda (see Box 1). Each pathway is characterised by differences in factors such as technologies deployed, farming systems, crops

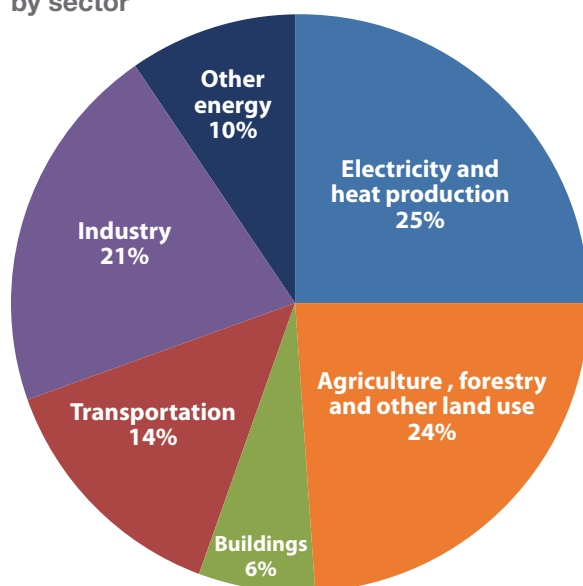
grown, gendered divisions of labour, and access to productive resources. We therefore conjecture that the implications for climate change for different agricultural commercialisation pathways will differ precisely because of the divergent, specific characteristics of each pathway. This is a necessarily hypothetical statement: there is not yet a sufficiently strong evidence base on climate impacts on specific commercialisation pathways which would allow us to make definitive statements. We therefore present and reflect on the existing evidence, but suggest also that there is an opportunity for APRA to contribute to building knowledge in this area. Section 4 is devoted to teasing out the ways in which the three work streams that comprise APRA can incorporate climate considerations, and conduct a similar exercise for the crosscutting research themes.

1. SCIENCE, TECHNOLOGY AND INNOVATION IN AFRICA'S DEVELOPMENT

1.1 Framing the problem: the relationship between climate change and agricultural commercialisation

From the perspective of commentators concerned with climate change, agricultural commercialisation is a conundrum. This is in essence because it is implicated at a fundamental causal level in generating anthropogenic climate change, and at the same time one of the modes of economic activity most sensitive to climate impacts.

Figure 1: Global greenhouse gas emissions by sector



Source: IPCC (2014).

Most commonly, the greenhouse gas emissions from agriculture, as a percentage of the total global anthropogenic emissions, are accounted for along with forestry and other land uses. On this measure, they contribute to 24 percent of global greenhouse gas emissions – see Figure 1. According to the Intergovernmental Panel on Climate Change (IPCC) (Smith et al. 2014), agriculture is the largest single contributor to global anthropogenic non-CO₂ greenhouse gas emissions, accounting in 2005 for 56 percent of such emissions. In 2010, annual non-CO₂ greenhouse gas emissions were estimated at

the equivalent of 5.2 5.8 gigatonnes of CO₂, or 10–12 percent of global anthropogenic emissions (FAOSTAT 2013). Smith et al. (2014) report that there is not full agreement between the main databases used to disaggregate the proportion of greenhouse gases generated by different agricultural activities. However, there is agreement that enteric fermentation² and agricultural soils represent together about 70 percent of total emissions, followed by paddy rice cultivation (9–11 percent), biomass burning (6–12 percent) and manure management (7–8 percent). Some appraisals have gone further than agriculture itself, and have sought to estimate the contribution of the global food system – including elements such as indirect emissions associated with land cover change, fertiliser manufacturing, food storage and packaging – to anthropogenic emissions. Vermeulen et al. (2012) put that figure at 19–29 percent of anthropogenic emissions, based on 2008 data. It is possible to extrapolate this figure further, if the emissions generated not only through the production of food but the carbon intensity of international trade in food are taken into account.

Broadly speaking, the more commercial the agriculture, the more industrial the mode of agricultural production tends to be. The more industrial the mode of production, the greater its contribution to the greenhouse gases driving the biggest global environmental problem we face. At the same time, the vulnerability of agriculture and food systems to disturbance (via climate impacts or otherwise) has increased (Beroya-Eitner 2016). In other words, one of the biggest threats to the prospects for commercial agriculture is commercial agriculture itself, at least as currently practised. This dynamic is fundamental to any discussion of commercialisation pathways, in sub-Saharan Africa or anywhere else. This is essentially why climate change has been chosen as one of the crosscutting themes for the APRA project.

If agricultural commercialisation is to remain a viable proposition in the medium-to-long term, it would appear that its modes of production need to change fundamentally. However, it needs to be recognised that not all forms of commercialisation have contributed equally to climate change: Africa's contribution to

agriculture-related emissions – or indeed to greenhouse gas emissions more broadly – remains minimal. The industrialisation of agriculture in countries like the United States, and the widespread use of industrial methods of intensive agriculture, are far more important contributors than, for instance, increased maize yields produced by Zimbabwean farmers who were given land in the country's land reform process in the 2000s. Ultimately, some commentators argue that a thoroughgoing solution to this conundrum requires a process of agricultural de-intensification in the places in which it is most industrially practised, even whilst sustainable intensification could be permitted in regions which do not currently contribute very much to global greenhouse gas emissions (Struik and Kuyper 2017). Getting smallholder farmers in sub-Saharan Africa with an interest in reaching a bigger market to adopt conservation agriculture is not going to make much of a dent in global climate emissions attributable to the agricultural sector. There are also powerful ethical considerations relating to the historical and contemporary responsibility for greenhouse gas emissions of different parts of the world. Moreover, sustainable intensification of commercialisation pathways in Africa will remain a hostage to fortune of the broader tendency of global industrial agriculture to contribute to the conditions for a more hostile future climate. However, if commercialisation in Africa, with a view to empowering women and girls, is to be commercially and environmentally viable over the medium-to-long term, then sustainable intensification may offer better prospects than conventional agricultural industrialisation. Furthermore, given the importance of at least maintaining, and ideally increasing, crop yield per level of input as a prerequisite for commercial activity – not to mention local, regional or global food security – it would seem necessary to explore the options offered by and the prospects for sustainable intensification.

In view of this discussion, this section therefore has two aims. First it discusses the known implications of a changing climate on agricultural production, partly in terms of its agro-ecological implications but also in terms of other important dimensions, including value chains and social impacts, such as those that are gendered in character. Second, it outlines some of the practices and techniques most associated with the concept of sustainable intensification. This section thereby informs the later sections on the implications of climate change for specific commercialisation pathways: large-scale commercial farming, outgrowing, medium-scale commercial farming, and commercialising smallholder farmers.

1.2 Global and regional climate impacts: implications for agricultural production

Climate change is, it is argued increasingly, already changing agriculture. There is increasing evidence of climate impacts on production, and climate change is significantly affecting priorities and actions in the agricultural sector, notably through investments in 'climate-smart agriculture'. The IPCC (2014) reports that according to global, regional, national and local studies across countries and crops, the effects of climate change have been more negative than positive to date. Impacts are, however, variable. Climate change has led to both increases and decreases in agricultural yields, depending on the change in precipitation and temperature and its positive or negative effect on the crop planted (ibid.: 491). It is reported to have reduced crop yields overall, with notable reduction in the global production of wheat and maize as well as small negative effects on global rice and soybean production. Conversely, there has also been a net benefit to 'crop production in some high-latitude regions, such as northeast China or the UK' (ibid.: 491). According to the IPCC, climate change affects agricultural crop production by changing rainfall, increasing frost damage, and increasing temperatures (ibid.: 492–93). For another summary of the relevant global scenario studies on climate change impacts, global environmental change, changes in ecosystem services, and changes in agriculture, see also van Vuren et al. (2009).

Looking to the future, researchers using climate scenarios project that there will be 'increases in air and soil temperatures, changes in CO₂ concentration in the atmosphere, sea level rise, changes in the hydrological cycle and in water quality and availability, intensification and increase in frequency of extreme weather, including droughts and floods, changes in the altitudinal level of dew points', amongst other impacts with fundamental implications for agricultural activity (Vergara et al. 2014: 1). According to a 2011 global review,³ the changes in the water cycle will include increased floods, mudslides, river erosion, storms, drought, sea level rise, changes to the length and stability of rain throughout the growing season, shifts in pest and disease problems, and increased evaporation from plants and soils (Toulmin 2011). These environmental changes are expected to impinge upon agricultural production systems worldwide.

In Africa, the IPCC reports that climate change will result in negative effects on yields of major cereal

Table 1: Projected changes in agro-climatic suitability for perennial crops in Africa by mid-century under an A2 scenario

Crop	Suitability change	Country	Source
Coffee	Increased suitability at high latitudes Decreased suitability at low latitudes	Kenya	Läderach et al. (2011)
Tea	Decreased suitability	Uganda	Eitzinger et al. (2011a, 2011b)
	Increased suitability at high latitudes; decreased suitability at low latitudes	Kenya	
Cocoa	Constant or increased suitability at high latitudes; decreased suitability at low latitudes	Ghana, Côte d'Ivoire	Läderach et al. (2011)
Cashew	Increased suitability	Ghana, Côte d'Ivoire	Läderach et al. (2011)
Cotton	Decreased suitability	Ghana, Côte d'Ivoire	Läderach et al. (2011)

Source: IPCC (2014: 1219).

crops, including maize at lower elevations (where the majority of current maize production occurs), wheat, and to a lesser extent sorghum (IPCC 2014: 1218). While some areas of East Africa and central Africa may become optimally suitable for maize production, today's 'maize-based systems, particularly in Southern Africa are among the most vulnerable to climate change' with estimated losses of 18 percent by 2050, 22 percent across sub-Saharan Africa (ibid.: 1218). Simulations anticipate high vulnerability in wheat production with negative effects of 35 percent by 2050 (ibid.: 1218). In West Africa, precipitation is projected to increase but potential benefits are likely to be offset by temperature rise, entailing a lower likelihood of positive effects for millet or sorghum yields. Negative effects are likelier to be seen in the savannah. Of particular relevance to the prospects for agricultural commercialisation, negative effects are projected to be higher 'with modern cereal varieties compared with traditional ones' (ibid.: 1218). Impacts on crops are anticipated to be particularly negative for the region because they are already grown 'close to their limits of thermal tolerance (Conway 2009, in Phiiri et al. 2016: 59).⁴

Overall, in the absence of appropriate adaptation, crop yields in some African countries could decline by as much as 50 percent by 2020, under particular scenarios (IPCC 2007). Yield declines of this order of magnitude would put greater pressure on food access, due to increases in prices of major food crops such as wheat, rice and maize (Nelson et al. 2010).

The IPCC reports that projections for implications of climate change indicate variable impacts on non-cereal crops, with losses in different areas for different

crops and changes in suitable growing areas in Africa. For example, cassava yields could increase in eastern and central Africa. Cassava is hardy enough to withstand high temperatures and sporadic rainfall, and in consequence 'it may provide a potential option for substitution of cereals as an adaptation response to climate change' (IPCC 2014: 1218–19). While banana and plantain production may decline in West and lowland East Africa, it may increase in the East Africa highlands (ibid.: 1219).

Perennial crops may face serious challenges, with projected high losses in the production of high-value crops including tea, coffee, and cocoa. The areas that are currently suitable for these crops are projected to become less so (see Table 1). Because these crops take years to come into full production, requiring resource investment up front, and because many perennial crops are grown under contract farming arrangements, yield reduction or failure is potentially a serious problem for producers in particular areas. Conversely, it is a potential opportunity for producers in other areas. Mapping potential changes in these areas, to indicate the implications for the outcomes of commercialisation, and the winners and losers from these changes, could be relevant to the aims of all three APRA work streams, but would ultimately depend upon the level of certainty around projections of change in underlying growing conditions.

There is a large body of literature on the likely direct impacts of climate change on agricultural output and crop production impacts at regional levels.⁵ In 2013, the International Food Policy Research Institute (IFPRI) published a series of comprehensive regional

publications for East, West and South Africa that provide country-level analysis of climate projections, The Climate Change in Africa series. The relevant country data is given in Annex 1 of this paper. It is, however, necessary to clarify that the information offered by climate projections is inevitably uncertain, given data and modelling constraints. For instance, when Namibia first attempted to model the impacts of climate change upon agriculture at the country level, using downscaled regional models (Dirkx et al. 2008), three of the scenarios suggested an increase in rain, whilst three suggested a decrease, in the areas of the country most intensely cultivated. Adapting to a decrease in rainfall would require a very different set of interventions to adaptation to an increase in rainfall, and the information provided in these projections was not a sufficient basis for making policy decisions about agricultural adaptation (Newsham and Thomas 2009). Furthermore, the annual average rainfall projections offered by models did not pick up on rainfall variation experienced within a given growing season, even though this can be fundamental to the size of crop yields. For instance, farmers practising rainfed agriculture in North-Central Namibia reported changes from one growing season to the next in the arrival and intensity of rain, with significantly adverse implications for maize and pearl millet crops (Newsham and Thomas 2011).

In a more recent review of climate change in West Africa, Bamba Sylla et al. (2016) confirm that temperature increased in recent decades and projections indicate stronger warming in the future. The authors present evidence that although the Sahel has recovered from previous droughts in the 1970s and 1980s, projections show a significant decrease in rain for all of West Africa in the future, most markedly in the westernmost Sahel. Overall, the region is expected to experience a shorter growing season, shorter rainy seasons, extended torrid, arid and semi-arid climate conditions, longer dry spells and more intense extreme rain, all of which are expected to negatively affect agricultural production (ibid.). In the same book, Pardo et al. (2016) confirm that projections in rainfall patterns for the region generally agree that inconsistency will increase, resulting in greater seasonal variability – but projections cannot yet clarify the direction of change, with some predicting an increase while others predict a decrease (ibid.). While detailed and localised projections remain unclear, climate in the region is unmistakably changing; Yaro et al. (2016) present the case of Northern Ghana where farmers are adopting adaptation strategies to deal with the climate stress they are experiencing, such as irrigation, use of fertilisers, and modern agronomy, shifting to non-farm activities, and migrating seasonally.

Even more uncertain is our understanding of the changing character of future human agricultural activity, and its implications either for mitigation or adaptation (Ensor 2009; Lipper et al. 2014). Ensor argues that ‘optimising agricultural, aquacultural or pastoral strategies to a particular climate future risks maladaptation and will always be a mistake as long as uncertainty remains in climate projections’ (2009: 6). The projections on which country level analysis offered in Annex 1, and especially the extent to which they can serve as a basis for decision-making, should be considered against this background. The summary intentionally highlights whether or not the various models used were in agreement in their findings, which may indicate a more plausible anticipated scenario, or whether they were not in agreement, and are therefore unable to indicate potential implications.

1.3 Climate impacts, commercialisation and (differentiated) adaptation prospects

The geography of the physical implications of climate change is becoming clearer, and what is already known is extremely relevant for researchers, policymakers, and farmers to understand the implications of climate change for different types of farming in different places.

Suitable growing areas will shift, and the winners and losers will change. But in order for anyone to benefit from these shifts, farmers will need to anticipate the changes and adapt to grow the right crops in the right areas at the right time, anticipating and adapting to climatic changes that may differ from one season to the next. There is therefore a related large body of literature on climate information dissemination (Kadi et al. 2011a, 2011b; Policarpio and Sheinkman 2015). Men are more likely to be connected to sources of climate information than women (Skinner 2011), as are organised farmer groups and better-off farmers. For example, Thomas et al. (2007) investigate farmer response to rainfall variability in three regions in South Africa to see whose coping and adaptation is stronger; two of the three had stronger adaptation due to collective action in farming cooperatives where they were able to pool resources, information, and advice. There is also evidence that men have more access than women to information on climate-smart agriculture and agricultural extension (Jost et al. 2015; Huyer et al. 2015).

Likewise, incentives are likely to change. For example, the private sector may invest in contract farming schemes for coffee or cocoa in new or anticipated suitability areas or increasing risks and uncertainty may

discourage companies from investing. Smallholders, medium-sized farmers, and estate farmers are likely to face different opportunities and risks depending on the changes in the natural environment, as well as policy environment as governments, private sector and citizens navigate changing suitability of areas for major crops.

Box 2: Increased commercialisation in Africa

- Population growth is driving demand;
- Connectivity between rural and urban centres is improving;
- Grocery outlets and retail opportunities are growing.

Source: AGRA (2016).

Women may face particular barriers. Carr and Thompson (2014) cite 11 studies that demonstrate that men and women grow different crops, resulting in different vulnerabilities to climate change. They report that this body of literature concludes that ‘women often raise crops that are more sensitive to climate variability than men’ (ibid.: 184). Conversely, whilst men may grow hardier crops on average, to the extent that they are likelier to be growing commercial crops, and to the extent that these are more sensitive to climate impacts than better adapted local crops with lower commercial potential, men’s vulnerability profiles may be more relevant to the consideration of agricultural commercialisation prospects. Understanding both individual male and female vulnerability profiles, and in relation to each other, through social relations such as household units, class and ethnicity, is key to getting a handle on adaptation and commercialisation dynamics.

There are several large bodies of literature related to how to manage the implications for agriculture, which are relevant to this review. There is a large body of literature focused on related technical developments and opportunities, including biotechnology, seed varieties – both new and traditional – that are drought- and flood-resistant as well as the implications of climate change for commercialised agriculture by crop type and geographic region (Hertel et al. 2010; La Rovere et al. 2010).⁶

1.4 Gendered impacts of climate change and barriers to commercialisation

A brief review of the literature on the gendered impacts

of climate change reveals a changing narrative that is important to understanding gender-related barriers to commercialisation. A large literature exists on women being more vulnerable to and disproportionately affected by climate change (e.g. AFDB 2011; CARE 2010; Skinner 2011). However, a new wave of literature now calls for an approach to gender in climate change that goes beyond generalisations about women’s vulnerability, acknowledging the intersections between gender, caste, ethnicity, age and other important drivers of exclusion and vulnerability (Arora-Jonsson 2011, 2014; Jost et al. 2015; Gonda 2016; Twyman and Ashby 2015). Table 2 provides an overview of some commonly noted gendered vulnerabilities and the relationship with climate change.

Gender roles, gendered access to resources, and gender-constricted access to power may contribute to climate vulnerability in specific contexts. However, reappraisals of gender and vulnerability to climate impacts argue that they may not be generalised. According to Jost et al.: ‘A main challenge for the climate change research community is to move beyond the current simplistic understanding of smallholder women as a homogenous group that is inherently nature-protecting, but unable to adapt to climate change because of their overwhelming vulnerability’ (2016: 142). Indeed, narratives that cast women and girls in the light of victimhood and vulnerability may have important implications for female access to opportunities for commercialisation and for the kinds of adaptation policies that are aimed at them.

In March 2015, CGIAR’s research programme on Climate Change, Agriculture and Food Security (CCAFS) hosted a workshop, Closing the Gender Gap in Farming Under Climate Change. The keynote speakers highlighted common myths that had permeated the climate change community about women, namely that they are more vulnerable to climate change because they are poorer, they make better stewards of natural resources than men, and new climate-smart technologies can close the gender gap. But they presented evidence that men and women do have different vulnerabilities to climate change, which are related to gender norms, division of labour, access to and control over resources, and decision-making power, which coincides with earlier literature. They presented the argument that these issues must be placed in context, referring to the case made by Arora-Jonsson that focusing on women’s vulnerability or virtuousness can deflect attention from inequalities and have negative effects (Twyman and Ashby 2015).

Arora-Jonsson (2014) provides an example of a climate programme that intended to influence gender norms by granting land tenure to women, but the programme did so regardless of the women's preference or intention. She describes the programme in Andhra Pradesh in India that awarded individual land title and wages through a government scheme (NREGA) in return for planting cash crops on their land:

These crops made the women vulnerable to irrigation problems, volatile markets, and agricultural chemicals and resulted in a total change in their livelihoods. In some districts women were 'encouraged' to grow biodiesel plants (*Pongamia pinnata*) as part of climate programs that would enable them to earn carbon credits. The degraded forests, which they would have regenerated with indigenous species, and agriculture lands that supported food crops were replaced with mono-plantations as they were assured a regular income from the sale of seeds. After one payment from the World Bank for

neutralising carbon emissions, a few years down the line, 80 percent of the trees perished, most families were forced to sell their cattle, were subject to an increased dependence on chemicals and ruined their land in the process. What also emerged was that the women were completely unaware of the reason they had received the money and had no idea about the ramifications of carbon trade and the relationship of their self-help group activities to climate change (Ramdas 2009, in Arora-Jonsson 2014: 301–02)

Arora-Jonsson (2014) argues that the focus on women in climate change programmes can curb agency when it is not part of a gendered analysis of neoliberal policies, technocratic solutions, and decision-making related to climate change that is often performed in high-level meetings with governments, international non-governmental organisations (INGOs), companies and scientists, and without the participation of the women who are intended to 'benefit' and/or carry out the work of the programmes.

Table 2: Gender-differentiated vulnerability to climate impacts

	Women	Men	Link to climate change vulnerability
Roles	Stay home to care for children, as well as sick or elderly family members	Can migrate to access economic opportunities	Their ability to migrate in search of economic opportunities makes it easier for men to deal with crisis, and may result in benefits for the family as a whole. However, male migration often increases women's workload, as they are left behind to manage the household in addition to usual tasks. It can also increase women's exposure to other risks, such as gender-based violence and HIV infection.
	Produce household-oriented crops and livestock products	Likelier to produce market-oriented crops and livestock products	Both crops and livestock are affected by climate change, and this has profound consequences for household food security. Men often claim safer/more fertile land for growing market-oriented crops, leaving women to grow household-oriented crops on more vulnerable/less fertile land.
	Are responsible for food storage and preparation	Are responsible for selling valuable produce and livestock	In addition to the challenges described above, climate change has implications for food preparation and storage (in terms of water for food preparation and the vulnerability of food stores to extreme events, such as cyclones and floods). Harvests may be reduced or even wiped out by floods or droughts. This affects market prices and the availability of surplus to sell – placing pressure on both men and women to identify other sources of income and reduce major expenditures (e.g. school fees). In times of food shortage, women are often expected to feed other members.

Roles	Have lower incomes and are more likely to be economically dependent	Have higher incomes, likelier to own land/other assets	Men typically have more money and other assets than women. Men's savings provide a 'buffer' during tough times and, along with other assets, make it easier for them to invest in alternative livelihoods.
	Have less access to education and information	Have more access to education and information	Managing climate-related risks to agricultural production requires new information, skills and technologies, such as seasonal forecasts, risk analysis and water-saving agricultural practices. Men are more likely to have access to these resources and the power to use them and are, therefore, better equipped to adapt. At the same time, women often have traditional knowledge that can inform adaptation efforts. Both new and old information is important in the context of adaptation.
Roles	Have less power over family finances and other assets	Have more power over family finances and other assets	Without the power to decide on family resources and finances, women's ability to manage risks by, for example, diversifying crops, storing harvested crops, etc. may be reduced.
	Have limited engagement in community politics	Have greater decision-making power in community politics	Men are likely to have more influence over local governance-promoting policies and programmes that may not support women's rights and priorities.
	Face many cultural restrictions on mobility	Face few cultural restrictions on mobility	Mobility is a key factor in accessing information and services. It is also critical for escaping the danger posed by extreme weather such as floods. Therefore, women are often at higher risk from these events.

Source: CARE (2010). Available online: www.careclimatechange.org/files/adaptation/CARE_Gender_Brief_Oct_2010.pdf

Gonda (2016) provides another example through her research in Nicaragua on a climate adaptation project. She finds that the project was based on generalised narratives about women's roles and vulnerabilities, and thereby reinforced gender stereotypes and roles and was out of sync with reality. In her study, she found that men and women typically shared household duties of collecting water and firewood in the community, and it was the non-governmental organisation (NGO) workers' assumptions that introduced 'improved' cooking stoves and water reservoirs intended for women's benefit, but that actually benefited both genders (ibid.). Efforts to ensure that agricultural commercialisation contributed to women and girls' empowerment would do well to avoid similarly imprecise generalisations.

Carr and Thompson provide a review of gender and climate change adaptations in agrarian settings, finding that 'the contemporary literature on adaptation widely acknowledges that the patterns of vulnerability to climate change impacts we see today are largely, if not principally, shaped by roles, responsibilities

and entitlements associated with various markers of social status and expectation including gender, class and caste' (2014: 183). However, they argue that the literature on gender and adaptation 'makes its case through very narrow binary gender analyses, where "man" and "woman" are treated as unitary categories with contrasting needs' without adequately situating the gender analysis within 'a host of other social markers like age, income and ethnicity' (ibid.: 183). For example, they argue that the vulnerability of a wealthy woman's livelihood may have more in common with a wealthy man, than with a poor woman's; the majority of their excellent discussion is related to the small but growing literature that deals with adaptation at this level of analysis.

Another example of this change in the literature can be seen in the discussion on gender roles. There is evidence that gender roles contribute to women's greater vulnerability to climate change. Romero González et al. (2011) found that in Burkina Faso, despite the negative implications of climate change for housework as well as agricultural tasks, women maintain their reproductive

and care roles while taking on more productive roles with no re-distribution of access to and control over assets, making them more vulnerable to climate change than men.

However, Okali and Naess (2013) argue that while gender roles may contribute to women's vulnerability to climate change, it is essential to acknowledge social complexity beyond arguments that essentialise women's and men's roles in order to understand the complex and layered barriers to women's full inclusion. For example, while women farmers may have limited access to inputs, even when they have equal access, they produce less than their male counterparts because of other barriers to inclusion. A recent study by the World Bank and the ONE Campaign (2014) argues that the drivers of the gender gap in agriculture are beyond the focus on access and gender roles, including less household labour availability, less hired labour, lower use of and return on inputs, less effective extension services, less access to land and markets, less human capital and access to social networks, and poorer soil quality. The study provides country-specific analysis of the gender gap for agriculture in Ethiopia, Malawi, Niger, Nigeria, Tanzania and Uganda.

Women face climate change impacts in the context of barriers to commercialisation as well.⁷ According to a recent review, these include: lagging land ownership, less decision-making power within and outside the household, lower levels of access to and control over key agricultural resources namely finance and credit, less access to agricultural inputs, and less access to extension services, technology, training and information including climate information (Huyer et al. 2016). Some commentators go even further than identifying specific barriers to entry in commercialised agriculture for women. For instance, both Akram-Lodhi (2016) and O'Laughlin (2009) contend that women are not involved in commercialisation activities precisely because these are governed by a patriarchal division of labour in which men seek either to profit from their own labour or to sell it, whilst it falls to women to occupy themselves with the unpaid work associated with reproducing labour. It is possible that this underlying gendered division of labour has implications as adverse, and possibly more so, for the involvement of women and girls in commercialisation activities, and their likelihood of benefiting from them, than climate impacts.

Dancer and Tsikata (2015) review gender and commercialisation in various forms, small- and medium-scale, contract farming, and estate/plantation farming, in Africa in order to look at sources of women's

subordination in the commercialisation process. They find key barriers to women's advancements in commercialisation to be: (a) lack of land ownership and title, land loss and displacement, (b) labour patterns and work burdens, including the impacts of mechanisation, and (c) constraints in bargaining power and control over resources (ibid.). While their excellent review of the literature sheds light on how commercialising pathways are shaping women's access to resources and power relations in Africa, it does not consider implications of climate change on these pathways. This review attempts to look at the literature on implications of climate change on these pathways in order to better understand what the implications may be for the women, men, girls and boys engaged in agricultural commercialisation activities along the various pathways.

1.5 Implications for livelihood resilience and prospects

While there is large literature on the implications of the direct physical implications to agricultural commercialisation as outlined in the first section of this review, there is less evidence on the implications of climate change for women, men, girls' and boys' livelihood prospects in agricultural commercialisation activities.

Commercialisation of agriculture is uneven, with women facing more barriers than men (Dancer and Tsikata 2015); therefore, both groups face climatic changes and shocks resulting in distinct vulnerabilities (Taylor 2014). Societal relationships enable and limit efforts (Toulmin 2011). For example, commercialising requires farmers to have the skills to make use of market information and climate information, which is unevenly available to men and women, as is the social capital to act upon the information.

In Zambia and Ghana, van Koppen et al. found that men could more easily adopt irrigation technologies because they had lighter workloads and easier access to equipment, inputs, finance, public support, transportation and markets (2012, in Bernier et al. 2015). Similarly, Magnan et al. found that poor women in India had larger networks, but men had more effective and smaller networks that connected them to knowledge about new agricultural technologies (2013, in Bernier et al. 2015).

Some of these themes are echoed in the literature on gender and climate-smart agriculture, for example in suggestions that gender relations is a key factor in

determining the feasibility of climate-smart agricultural practices (Thornton et al. 2017). One example is Conservation Agriculture (CA), widely considered an attractive climate-smart agriculture practice (Thierfelder et al. 2017). CA has been promoted across East and Southern Africa, while also being critiqued for disadvantaging women and children due to its higher labour requirements for land preparation and weeding.

However, while the literature demonstrates that the gender barriers result in uneven commercialisation and uneven climate change impacts, it also points to the possibility that because women have not entirely entered the commercial approach they may be spared the negative implications of climate change on single crop, market-based approaches.

Kirsten et al. (2013) identify the socioeconomic characteristics of smallholder producers that are determinants for success in commercialisation. Their discussion includes how gender influences the types of crops grown (less marketable varieties) amidst other variables including isolation from markets, household asset base, and access to agricultural support services (ibid.). While this discussion is helpful to understanding implications for livelihood resilience along commercialising pathways, further research is needed to understand the uneven processes of commercialisation and the differentiated implications of climate change.

1.6 Climate change impacts on commercialisation from the value chain perspective

Agricultural value chains encompass the flow of products and services including information between farmers and consumers. The agricultural value chain remains a core element of agricultural commercialisation as it defines the various stages through which agricultural products pass to achieve specified commercial value (Lawton 2011). Value chains enable farmers – whether small or large scale – to gain added value on their products, thus enhancing the market reach and potentially, depending on the commercialisation activities chosen, the resilience of products. However, climate change impacts are largely embedded within value chain stages including production, processing and consumption. As illustrated in Figure 2, the three value chain levels are connected to each other through flow of materials and products and this depicts the fact that climate change impacts are also linked across the

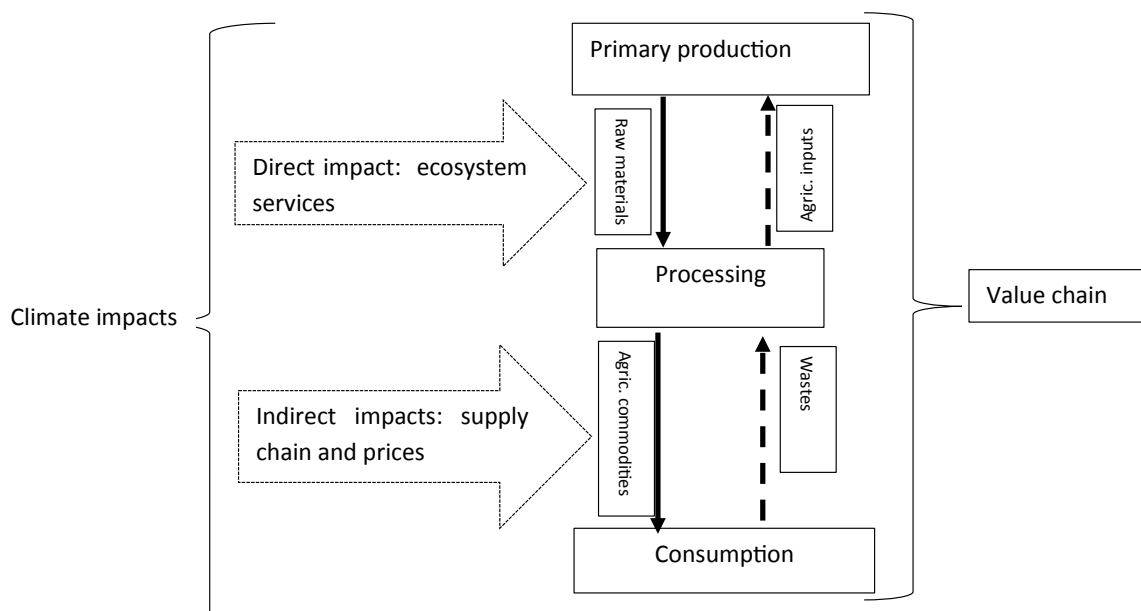
value chain. Studies have therefore emphasised that looking into the climate change impacts on agricultural commercialisation through the value chain lens enables farmers to analyse vulnerability to climate, identify hotspots for risk across the whole chain, and identify opportunities for new products and markets for a more resilient commercialisation pursuit.

Primary production represents the first stages of a value chain where agricultural products are produced through natural bio-geochemical processes. This involves intense interactions of ecosystem services including soil formation, nutrient cycling (for crops) and biological processes for livestock to produce agricultural products. As already discussed, there is a general consensus within a wide range of literature (e.g. IPCC 2014; Malhi and Wright 2004; UNDP 2007) that primary production of crops and livestock products is already suffering the most impacts of climate change. Climate change directly affects critical ecosystems services such as rainfall availability, nutrient cycling, etc. which in turn results in decline in yields. Varying rainfall over time and space already causes severe declines in yields of rainfed crops resulting in hunger among smallholder farmers who are the main food producers and the majority in Africa (World Bank 2008). Further incidences of extreme events such as heat waves and pests and diseases further pose threats to crop yields.

The processing and value addition stage of commercialisation is largely characterised by the refining of original agricultural products – for example maize cobs, tea leaves, coffee beans (for crops) or milk, meat (for livestock) – into commodities with added value, such as enhanced durability, packaging, nutrition, etc. Processing takes place either through advanced equipment or machinery, particularly for large-scale farmers, while for small-scale farmers, basic equipment and processes are employed. Climate change impacts this level indirectly, to the extent that it disrupts the supply chains both in terms of reducing raw materials and infrastructural efficiency. For instance, most agricultural industries in Africa utilising water now experience increased costs of production, for example water constraints especially. Further, several African countries are now experiencing climatically induced human diseases, health and safety hazards for the agricultural workforce, and reduced timeliness and efficiency in commercialisation processes (UNDP 2007).

The consumption level of commercialisation occurs at the end stage where processed commodities are

Figure 2: Schematic illustration of climate change interactions with agricultural value chain



Source: Authors' own.

utilised by consumers in various ways, either for direct consumption or other utilities. At this level, climate impacts on commercialisation are indirect – mainly manifesting via impacts on consumer/households' access to commodities as well as impacts on the wellbeing and lifestyle of consumers which affects consumption patterns and commodity market value. In many African countries, climate change has reportedly disrupted agricultural commodity distribution and networks, affecting delivery times and causing production interruptions, poor commodity access and sales losses. Further, climatically vulnerable communities are often forced to change their lifestyles as part of adaptation, including eating habits that shifts focus from certain commodities. According to Amado and Adams (2011), communities provide the 'social licence' for businesses to operate and so their vulnerability to climate change posits commercialisation risks.

Despite the novelty of the value chain approach to understanding climate impacts on agricultural commercialisation, a number of challenges exist. The key ones include poor access to climate-related data for specific value chain levels, especially in Africa, and uncertainties associated with future climatic changes

makes it difficult to predict the actual costs of climatic uncertainties. Nonetheless, we think that the value chain approach will be a critical tool to utilise for an in-depth analysis of climate change impacts on agricultural commercialisation under the APRA project.

1.7 How resilient to climate change is modern agriculture?

Farmers pursuing any of the four pathways to commercialisation (see Box 1) may employ 'modern' techniques such as using improved seed varieties, non-organic fertilisers, and mechanised farming methods. Alternatively, farmers may intensify production for surplus sale using traditional seed varieties, conservation agriculture techniques, and other sustainable intensification methods, such as permaculture or organic farming. Techniques that improve water retention and reduce run-off, such as integrated soil fertility management practices or soil and water conservation, can stabilise yields whether inputs are organic or modern.

Still, there seems to be a divide in the literature between those who either argue or assume that pursuing modern techniques is better for farmers, and conversely, those

who make the argument that modern techniques are more climate-sensitive and require optimum conditions, and are more implicated in driving anthropogenic climate change the more industrial the scale at which they are practised. Particularly in Africa, the assumption often leans toward pro-modernisation in part because yield levels are much lower than the rest of the world, so food production can grow to a higher potential before reaching biophysical limits (Grassini et al. 2013; Jayne et al. 2016; Livingston et al. 2011). However, much of the climate change literature argues that while heavy use of inputs may help farmers to offset some of the effects of climate change in the near term through higher incomes, in the medium-to-long term, it is an unsustainable approach to climate adaptation. More diverse farms, which intercrop, manage soils with organic inputs, maintain seed diversity and keep indigenous livestock breeds, may be more drought, flood and pest resilient in the longer term.

Fortier and Trang make the argument that a reliance on inputs, particularly agrochemicals and modern rice varieties in the case of Vietnam, impoverishes environmental and social ecosystems:

We argue that this modernisation has locked both family and large-scale farms into technological path dependencies of energy- and input-intensive production, notably for agrochemicals, biotechnologies and water. This in turn, has led to a vicious circle of induced systemic fragility through engineered landscapes, reduced agro-biodiversity, and weakened social networks, knowledge and skills. As a result, Vietnam has become more sensitive to structural changes and less able to adapt to the unpredictable context of climate instability. Beyond those systemic contradictions, however, we argue that the most damaging impact of modernisation under Doi moi (market reform) has been to generate a new class dynamic and transform state-society relations in ways that now undermine the country's ability to respond to climate change (Fortier and Trang 2013: 2).

The authors argue that Vietnam's agricultural modernisation has 'made the country increasingly reliant on complex processes and has locked in various technological path dependencies' while reducing agro-biodiversity and weakening social networks, knowledge and skills (ibid.: 1). Likewise, Sokoni (2008) makes the argument that commercialisation aggravates the erosion of the natural resource base.

One of the fundamental components of commercialisation, access to irrigation, could be seen

as an important aid to adaptation, to the extent that it reduces smallholder dependency on the vagaries of rainfall and shields them from the sometimes-devastating impacts of a failed harvest. However, the use of irrigation can also in some contexts heighten the vulnerability of smallholder farmers to precisely the kinds of environmental phenomena, such as droughts, that climate change is projected to exacerbate across many parts of Southern Africa. The experience of farmers in Andhra Pradesh provides a cautionary tale in this regard, as the work of Marcus Taylor (2013, 2014) demonstrates. Against a background of liberalisation policies from the 1990s onwards, farmers in Andhra Pradesh have responded by planting commercial and non-food grain crops such as paddy, groundnut, oil seeds, vegetables and cotton. This resulted in a much greater use of high-yield varieties of seed in combination with irrigation and inputs such as pesticides and fertilisers, to the extent where farmers were spending up to 35 percent of their income on such inputs. Often, loans to pay for these inputs would be taken out from the very people to whom farmers were looking to sell their crops, and interest rates charged would exceed the profits made from the sale in some cases. Compounding this dependency, in 2012–13, was the presence of severe drought in Andhra Pradesh, which brought about water shortages that meant insufficient water was available not only for irrigation purposes, but also for livestock. In some cases, this led to distress sales of cattle at very low prices that Hyderabad merchants subsequently profited from substantially. This was also a case of relational vulnerability, where the profits that merchants made, which consolidated a livelihood that was not very sensitive to climate impacts in itself, came at the expense of resilience to climate impacts of the farmers involved in distress sales. The cycle of poverty for these farmers is thus renewed with the stripping of their assets.

The implication here is that commercialisation pathways which do not take sufficiently into account the agro-environmental conditions in which they are being applied may end up contributing to heightened vulnerability to climate impacts, and that commercialisation activities may simultaneously strengthen the resilience of some directly at the expense of others. It would be useful in work streams 1 and 2 to investigate the prospects for such uses in the case study countries that APRA will focus on. It will also be important to understand, in the context of work stream 3, the extent to which the policy environment is likely to favour or dismiss commercialisation strategies which are more responsive to agro-environmental considerations.

Brooks et al. argue that modern agriculture is based on a 'concept of progress and the belief that societies tend to become more advanced through endogenous processes of social change leading to an increasing separation of humans from nature' (2009: 744). They argue that development policies supporting modernising agriculture have 'exacerbated social and/or environmental vulnerability to previous or potential future changes in climate' (ibid.: 745). They contend also that development sees climate concerns as a threat, with the potential to undermine development, instead of development being designed around environmental constraints and opportunities. 'This may require people to choose not to maximise production in the short term... [but] may prevent societies (from) becoming dependent on levels of production that require "optimum" climatic conditions and which are not suitable in the medium to long term' (ibid.: 755).

Brooks et al. (2009) provide three modernisation examples of areas where policies have promoted a shift from subsistence to commercial agriculture with negative implications in light of climate change. First, the authors discuss the Sahel where policies to modernise traditional livelihoods by expanding agriculture, reducing pastoralism, and moving away from subsistence to commercialisation have resulted in livelihood approaches that are less suited to changing climate conditions. Second, the authors discuss Brazil, where 'military-initiated resettlement and large investment in infrastructure from the late 1960s to 1980s led to unsustainable and inequitable patterns of development that are still continuing today' (ibid.: 745). Third, they discuss the Kenyan government's Kenya Vision 2030, which envisions a modern development of commercialised agriculture into new land and semi-arid areas. The authors argue that these approaches to commercialisation and modernisation fail 'to consider or plan for variations in climatic and environmental conditions on timescales longer than those associated with seasonal or inter-annual variability', and are, thereby, not appropriate for a world in which the climate is changing (ibid.: 746).

Ensor (2009) argues that modern, industrial agro-ecosystems have weak resilience and biodiverse agriculture has stronger resilience. He argues that agro-ecological approaches that build resilience include: traditional complex ecosystems and diversified cropping; use of local genetic diversity; enhanced soil organic matter; intercropping; agroforestry and mulching; and home gardening. Ensor's argument hinges on the concept that 'traditional agro-ecosystems

are less vulnerable to catastrophic loss because they grow a wide range of crops and varieties in various spatial and temporal arrangements'; agro-ecological methods better withstand shocks and stresses through diverse practices that enrich resources (ibid.: 12).

For example, Ensor (2009) cites a project in the Sahel that focused on improving soil quality, integrating stall-fed livestock into crop systems to improve the use of manures and phosphates, adding legumes and green manures, incorporating water harvesting systems, and developing effective composting systems, reporting results at a 75–195 percent improvement in millet and groundnut yields. According to programme participants, yields are variable according to drought, but poor rains have a negative effect instead of total crop failure. He furthers his case with evidence from Central America in the wake of Hurricane Mitch when farmers who practiced agro-ecology suffered fewer economic losses; their land was found to have 20–40 percent more topsoil, which had greater capacity to retain large quantities of moisture and resulted in less erosion (ibid.).

Ensor (2009) further cites two long-running studies that compared organic and conventional farms, which found higher levels of organic matter in the organically farmed soils, which one study found to be of consequential benefit during drought years. His review includes discussion of studies comparing organic and conventional farm systems, as well as studies comparing diversified versus single crop farms, arguing that yield increases can and do happen in diversified organic farms in a more sustainable manner. His argument concludes that in addition to increasing yields, focusing efforts on organic matter accumulation and natural control mechanisms, versus inputs, conserves resources and allows for regeneration and higher adaptive capacity to shocks and stresses (ibid.).

If commentators, such as Jonathan Ensor, who suggest that a focus on organic farming is likely to increase resilience in the face of climate impacts are proved right, then the implications for pathways of commercialisation in sub-Saharan Africa are difficult to reconcile. On the one hand, purely from an adaptation perspective, it is tempting to recommend organic farming methods. However, there is not universal agreement that these methods deliver better yields than modernised agricultural methods relying on inputs such as fertilisers and modified seeds. Advocating farming methods which offer lower yields per hectare is not automatically compatible with commercialisation

objectives. Nevertheless, there are options for building climate resilience and increasing agricultural productivity which we review in the following section.

By way of concluding this section, these debates link to considerations around resilience or transformation as an adaptation strategy. Increasingly, a number of commentators have called into question whether resilience – in the sense of incremental adaptation to ensure the current system or status quo can retain form and function in the face of external shocks and stresses such as climate impacts – should really be the object of development (and perhaps especially development which remains a byword for ‘business as usual’ economic growth). The concern is that making incremental adjustments to current social-ecological systems perpetuates, rather than confronts, system structures and characteristics which entrench and perpetuate vulnerability to climate impacts, or indeed to poverty and marginalisation more broadly (Pelling 2011; Inderberg et al. 2015). This particular framing has been christened ‘liberal resilience’ (Rigg and Oven 2015). It has led on the part of some to calls for a focus on transformation, rather than resilience, and correspondingly, for transformative adaptation as opposed to the incremental kind that arguably characterises most current adaptation intervention (Pelling 2011; O’Brien 2012). At a glance, this agenda may seem quite similar to that which underpins agricultural commercialisation, which can broadly be understood as the end result of processes of wider structural transformation central to our understandings of the stages of economic development. Yet commentators interested in the idea of transformative adaptation are critical of precisely this development model, which they equate with status quo-maintaining resilience rather than any genuine transformation in the prospects of the poorest and most vulnerable. From this perspective, therefore, we cannot divorce our considerations of the pathways for agricultural commercialisation which are best suited to a changing climate from an underlying consideration of the kinds of social, political and economic transformations towards which they are tending.

2 ALTERNATIVE AGRICULTURES FOR SUSTAINABLE, CLIMATE-RESILIENT COMMERCIALISATION

Against this background, and considering the staggering contribution that we saw modern industrialised agriculture making to anthropogenic climate change (see Section 1), it would appear that something has to give. But what are the options for commercial farmers to make their activities more climate resilient? Can such options allow an increase in yields in ways that can withstand climate impacts, whilst reducing the adverse environmental impacts of production? In this section, we consider conceptualisations and techniques which (claim to) offer an alternative to conventional intensive, commercial agriculture, with a view to gauging their utility and relevance to agricultural commercialisation pathways in sub-Saharan Africa.

2.1 Conceptualising alternative agricultures

Before getting into alternative methods and techniques of agricultural production, it is necessary to sketch out the diverse but often overlapping concepts which, to differing extents, offer visions of alternative agriculture, but which frequently package and recommend the same agricultural practices. Perhaps what they all have in common is that they attempt to reconcile the need to:

- a) continue producing enough food to feed populations which both in Africa and globally are projected to continue to grow until 2050;
- b) maintain the commercial viability of agricultural production; and
- c) minimise environmental impacts, especially those which adversely affect yield levels, so that agricultural production remains ecologically viable over the long term.

The list runs long, and a comprehensive treatment would have to delve into agro-ecology (i.e. Valenzuela 2016), climate-smart agriculture (i.e. FAO 2013), integrated soil fertility management (i.e. Sanginga and Woomer 2009), sustainable intensification (i.e. Pretty et al. 2011), ecological intensification (i.e. Petersen and

Snapp 2015) and even agro-ecological intensification (i.e. Wezel et al. 2015). More recently, Sitko and Jayne (2017) have proposed a sustainable agri-food system productivity framework, which synthesises and organises these (and other) concepts according to the broader logic of social-ecological systems and sets them against the background of key determinants of agricultural production. Owing to its utility in relation to identifying potentially relevant production methods for sustainable commercial agriculture, we will return to this framework. In the meantime, we outline the two overarching concepts most salient to an examination of commercialisation pathways in a changing climate: climate-smart agriculture and sustainable intensification.

Much like the even broader notion of sustainable development, both climate-smart agriculture and sustainable intensification are concepts which hold much in the way of ‘motherhood and apple pie’ intuitive appeal. They are usefully ambiguous enough to accommodate the visions and perspectives of a very wide range of people who all mean different things by it and hold (or desire) it to serve purposes which are, to a greater or lesser extent, (ir)reconcilable. For the very same reason, it is difficult to offer a definition of either which can widely be held intrinsically coherent (i.e. not oxymoronic, as some commentators have branded them), or to decide what kinds of agriculture would in practice count as climate-smart agriculture or sustainable intensification, and whose criteria for inclusion/exclusion we would accept. This is not a conundrum we can hope to resolve in this paper. But it is worth starting with (relatively) simple definitions of these terms, noting some of the difficulties inherent to them and in the ways they are used, and seeing whether they might be deployed in ways relevant to our purposes (the pursuit of agricultural commercialisation in sub-Saharan Africa in a changing climate).

2.2 Climate-smart agriculture

The concept of ‘climate-smart agriculture’ (CSA) was introduced by the Food and Agriculture Organization of the United Nations (FAO) in 2009 and has since gained

considerable traction in funded programmes as well as policy debates, while also attracting major controversy among civil society organisations in particular (Karlsson et al. 2018; Newell and Taylor 2018). It emerged in the context of increasing concern over how global food security could be achieved amidst rising global populations and climate change. CSA is defined as agricultural activities that simultaneously increase agricultural productivity and incomes and support adaptation, while also helping to reduce emissions (FAO 2010). The link to emission reductions has attracted particular controversy, and later iterations emphasise that mitigation should only be considered a co-benefit, and addressed 'where possible' (FAO 2013: ix).

While not an explicit goal, activities and actor networks surrounding CSA have had a strong private sector presence from the outset, and commercialisation is seen as a key part of the spread of CSA. In a recent study from Central Asia, Mirzabaev (2017) argues that commercialisation can be a major driver for the uptake of climate-smart agricultural technologies. The author found that higher levels of commercialisation increased households' profits, in turn providing incentives and enabling conditions for investments into climate-smart agricultural technologies. In turn, these investments were found to be raising profit levels, with the highest positive impact among richer farmers. Zilberman et al. (2017) similarly argue that commercialisation-related factors are major barriers to climate-smart agriculture innovations. There is as yet a paucity of further studies to corroborate the above arguments. However, the link to commercialisation has also been one of the key areas of contention and polarisation of debates on CSA, with some seeing it as a potentially transformative approach towards more sustainable and climate-resilient forms of agriculture (cf. FAO 2016; Lipper et al. 2014), and others arguing that CSA simply represents a rebranding of well-known techno-managerial approaches to commercial agriculture, at odds with agricultural development founded on agro-ecological principles (cf. Stabinsky 2014).

For example, market integration has been presented by some as a 'climate-smart agriculture' strategy, alleviating poverty and food insecurity through adoption of CSA technologies such as drought-tolerant varieties or improving access to markets for producers. As evidence is starting to emerge on CSA investments (Rosenstock et al. 2016), it is important to understand whether and how it is driving particular commercialisation pathways, and their implications for different groups of farmers, in different contexts.

2.3 Sustainable intensification

The emergence of the term 'sustainable intensification' as a topic of debate and inquiry is often traced back to Jules Pretty's (1997) 'The Sustainable Intensification of Agriculture' (although this paper itself cites earlier sources which used the concept). Pretty does not offer a concise, one-sentence definition, but argued that in areas like sub-Saharan Africa with degraded and under-utilised land, substantial yield increases per unit of land were both necessary and achievable in ways which simultaneously were environmentally enriching and provided economic benefits. Crucially, for Pretty, this was only achievable with farmer participation 'in all stages of technology development and extension' (ibid.: 248). The three elements of yield increase with environmental and economic benefits feature to varying degrees in the majority of definitions and applications of sustainable intensification that have since been proposed. The requirement for participation – so fundamental that it prefigured what Pretty identified as in need of sustaining in the first instance – has often (though by no means universally) dropped out of the picture.

In the abstract, sustainable intensification seems comparatively straightforward, and even back in 1997, Pretty was referring to empirical evidence which he held to support his case that it was already happening, adding to the impression of its feasibility. As debates have deepened around intensification and sustainability – both separately and when the two terms are put together – it has become clearer that the requirements for achieving sustainable intensification would in fact appear to be very demanding, and indeed to require reconciliation of potentially contradictory tendencies and approaches. Intensification itself is often conceived in a way which is at odds with requirements for agricultural sustainability, because intensification is commonly defined in terms of increasing agricultural production per unit of input; most typically land (Struik and Kuyper 2017). Even in Pretty's definition, land is the unit of input in which to increase yields. However, the set of inputs required for intensification are numerous: they may be ecological (i.e. water, nutrients, soil and vegetation structure, etc.), human modifications of ecological inputs (i.e. fertiliser, crop protectants), or socioeconomic (i.e. labour, knowledge, capital). In the short term, the intensive use of inputs such as fertiliser can increase yields, but over the long term, all of these inputs need to be managed efficiently for the increase in the yield to be sustainable (Struik and Kuyper 2017). There is, by extension, a sense in which intensification

is the result of the efficient use of all relevant resources (following de Wit 1992). On this logic, rapidly increasing one input, such as nitrogen and phosphorus fertiliser – which is a staple of ‘business as usual’ commercial agriculture – can adversely affect water quality, thereby reducing, rather than increasing, overall efficiency (Bouwman et al. 2017). Indeed, to the extent that intensification formulated in terms of a couple of inputs, rather than managing all relevant inputs carefully, it is incompatible with the broader logic of efficiency. There is greater complexity in managing all relevant inputs with a view to achieving agronomic efficiency, and there are no guarantees that any of the inputs required in specific circumstances – be it land, labour, fertiliser, knowledge or water – will be available in the right quantities and at the right time. In the resource-constrained context of agricultural production in sub-Saharan Africa, this level of complexity and greater difficulty becomes very pertinent, even without considering the implications of climate change.

Sustainable intensification becomes more difficult still when we attempt to understand scalar dimensions of efficiency, and within the even wider set of parameters which operate upon it, all of which increase depending upon the kinds of efficiencies we are trying to achieve. Efficiency describes a relationship between the achievement of a goal and the level of effort required for that achievement. Efficiency is thereby realised when the level of effort required to achieve a particular goal is minimised. By definition, efficiency (and, concomitantly, sustainable intensification) becomes more difficult to realise the greater the number of goals that we are trying to achieve, especially when the achievement of one goal may jeopardise the achievement of another. This becomes increasingly likely when we start to contemplate the ‘hierarchy of goals across scales’ (Struik and Kuyper 2017: 39) that a broad objective like sustainable intensification implies. At some level, if sustainable intensification is to make a thoroughgoing contribution to the global goal of mitigating and adapting to climate change, then efforts at the local level must cohere rather than clash with efforts at other levels and, ultimately, the global level. As Struik and Kuyper (2017) note, this requires changes in the way that we think about everything from agronomic to economic efficiency. Yet this is difficult, precisely because efficiency at one sub-system level is in no way guaranteed to lead to overall system efficiency, as commentators like van Noordwijk and Brussaard (2014) have documented. Adding a further layer of complexity, we can also ask the question of which dimension of efficiency we are trying to address. If we privilege the agronomic dimension of efficiency, are we also able

to take into account the environmental, economic, social, justice, equity and intergenerational dimensions sufficiently (Struik and Kuyper 2017)?

Against this background, it is much harder even to understand what sustainable intensification is, let alone what it should look like in practice. This is the flipside of the complex social-ecological systems perspective thinking that increasingly underpins scholarship on agricultural production: it introduces a level of complexity that can be (or at least seem) either incomprehensible, unmanageable, or both. And this is perhaps one (if not the only) reason why we should not be too surprised if we find that prevailing usage of the term sustainable intensification to describe more ‘business as usual’ forms of intensification (Wezel et al. 2015; Petersen and Snapp 2015): it is so dauntingly difficult. Perhaps we do not know very much about how to achieve its many objectives at once, not least because these have expanded over the lifetime of its currency (see, for instance, the elements added to it even by Pretty (2008; Pretty et al. 2011) in later publications on it). Conversely, increasing yield and, thereby profit, by applying one or two extra inputs, such as fertiliser, with perhaps a nod towards the need to think about the implications for water quality, for instance, without much changing the practice of intensification, is much easier. Yet it is very different from what Pretty envisaged for sustainable intensification back in 1997: a gradual substitution of external inputs with natural processes which were less environmentally harmful.

Add to these dynamics the historical tendency of intensive agriculture to privilege capital accumulation over environmental or equity concerns (see Akram-Lodhi and Kay 2010a, 2010b for a review), and there is a powerful incentive for business to continue as usual, even if labelled otherwise. However, if only the label has changed and not the practices it describes, we can equally understand why Mahon et al. (2017) would brand sustainable intensification an oxymoron. And it is the perceived co-optation of the meaning of sustainable intensification which has led to the proposal to use other terms – such as ecological intensification (cf. Cassman 1999) or agro-ecological intensification (cf. Garbach et al. 2017) – to rescue (and refine) the original objectives of sustainable intensification from the fate of the term itself, which at least for these authors, has become irreparably tainted.

All of these difficulties lead Kuyper and Struik to pose the question: is there ‘a way out of this quagmire’ (2017: 39)? Ultimately, they call for a new agronomy and a new role for agronomists fuelled by processes of knowledge

exchange and (re-)education, in order to ensure that empirically, sustainable intensification genuinely delivers what they term a 'richer shade of green'. There is merit in this conclusion, but it is a broad vision and one that does not tell us more concretely how the theory and practice of sustainable intensification may, within a more immediate timeframe, serve the objectives of the four agricultural commercialisation pathways that APRA research is seeking to explore. It is in relation to this consideration that we return to the framework that we mentioned earlier, proposed by Sitko and Jayne (2017).

2.4 The sustainable agri-food system productivity framework

Sitko and Jayne are essentially concerned with providing an approach 'for promoting productivity and resilience of African agri-food systems' (2017: 6), and propose the 'sustainable agri-food system productivity' (SAP) framework as a means of achieving these objectives. Their framework is, as its title suggests, premised on the need to look beyond farm-level dynamics and techniques to phenomena occurring at 'higher' levels within a social-ecological system, and which impinge upon the prospects for commercial viability and ecological sustainability in sub-Saharan African agriculture. For this reason it seeks to integrate sustainable intensification, climate-smart and market-smart approaches to agricultural production, with a view to situating them more insightfully within a context of rapid change within African agri-food systems. They see this act of conceptual integration as a necessary step in understanding whether any particular farming method branded climate smart, sustainable intensification or market smart can genuinely be held to contribute to productivity growth and resilience. Whilst laudable in their own terms, for Sitko and Jayne, these concepts pay insufficient attention to the kinds of concerns which arise from taking a wider look at an entire agri-food system, and not just one part of it. In order, then, to gauge the substantive prospects for farming techniques deemed climate-smart, market-smart or sustainably intensified agriculture, as well as where and when they might most effectively be deployed, Sitko and Jayne argue that they must be:

- Contextualised against a background of broader, exogenous factors operating on the agri-food system – such as population growth, urbanisation, climate change, the implications of a demographic skewed towards a young population, etc.
- Situated within authority understanding of the local dynamics – such as agro-ecological

characteristics, farm size, soil conditions, household productive assets, etc. – which pertain at the farm level.

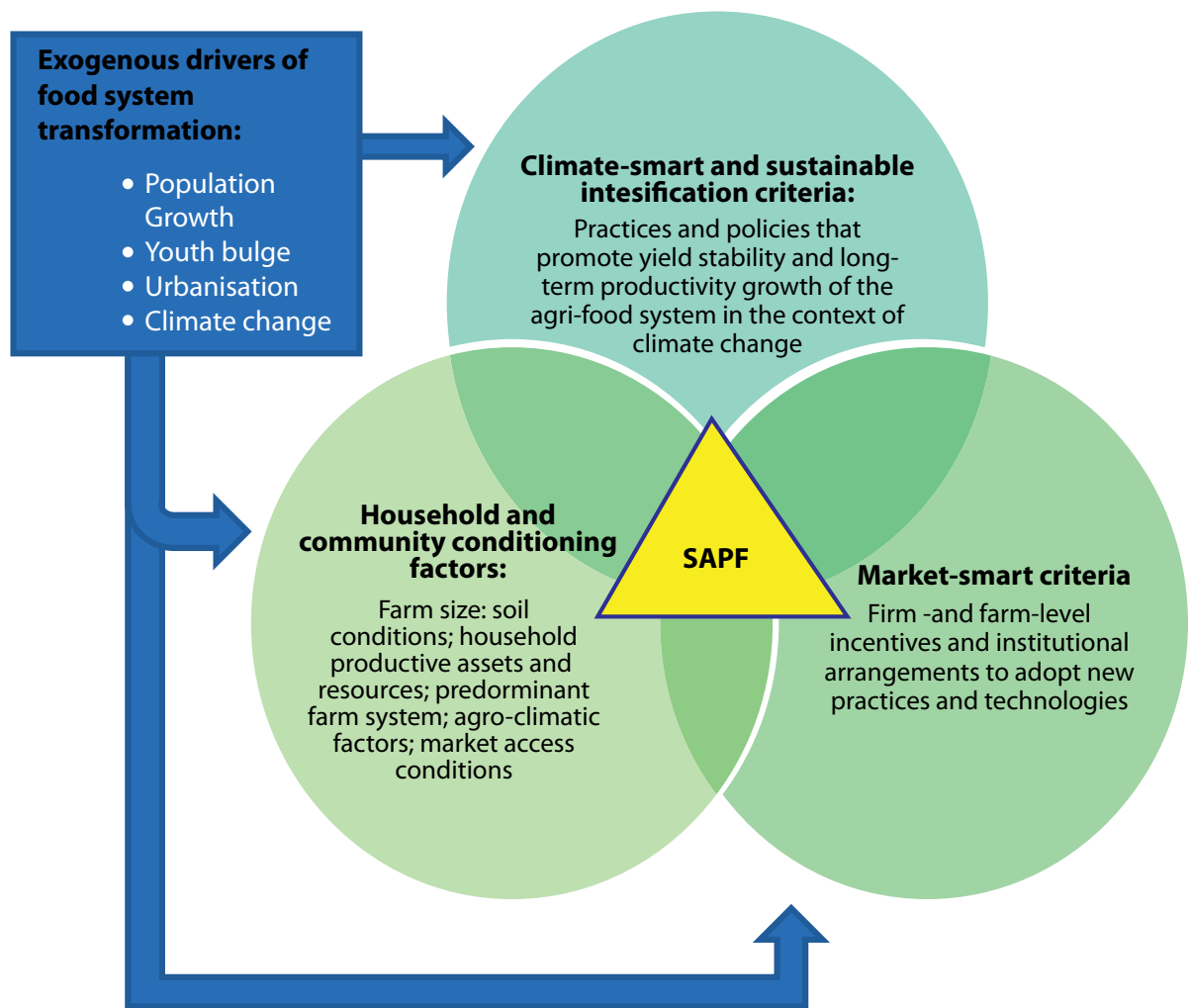
At the heart of their thinking is a concern with the need for farmers in sub-Saharan Africa to escape from a 'social trap' (following Platt 1973) which is inimical to the prospects for commercial and ecological sustainability. This trap consists of living in conditions which require people to put short-term priorities before long-term imperatives, with adverse consequences. In the context of agri-food systems, this can be seen as a very understandable tendency to prioritise feeding the family over the longer-term objective of maintaining the fertility of the soil.

Encouragingly, this model of thinking leaves scope for collective action, aimed at nudging behaviours towards the achievement of more favourable longer-term objectives, and Sitko and Jayne see scope for fruitful policy intervention therein. However, they contend that currently, social traps across sub-Saharan Africa are implicated in increasing the levels of environmental degradation, exacerbated by population growth and increased production for the urban areas and centres which are experiencing the bulk of that population growth.

Within the familiar form of the Venn diagram, Sitko and Jayne chart the various elements of the sustainable agri-food system productivity framework, indicate the relationships between them, and highlight potential areas of synergy between objectives (see Figure 3). In the same paper, they proceed to apply the framework across many of methods and techniques often held to be examples of climate-smart/market-smart agriculture or sustainable intensification, within the sub-Saharan African context. We will return to their findings later by incorporating their assessments into the coverage of such methods and techniques, which comprises Section 2.5. By way of concluding this discussion about conceptualising alternative agricultures, it is worth outlining the extent to which this framework does (or does not) offer us a way out of Struik and Kuyper's (2017) sustainable intensification 'quagmire', in order to avoid setting it up either as a panacea or a priori unworkable, given the difficulties we have noted in conceptualising sustainable intensification.

The synthetic character of the SAP framework to some extent means that it repeats, rather than resolves, issues and concerns which can be raised in relation to its component elements. It is, for instance, just as vulnerable to co-optation as sustainable intensification

Figure 3: Sitko and Jayne's sustainable agri-food system productivity framework



Source: Sitko and Jayne (2017).

and climate-smart agriculture. Even assuming that with the framework we can make viable recommendations for support to agricultural commercialisation which delivers co-benefits or even hits the SAP sweet spot, in practice the extent to which this will be possible will be subject to a broader set of political economy considerations which determine how trade-offs between potentially conflicting objectives will be handled, and in whose interests. Work in Kenya and Mozambique on the political economy of climate-compatible development (CCD) – another concept seeking to achieve ‘triple wins’ – demonstrates that the initiatives likeliest to achieve CCD objectives may in fact be marginalised relative to forms of less synergistic interventions which nevertheless serve more powerful interests (Naess et al. 2015).

Perhaps most crucially, the treatment within the

framework of market-smart initiatives as a means to achieve sustainable intensification does not explicitly recognise that the globalisation of the agricultural market, rather than inherently synergistic with objectives of sustainability and resilience, have historically tended to be antagonistic, very difficult to reconcile. This is precisely why agriculture is a large contributor to global greenhouse gas emissions. Putting so much emphasis on market smartness as a criterion for selection of productive, resilient agriculture is arguably at risk of promoting a historical cause of environmental degradation as its solution, tied to a capitalist economic logic which, for some commentators like John Bellamy Foster (2000) and Jason Moore (2015), is intrinsically unsustainable, environmentally speaking.

Furthermore, the SAP framework uncritically adopts the logic of a complex social-ecological

systems perspective (Berkes et al. 2008), bypassing debates around poststructuralism in disciplines like anthropology, literary theory, sociology, human geography and political science. These debates have raised the question of whether the functionalist logic that underlies systems theory is ineluctably circular (Taylor 2014; Watts 2015). Efforts have been made in recent decades to formulate a way of thinking about human–environmental interactions which attempt to get beyond circularity of this kind, for instance in the work of Bruno Latour (1993, 2004, 2013), whose radical ontology, he contends, is in fact necessary if we are to get to grips with understanding and responding to the Anthropocene. This is not the place to explore critiques quite this fundamental, let alone adjudicate between these ostensibly rival approaches. (Latour’s position has also been subjected to powerful, arguably devastating critique – see, for instance Bloor 1999). Yet it is important to recognise that whilst systems perspectives are often used as a kind of meta-level theory within much thinking on climate change and agriculture, it may be wise not to treat them as an analytical given.

In view of these concerns, it might be tempting to conclude that setting sustainable intensification, climate-smart and market-smart agriculture within the context of agri-food systems, as the SAP framework has done, fails to resolve the difficulties inherent in each of these terms, or to recognise sufficiently quite how difficult it is to reconcile their objectives. However, if we return to the idea that they may serve particular purposes, in specific contexts, to a greater or lesser extent, and can use them coherently and systematically within these constraints, we can relieve the SAP framework of the requirement to address these bigger problems single-handedly. Against this background, it can have a useful purpose to serve, as long as we are prepared to accept the following assumptions and caveats:

1. In some way, the notion of a system, even if potentially tautological, captures something important about how commercialisation strategies on particular farms/in particular areas will be affected by processes much bigger than them – land access, population dynamics, exiting from farming as a livelihood, climate change, etc., which will be critical for the prospects of achieving SAP objectives.
2. Markets – and the wider system of capitalism in which they are embedded – are, pace Bellamy Foster, Moore and others, susceptible to the kinds of reform which would reduce their role in processes of environmental degradation.
3. Whatever the agro-ecological viability for ‘SAP-

compatible’ methods and techniques which are productive, environmentally sustainable and commercially viable, the extent to which these outcomes are ultimately achievable will depend on how favourable (or not) the broader political economy in which they are being proposed is to their achievement.

These are issues for the broader APRA research effort to grapple with collectively (not least, in relation to the third point, the crosscutting theme on political economy), and we would suggest that there is a role for this framework in assisting or facilitating that process.

2.5 Alternative techniques and methods for sustainability in agricultural commercialisation

This section briefly surveys commonly identified ways of farming which hold out the promise of higher yields whilst maintaining good soil quality and nutrient richness over the longer term, even in conditions of considerable climate variability and change. The practices we cover, all chosen on account of their existing prevalence in sub-Saharan Africa, are:

1. conservation agriculture;
2. cover crops;
3. agroforestry;
4. soil conservation; and
5. irrigation.

With each practice, we report the assessment made of its viability offered by Sitko and Jayne (2017) using the sustainable agri-food system productivity (SAP) framework.

2.5.1 Conservation agriculture

Conservation agriculture is underpinned by three core principles and related practices: the minimum possible level of disturbance to the soil; the retention of crop residue; and crop diversification either through crop rotation or intercropping (FAO 2015). Although they are often used separately, the consensus is that using them in combination gives much better results, especially when Kassam et al. (2015) find that globally, 157 million hectares of land are cultivated using conservation agriculture methods, and whilst they are widely promoted in sub-Saharan Africa, adoption rates are quite low (Arslan et al. 2014). In the context of East and Southern Africa, Wall et al. (2013) report that where

there is uptake, most of it (99 percent) is accounted for by commercial rather than smallholder farming. This suggests already that although conservation agriculture has commercial viability credentials, it is not being used by farmers who represent one of the key commercialisation pathways APRA is seeking to explore.

Zero and minimum tillage practices aim to tackle soil erosion, increase the capacity of the soil to retain water, and arrest soil organic carbon decomposition, ultimately with a view to permitting high yields under conditions of considerable climate variability (Branca 2011 et al.). However, the evidence on yield and soil quality effects of zero and minimum tillage is mixed, to say the least. Broadly speaking, there is consensus that in the short term, there may be little improvement, or even a reduction in yield (Paul et al. 2013) when such practices are introduced. In order to give the best results, it is often suggested that they need to be combined with the other conservation agriculture practices (Govaerts et al. 2005). Critical to the prospects for uptake of zero and minimum tillage practices, they tend to be adopted by better-off farmers who own (or at least have stable access rights to) larger quantities of land (Corbeels et al. 2014). For zero and minimum tillage techniques that do not require mechanised or animal draught power – such as basins and potholes – in addition to land availability considerations, adoption is also likely to be limited by costs of acquiring specialised implements, and heightened labour costs (Giller et al. 2009; Shetto and Owenya 2007). For these reasons, Sitko and Jayne (2017) suggest that minimum and zero tillage practices will have only marginal benefits measured against the criteria of their SAP framework. However, they do see some potential for this variety of conservation agriculture in regions characterised by farmland consolidation and mechanisation, because under these conditions there is a key benefit in terms of reduction in fuel costs associated with land preparation. Whilst this could potentially bring large areas of land under a conservation agriculture regime, it would bring commercial benefits to relatively few farmers, and thereby scores more highly on environmental than on poverty reduction grounds.

Intercropping and rotation: by increasing soil fertility and nutrient supply, intercropping and rotation strategies seek to reduce reliance on inorganic fertilisers and increase yields simultaneously (Branca et al. 2011). Again, both are more effective and make a greater contribution to soil quality over the longer term when done in combination, but the dominant tendency in sub-Saharan Africa is to adopt intercropping only (often

of maize with legumes), often for reasons of limited land availability (Kamanga et al. 2010). Whilst in the short term the effects of intercropping and rotation on yield and profitability are variable (Thierfelder et al. 2017), adoption is higher where input and output markets are well developed (Corbeels et al. 2014). For Sitko and Jayne (2017), SAP outcomes are contingent on two main sets of factors:

1. The presence of population and economic growth which give rise to demand for legumes and create improved conditions of market access; and
2. Developing arrangements for the provision of legume seed which function at the system rather than farm level. This entails going beyond simply providing seed locally, but integrating 'legume supply chains in ways that strengthen the link between consumer demand, seed supply and smallholder production' (ibid.: 35).

Mulching and residue retention: the use of animal and crop manure, or retaining the residue from field crops, are employed in order to increase soil organic carbon levels, improve nutrient utilisation and the capacity of the soil to retain water, and better regulate soil temperatures (Thierfelder et al. 2017). Whilst the results can be variable, they can also be spectacular: Yamoah et al. (2002) report that just retaining rather than clearing residue increased pearl millet yields by a factor of 1.2. In combination with the use of inorganic fertiliser, they reported a fourfold increase in yield. Similarly impressive results have been found in other studies (i.e. Subbarao et al. 2000; Kapkiyai et al. 1999). Despite this potential, Sitko and Jayne (2017) deem these techniques to have low potential to achieve SAP outcomes. Because of competing uses for the residue (principally as animal feed), there is an opportunity cost to retaining it for cropping purposes, especially on smaller farms; although there is more potential for residue retention on larger farms.

2.5.2 Cover crops

This technique entails planting leguminous crops, grasses or other crops at times when cash crops are not being cultivated, with a view to managing soil erosion, fertility and quality, water, pests and weeds (Lu et al. 2000; Branca et al. 2011). Substantial benefits from cover crops have been found in studies in sub-Saharan African contexts. For instance, in Kenya, work by Kaumbutho and Kienzle (2007) recorded maize yield increases from 1.2 t/ha to 1.8–2.0 t/ha when mucuna, a native tropical legume, was used as a cover crop (see also Pretty 1999, who cited it as evidence of the extent

to which sustainable intensification practices might feed (Africa).

Despite this quite wide range of promising applications, and despite suggesting the potential for climate resilience benefits, Sitko and Jayne (2017) do not find cover crops a very likely candidate for the achievement of the objectives of the sustainable agri-food system productivity (SAP) framework. Principally, they argue that this is because many farmers would struggle to devote scarce land to the purposes of non-food crop production, which is what primarily explains low adoption rates. However, additionally, they follow Place et al. (2003) in being sceptical at the prospects for increased adoption of cover crops when the main vehicle for promotion is through the distribution of free or subsidised seeds. Place et al. found that once subsidies were removed, farmers were not prepared to pay for the seeds. Nevertheless, Sitko and Jayne suggest that in areas where there is increased cost of on-farm labour, owing to lower availability or higher returns to farm labour, the greatly reduced weeding that cover crops require can offer greater incentives for its uptake.

2.5.3 Agroforestry

The FAO (2015) defines agroforestry as ‘a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence’. Agroforestry techniques hold out greater prospects for improved microclimate, more efficient water use, better soil quality, options for pest control and off-farm sources of revenue (Lasco et al. 2014). There is also evidence to suggest that in a number of sub-Saharan African countries, they have contributed substantially to yield increases (Akinnifesi et al. 2008) and also yield stability (i.e. Snapp et al. 2010). As such, agroforestry appears to have good credentials for climate-smart agriculture or sustainable intensification objectives.

However, measured against the SAP framework, Sitko and Jayne (2017) suggest a mixed picture for the potential efficacy of agroforestry strategies. Much like conservation agriculture, one of the key difficulties with agroforestry is that its potential benefits become only slowly available, over the medium-to-long term. This means that effectively, only the better-off farms, with more land and income, tend to adopt these practices in the first place (McCarthy et al. 2011). Even with

subsidised or free seedling promotion, in combination with training in agroforestry techniques that are otherwise relatively uncommon in the sub-Saharan African context, adoption rates are quite low (Akinnifesi et al. 2008). On this basis, Sitko and Jayne argue that in areas with quite high population growth, greater land fragmentation and rising land prices, agroforestry is unlikely to be adopted in ways capable of meeting the SAP framework criteria. Conversely, in areas close to urban centres with poor power supplies, the potential for agroforestry that produces fuelwood and charcoal may be a significant and overlooked strategy for increasing income growth.

2.5.4 Soil conservation and erosion management

Practices such as tied ridge systems, bunds, contour farming and terracing tend to be used with a view to managing water and increasing its availability to plant roots during growth (Rockström and Barron 2007). When effective, such water management practices can aid the production of biomass, returning more biomass – both above-ground and root varieties – to the soil, thereby improving soil organic carbon composition (Pretty et al. 2011). There is also evidence of substantial yield increases, especially in cropping systems in which moisture is a substantial constraint to production (Lal 1987, cited in Sitko and Jayne 2017).

However, these practices can be both land and labour intensive (Pretty et al. 2011), and as is the case with other techniques and systems relevant to sustainable agricultural productivity, these factors can be an important constraint for adoption. Sitko and Jayne observe that adoption is likely to be higher where there is greater knowledge of the adverse implications of soil erosion and, thereby, greater demand for techniques that address it, in combination with the presence of service markets which provide such techniques. They cite work by Jules Pretty et al. (2011) in Burkina Faso, which documents the groups of young men specialising in soil conservation techniques who, in response to farmer demand for tassa and zai planting pits, travelled between local villages offering their services. Under such conditions, they could potentially contribute to SAP outcomes.

2.5.5 Irrigation

Whilst not a technique exclusive to efforts towards sustainable agriculture, access to irrigation technologies is commonly held to be key to assisting smallholder farmers in overcoming the constraints on crop productivity growth and stability in sub-Saharan Africa imposed by erratic and insufficient water supplies (Lal 1987, cited in Sitko and Jayne 2017). At the same time, evidence abounds of limited success in the use of irrigation relative to its potential, with farmer abandonment of techniques intended to be appropriate to specific contexts – such as drip and treadle pump forms of irrigation (i.e. Adeoti et al. 2007). Moreover, the economic returns from irrigation when used with low-value crops can be very low, suggesting the expediency of using irrigation with higher-value crops (Burney and Naylor 2012). This leads Sitko and Jayne to suggest that a SAP strategy in relation to irrigation would most effectively be applied to areas in which land prices were rising as a result of population growth and urban expansion, giving rise to greater incentives for land intensification.

3. CLIMATE IMPACTS ON SPECIFIC COMMERCIALISATION PATHWAYS

There is a growing but still small and decidedly incomplete literature on the extent to which particular kinds of commercialisation are likely to be more vulnerable to climate impacts. Agriculture across sub-Saharan Africa is highly heterogeneous and going through major shifts (AGRA 2016), and current farming arrangements are complex and changing (Livingston et al. 2011). Likewise, the impacts of climate change are context and temporally specific. Therefore, this review considers context-specific evidence on the implications of climate change for four different commercial agriculture pathways in specific places and times.⁸

It should be noted that there is often a conceptual overlap between these pathways. For example, a nucleus estate arrangement is a combination of smallholder farmers and estate farming, where contracted smallholders complement production on a central estate. In this inception paper, nucleus estate arrangements are considered to be a type of contract farming.

Box 3: Opportunities for nucleus estates

- Livingston et al. argue that while estate farming will continue in sub-Saharan Africa, there is significant scope for smallholders to increase their role as commercial suppliers.
- Low population density, remote populations, and poor road networks in sub-Saharan Africa may lead to more nucleus estates that maintain the central role of smallholders.

Source: Livingston et al. (2011).

3.1 Estate/plantation/large-scale commercial farming

The literature suggests that estate farms likely have greater capital to anticipate and respond to climate changes and shocks and are therefore more resilient to climate change. However, their tendency to focus on one crop increases vulnerability.

There is a gap in the literature on what the expected implications of climate change for large-scale commercial farming, including potential adaptation measures, will mean for the men, women, boys and girls who may work on these farms. A shift in types of crops grown may have implications on labour demands, quality and benefits, which may be leading toward casualisation with disproportionately negative implications especially for the female labour force (Dancer and Tsikata 2015). For example, Mahajan (n.d.) studied agricultural wages in India, finding that women were more likely to suffer wage losses in drought times than men due to the greater value for women's labour for rice cultivation.

3.2 Outgrowing/contract farming

According to Kirsten et al., contract farming is especially relevant in sub-Saharan Africa for fruits and vegetables, and 'such arrangements have facilitated smallholder farmer linkage to high-value European markets' (2013: 9).

According to Smalley's (2013) review of the evidence, contract farming can offer participants higher earnings, a stable income and access to credit, though participants are often not the poorest, and some schemes have caused landlessness and dependency. According to Dancer and Tsikata (2015), when contracts require farmers to use their own land, then women who do not have land titles are excluded from the opportunity, and when the contract scheme takes up customary land, women may lose the autonomy of their subsistence farming areas. The authors also find from a review of the literature that women's roles in the production of the crops may go undervalued and their power over the income may be limited (ibid.). It is unclear whether and how climate change will have implications for women's access to and benefits from contract farming. However, if climate impacts make it harder to cultivate particular crops in the areas where specific out-growers live, there clearly would be adverse impacts for women who were either out-growers in their own right or part

of households for which outgrowing was the principal source of income and/or who specialised in outgrowing.

Out-grower schemes can improve market linkages, and influence participating farmers and surrounding areas to use improved inputs, access financial services, and pursue commercial farming (AGRA 2016). They can also lead to reductions in transaction costs for groups of farmers (Kirsten et al. 2013).

In Ghana, Azumah et al. (2017) find that contract farming can also increase farmer climate knowledge and climate change adaptation strategies, but at other times these schemes may exclude those farmers who do not have access to the knowledge and technology already. However, in the United States, Schewe and Stuart (2016) find that seed-corn industry contracts limited farmers by incentivising production over adaptation and limiting farmers' information on climate change impacts.

Mishra et al. find that contract farming can increase diversification, a key adaptation strategy, but that many arrangements are informal and hard to enforce if violated: 'in case of pests' attacks and diseases, contract farmers are often left in lurch by contracting parties' (2015: 22). Given the likelihood that pests and diseases will increase with climate change, as well as growing conditions and suitability, much depends on the inclusivity of the contracting arrangement.

Coffee is often grown under contract farming arrangements, and is highly vulnerable to climate change. Sometimes called the goldilocks plant owing to the comparatively narrow range of agro-ecological conditions under which it will grow, suitability regions are likely to shift due to climate change, and the burden of double exposure due to global price variability is already affecting coffee farmers worldwide. A review of coffee farmers in Honduras, Guatemala and Mexico show that coffee farmers are trying to diversify to absorb poor yields and/or price shocks (Eakin et al. 2005). Better-off farmers are replacing their coffee orchards with sugar cane, even though sugar cane is vulnerable to higher temperatures; smaller farmers reported investing in alternative cash crops, small livestock, and pasture. Few decided to expand coffee production in the hope of cashing in if a good crop came in and others dropped out (Eakin et al. 2005).

Criticisms of contract farming cite the unequal power relationship between a company and farmers, arguing that farmers often provide land and cheap labour, and carry most of the risk (ActionAid 2015; Kirsten et al. 2013; Martin-Prével 2015). As climate change will

increase risk, this is a critical factor in the vulnerability of women, men, boys and girls involved in contract farming. Understanding the implications of climate change for out-growers, against a shifting background of unevenly distributed exposure to risk, will be important for gauging the outcomes of this activity, the livelihood prospects of those engaged with it, and for identifying relevant policy measures focused on reducing risk.

3.3 Medium-scale commercial farming

The number of medium- and large-scale farmers, a majority of whom farm commercially, has been increasing in African agriculture over the last decade (Jayne and Ameyaw 2016 in AGRA 2016). However, there is less literature on this particular group's vulnerability to climate change.

A small but emerging literature signals the prospect of higher vulnerability among farmers attempting to increase production for market (Ziervogel et al. 2006; Eakin 2005). For both medium- and large-scale farmers, the literature shows that their climate vulnerability increases because they tend to plant a single crop to respond to market opportunities, 'which can render no returns at all in unfavourable climate conditions' (Ziervogel et al. 2006: 300). However, when there are good returns, 'they may be able to increase their income base and thus their resilience' (ibid.: 301). Ziervogel et al. conclude:

Box 4: Medium- and large-scale farmers in Africa

- The number of indigenous medium- and large-scale farmers has increased in the past decade;
- Most are commercially oriented.

Source: Jayne et al. (2015), in AGRA (2016).

Better-off entrepreneurial farmers tend to block plant their whole plot with a single market crop, thereby producing a good income in a good year or potentially significant losses in a bad year (ibid.: 298).

To the extent that mono-cropping is a more lucrative option for commercially minded farmers, climate change seems likely to produce winners and losers. Those who find that the area they live in is less conducive to the conservation of the crops from which they derive a living will have to think hard about the resilience of a mono-cropping livelihood strategy to climate impacts.

Those living in areas in which conditions will become more propitious for the cultivation of crops with greater commercial potential may be presented with greater opportunities. Much may hinge on the ability of farmers, in combination with the presence of enabling conditions (or lack therein), to switch to a different commercially viable crop which does better under changing environmental conditions.

Carr finds that for Ghana, while men and women are both vulnerable to cropping and environmental shocks, men may be additionally vulnerable because they farm cash crops and therefore rely on the market (2008, in Bernier et al. 2015). Overall, however, there is a gap in the literature on the gendered implications of climate change for labourers who may work on commercialising small- and medium-sized farms.

A related topic for which there is a wider literature covers the impacts of land use for large commercial agricultural ventures at the cost of displacement and loss of the commons (Dancer and Tsikata 2015). This may increase vulnerability within the community to climate change impacts, not least because it can reduce not only the range of adaptation options available, but the livelihood

Box 5: State of smallholders in Africa

- Over 85 percent of the farms in sub-Saharan Africa are under smallholder ownership/management (about 50 million farms), about 70 percent of whom are female farmers;
- Compared to other regions in the world, sub-Saharan Africa's yield per hectare lags behind in nearly every crop.

Source: Phiiri et al. (2016).

prospects for 'stepping up' and 'stepping out'. For example, a recent review of livelihood trends in the drylands of East Africa concluded that in Kenya, Ethiopia and Somalia, 'the most significant trend redefining pastoralism is the fragmentation of rangelands through processes of excision, privatisation (often taking the form of enclosures) and commodification of rangeland resources' (Lind 2016: 2). Rangeland fragmentation threatens customary pastoral systems, particularly affecting those pastoralists whose herds are medium sized because they are not wealthy enough to own enclosures or absorb the financial impact of losing rangeland and still have a need to find grazing areas (ibid.). The chief advantage that livestock farming offers,

when considered in terms of climate change adaptation, is mobility: livestock can be moved to grazing areas in other locations if local pasture and water supply prove insufficient. By comparison, sedentary cultivation is almost by definition a non- (or less) mobile production strategy. Yet if access to grazing resources is reduced then the adaptive advantages of transhumance are compromised.

3.4 Smallholder farms and commercialisation

Smallholder farms produce much of the world's food, especially on the African continent. The majority of farms in Africa are smaller than two hectares, and because populations are continuing to rise, farms are likely to continue to divide and thereby grow in number (Fan et al. 2013, in AGRA 2016). The literature is widely in agreement that smallholder farmers are highly vulnerable to climate change because landholdings are small and in most cases rely on rainfed farming; therefore, when rainfall patterns and suitability conditions change, smallholders are directly affected. Farmers will likely need to adapt what, how and when they grow, while smallholders, particularly female farmers, often have less capital and connectivity to information to adapt effectively.

Kakota et al. argue that climate change inhibits commercial prospects for smallholders in Malawi because it undermines household food security. When household food security is on the line, households sell off productive assets and forgo using inputs, negatively affecting commercialising prospects (2011, in Kirsten et al. 2013).

Mapila et al. argue that in Malawi, smallholder commercialisation projects enabled households to take advantage of market incentives: '[T]here is evidence that these households may be more vulnerable to macroeconomic and agricultural sector policy shocks' (2011, in Kirsten et al. 2013: 26). Kirsten et al. report that critics of the Mapila et al. paper countered that it did not adequately take into account households' adaptive capacity in the face of these shocks (2013: 26). Indeed, what we term 'locally-held knowledge' (following Newsham and Bhagwat 2016)⁹ is a potentially rich source of adaptive capacity, and perhaps with particular relevance to smallholder farmers who lack access to land, finance, irrigation and other potentially adaptive technological options.

Concerns have been expressed about the extent to which locally-held knowledge will allow people to deal

with future as well as contemporary and historical climate variability (i.e. Berkes 2009; Ifejika Speranza et al. 2010; Smucker and Wisner 2008). However, others have argued that locally-held knowledge is more robust and dynamic than is often acknowledged (Mortimore 2010; Nyong et al. 2007; Tschakert et al. 2010). Newsham and Thomas (2009, 2011) found that in Namibia, farmers incorporated some elements of agricultural science (i.e. early-maturing varieties of pearl millet) into an existing agro-ecological knowledge system. This adaptation, derived from knowledge co-production between farmers and agricultural extension officers, who gave them more options to deal not only with contemporary and historical climate impacts but also some (if by no means all) future climate impacts – at least in the short-to-medium term. However, other agricultural extension efforts to improve local yields in North-Central Namibia had not found favour because they did not establish their relevance to existing agro-ecological knowledge and the farming practice based on it (Verlinden and Dayot 2005). When considered from the standpoint local agro-ecological knowledge – and, arguably, from that of agricultural science – the intervention was inadvisable. This experience highlights the importance of locally-held knowledge as the ‘knowledge frame’ (Roncoli et al. 2009; Ifejika Speranza et al. 2010) against which proposed interventions, be they for commercialisation or adaptation ends, will be interpreted, and the dangers of not engaging or understanding it. Moreover, to the extent that efforts towards greater commercialisation of agricultural activity encourages the abandonment of farming practices derived from locally-held knowledge, there is a substantial risk of losing adaptive capacity.

Box 6: Opportunities for sub-Saharan African agriculture

- Population and income growth creating demand for food supplies at the same time global productivity increases are levelling off.
- SSA’s low productivity is an unrealised opportunity to source increasing demand.

Source: Livingston et al. (2011).

Yaro and Hesselberg (2016) find greater vulnerability for rural communities in West Africa where a high proportion of the populations earn a living from the natural environment and their book provides information on variable adaptive capacity across the region. In particular, Yaro et al. (2016) find that amongst smallholder farmers, the following characteristics determine

whether households have greater adaptive capacity: age, gender, assets, family size, size and type of land, skills/education, and perception of climatic changes. In Laube’s chapter on Northern Ghana, he discusses commercialisation in two main areas. First, the structural conditions that undermine smallholders’ attempts to commercialise and sell at larger markets in Ghana: the risk of being crowded out in the face of competition from highly subsidised global food industries, fluctuating prices, changing quality requirements, consumer preferences, and he concludes that ‘the effects of global environmental change and disadvantageous patterns of global trade seems to partially question the focus on export-oriented agricultural commercialisation in climate change adaptation strategies for northern Ghana’ (in Yaro and Hesselberg 2016: 123). Second, the author addresses commercialisation arguing that while the Ghanaian government and international donors conceptualise Northern Ghana ‘as an area in which smallholder-based growth through climate-proof and commercial agriculture is leading to successful climate change adaptation and economic growth’ (ibid.: 124), the large parts of the population, 60 percent of which are under the age of 25, are prioritising education and professional careers. Laube argues that this rural transformation is being neglected by the government and donors who are enacting policy to modernise, commercialise and climate-proof agriculture instead of education and professional career development.

Chitimbe and Liwenga (2015) studied smallholders moving into commercialised agriculture to take advantage of market opportunities for maize in an area facing changing rainfall patterns and increasing temperatures in Tanzania. As they commercialised, farmers took up mechanised farming and used more inputs, which had some benefits but also led to abandoning traditional practices and seed varieties. The authors found that ‘though some of the new practices and crops/crop varieties had a positive implication on the adaptation to climate change and variability, most

Box 7: Agricultural transformation in Africa

- Since 2000, the share of the labour force primarily engaged in smallholder farming in Africa has been declining rapidly:
In 2000: 70–80 percent;
Today: 40–65 percent;
- The decline has been most rapid in countries with highest agricultural productivity growth.

Source: AGRA (2016).

of them were found to expose the farming communities more vulnerable to climatic shocks' (ibid.: 129). For example, with mechanisation, households did away with traditional practices of seed planting in advance of rains, and without adequate weather information, the timing of planting exposed some farmers to losses.

This study echoes findings from other parts of the world, interestingly. For instance, Eakin (2005) studied the livelihood strategies of Mexican smallholders, and concluded that increased commercialisation did not improve risk management for the farmer, but rather that subsistence maize agriculture was a more stable choice despite its sensitivity to hazards. Specifically, irrigation production meant that farmers risked losing multiple harvests in one year and could not pursue off-farm activities to keep afloat when the poor harvests occurred (ibid.). The apparent willingness to take these risks by moving away from cultivation strategies seemingly better adapted to local climate variability speaks, perhaps, to the lure of commercial crops. Conversely, in contexts where there is an absence of other viable livelihood options, farmers may feel more compelled to commercialise.

Van Eerdewijk and Danielsen (2015) studied gender and small-scale farm power mechanisation in growing maize in Ethiopia and Kenya. They found that women were less likely to articulate demand for and adoption of mechanisation, despite the intensity of women's labour, 'due to the complex interplay of values and assumptions, access to and control over resources, and intra-household decision-making' particularly that women's work was 'invisible' and the expectation was that women would work long and hard hours without voicing concern. A compounding factor was that women did not control resources or have control over land, income and extension services. Lastly, decision-making was considered within the male domain, which also prevented uptake (ibid.).

There are few studies that directly compare the vulnerability of smallholders compared to other types of farming. Ziervogel et al. (2006) do so in their study in South Africa, finding that poorer farmers are more vulnerable because they are directly dependent on climate conditions and they have fewer resources to offset bad climate conditions. However, they have increased their resilience by diversifying crops and livelihood strategies. They cite poorer farmers intercropping nitrogen-fixing crops with others, whereas

the larger farmers relied on fertiliser to keep yields up, which increased their vulnerability to crop failure (ibid.).

When smallholders move from subsistence to commercial agriculture, there is often a transition from food crop to cash crop production. According to Dancer and Tsikata's review of commercial agriculture in Africa and gender, this transition 'has consequences for intrahousehold relations, food security and the gendered division of resources, including land and labour' (2015: 20). For example, Bee (2014) found that in central Mexico women were less inclined to commercialise because they prioritise food security in the household, and therefore did not wish to move away from traditional seeds and into cash cropping.

4 IMPLICATIONS FOR APRA WORK STREAMS AND CROSSCUTTING THEMES

In this concluding section, we explore the implications of the review presented here for the research work streams into which APRA is organised. These are considered, as in the rest of the paper, in terms of impacts across commercialisation pathways and impacts specific to commercialisation. Given the lack

of research conducted on climate impacts in relation to specific commercialisation pathways, we flag the potential contributions APRA could make to knowledge in this area. Table 3 summarises the broad types of implications and related issues, identifying which work stream(s) they are most relevant to.

Table 3: Implications of climate change for commercialisation and relevance to work streams

Implications and issues	WS1	WS2	WS3
Long-term climate impacts			
1 Type and distribution of future impact	✓		
2 Recorded and perceived current and historical impacts	✓		
3 Implications for the value chain	✓	✓	✓
4 Commercialisation implications for climate change	✓	✓	✓
Gender, vulnerability and resilience			
1 Vulnerability disaggregated by gender, age, ethnicity and class	✓	✓	
2 Women-specific barriers to entry in commercialisation	✓	✓	✓
3 Policy-specific determinants of gendered commercialisation			✓
Modernised agriculture			
1 Does modern agriculture help or hinder adaptation?	✓	✓	✓
2 Switches between crops and varieties	✓	✓	
3 Policy space for organic farming			✓
Risks per commercialisation pathway			
Large scale			
1 Will particular cropping strategies still work in farm location?		✓	
2 Implications of shifts in areas of land acquisition for other commercialisation pathways		✓	
3 Resilience of specialised intensive agriculture to climate impacts	✓	✓	
Outgrowing and contract farming			
1 Can growers still meet contract requirements?	✓	✓	
2 Burden of adaptation falls on out-growers	✓	✓	✓
3 Are current commercial crops viable over time in a given area?		✓	✓
Medium scale			
1 Threats and opportunities from changing location of agro-ecological zones		✓	
2 Access to common resources/large-scale encroachment	✓	✓	
Smallholder			
1 Exposure to rainfall variability dynamics	✓	✓	
2 Prospects for female smallholders to commercialise		✓	

3 Does greater commercialisation lead to greater vulnerability?		✓	
4 Introduced technology fit with existing farming practice	✓	✓	
5 Environmental sustainability of commercialisation	✓	✓	✓

Source: IPCC (2014: 1219).

4.1 Climate variability and change: impacts on commercial crops

1. Understanding precisely what climate change entails for agricultural commercialisation is currently contingent upon the uncertainties inherent in climate projections, and indeed in predicting what choices humans will make in coming years and decades. The mixed picture that is emerging suggests potential disaster for some crops, such as coffee in Ethiopia, and better prospects for others, such as teff (also in Ethiopia). Maize is projected to do better than wheat across a number of countries. Most projections find growing suitability for cassava, and some for sorghum. It is entirely possible that without robust adaptation measures the kinds of impacts that are projected to occur could affect or even undermine the viability of the current outcomes from different types of agricultural commercialisation. This is relevant across all work streams but perhaps most of all to **work stream 1**.
2. There is less certainty over the distribution and timing of such impacts, even with the availability of studies for each of the countries that APRA will work in and it is unlikely that APRA research will be able to produce definitive statements on the implications of climate impacts for different commercialisation activities. Nevertheless, it should be possible to gather data on recorded and perceived impacts to date in the fieldsites, and to contemplate likelier future impacts based on projections for particular land types, latitudes and cultivation strategies, potentially 'ground-truthing' projected impacts against experience to date. This may be worth considering in the context of research planning for **work stream 1**.
3. Understanding the implications of climate impacts across the three stages of the agricultural value chain is difficult, given the uncertainties and lack of data. Nevertheless, given the importance of value chains in achieving beneficial outcomes from commercialisation processes, it may be useful, perhaps especially in **work streams 1 and 2**, to look at the impacts on value chains of a changing climate.
4. Another potential line of enquiry potentially relevant to **work stream 2** is the extent to which larger-scale commercialisation activities contribute to global warming processes through deforestation and associated emissions from more intensive agricultural processes. Given the low contemporary

and historical contribution of sub-Saharan Africa to greenhouse gas emissions, this may in all likelihood be less of an immediate concern than it would be in other areas of the world. Nevertheless, to the extent that particular commercialisation pathways engender a lock-in to carbon-intensive technologies and modes of production, this could become a greater concern for the future.

4.2 Gender, vulnerability and resilience to climate impacts and commercialisation

1. Within **work streams 1 and 2**, it will be fruitful to understand the vulnerability, adaptation and resilience dynamics within each fieldsite, in order to understand the implications of climate impacts for particular commercialisation pathways. Part of this exercise will be to tease out the differentiated ways in which climate impacts are experienced by women and girls, but also in relation to other (intersecting) social categories such as age and ethnicity.
2. One concern could be that women attempting to commercialise agricultural activities may face more barriers and difficulties than men, to the extent that they have lower access to information relevant to climate impacts on commercial crops, and less access to and control over productive resources. This has implications for **work stream 1**, in terms of the kinds of gendered outcomes that obtain from particular commercialisation activities, and for **work stream 2**, in terms of understanding differences and similarities in gendered vulnerability profiles within differing commercialisation pathways and **work stream 3**.
3. A policy concern which surfaces, and is of relevance to **work stream 3**, is around ensuring that particular policy initiatives, such as the NREGA-related project in India, not governed by conditionalities which enlisted women into commercially-oriented activities which may increase their vulnerability to climate impacts.

4.3 Modern agriculture and climate change

1. A key issue here is the extent to which modern agricultural techniques underpinning commercialisation are appropriate, environmentally, and able to contribute to resilience in the face of

climate impacts. Currently, there are cases in which modern agriculture appears to reduce resilience, and the prospects for this happening in the case of the countries which APRA will explore is highly relevant to **work streams 1, 2 and 3**.

2. In this regard, exploring the prospects for introducing agricultural practices and techniques variously clustered under a range of approaches and frameworks – chiefly climate-smart agriculture (CSA) and sustainable intensification – into the commercialisation pathways present in the empirical contexts in which APRA research will be conducted is key. Having a way to assess their feasibility and potential contribution is also very important. For example, to the extent that the term ‘climate-smart agriculture’ provides political cover for the kinds of techno-managerial agricultural commercialisation pathways which are (a) environmentally unfriendly, and (b) difficult to access by women and girls, it may prove something of a false hope. Using the Sitko and Jayne (2017) sustainable agri-food system productivity framework is a useful way to put approaches like CSA against a broader set of criteria and processes, so as to gauge the usefulness of particular approaches associated with CSA or sustainable intensification. This exercise is useful across **work streams 1, 2 and 3**.
3. A crucial consideration to understand in relation to responding to climate impacts is the extent to which switches, either from one crop to another, or in the variety of crop grown (for instance, the introduction of a drought-resistant variety), are proving necessary and have helped farmers deal with climate variability experienced in the last 10–30 years. This can be a good indicator of adaptive capacity at least in the short-to-medium term. For instance, cocoa has been grown commercially in Ghana for over a century, with higher yielding varieties introduced in recent decades. Notwithstanding these changes, some farmers have switched back to ‘traditional’ varieties of cocoa, because they are held to be better able to deal with recent climate variability (Dzingu pers. comm). Understanding some of the choices which are already being made will help us get a sense of how and to what extent commercially active farmers are ‘weathering the storm’. **Relevant to work streams 1 and 2**.
4. In particular, the prospects for organic farming methods which may contribute both to adaptive capacity and indeed to higher yields under some context, maybe worth exploring in the case study contexts (work streams 1 and 2). The extent to which the policy arena enables or constrains this objective may also be worthy of investigation (**work stream 3**).

4.4 Risks and impacts per commercialisation pathway

4.4.1 Large-scale activities

1. Currently, larger-scale estate plantation activities may have greater resources to adapt to climate impacts, but are not immune from the effects of it becoming harder to grow particular crops in particular geographic locations.
2. Depending on the extent to which actors currently involved in large-scale commercial activities actively sought to acquire land in areas which, owing to climate change, were becoming more suitable for the cultivation of key commercial crops, there could also be adverse implications for different commercialisation pathways existing in those areas (**work stream 2**).
3. Furthermore, larger-scale agricultural activities are more implicated in the production of climate change in the first instance and the broader environmental sustainability methods through which food is produced in the systems has also been called into question. Some varieties of large-scale commercialised agriculture are held to reduce resilience to climate shocks and stresses. Aside from the implications for the outcomes of particular commercialisation activities relevant to **work stream 1**, there are potential questions here about path dependency and lock-in to modes of commercialisation relevant to **work stream 2** which are potentially problematic both from a mitigation and an adaptation perspective.

4.4.2 Outgrowing and contract farming

1. Outgrowing is one way for comparatively small players to gain access to large, lucrative markets in rich countries. As a potential route for poverty reduction, therefore, there is potentially much at stake for those whose yield sizes and, thereby, ability to meet contract requirements, may be put at risk by climate impacts. Conversely, opportunities for outgrowing particular crops with high commercial value may emerge in areas where prospects are currently slim. Understanding these potential shifts would be very valuable for policymakers concerned with promoting commercialisation. To some extent, in some areas, we may have an inkling of where crop production may be likely to shift – for instance, from lower to higher elevation areas. What level of policy intervention we could confidently advocate on the basis of current climate projections to respond to these changing conditions, however, is a moot point. Yet this line of analysis is more relevant to **work streams 1 and 2**.

2. On the other hand, outgrowing reduces direct exposure to climate impacts for those who issue the contracts; although they may also be adversely affected if they cannot find an alternative buyer to purchase from in the event of reduced harvest or crop failure for an existing out-grower). Clearly, though, the risks and the burden of adaptation falls much more squarely on out-growers, in ways which may or may not be compensated for in the price they are paid for their produce. There are, then, questions around how resilience in the face of climate impacts is maintained by out-growers, which have implications for outcomes (**work stream 1**), and for the livelihood resilience issues linked to this commercialisation pathway (**work stream 2**). There are also considerations here relevant to **work stream 3**, around potential policy interventions to support out-growers in managing climate risk and maintaining financial viability in the face of potentially more adverse growing conditions.

3. It is conceivable that some out-growers will experience, over time, increasingly adverse environmental conditions which may even render unviable the cultivation of a particular cash crop in a particular geographical area. Identifying the likelihood of this prospect is important for **work streams 1 and 2**, and it may also be important to consider the policy interventions (**work stream 3**) which might best assist people at risk of finding themselves in this situation. Understanding the opportunities and constraints of switching to crops which may be more viable under changing environmental conditions may be key to this group. In cases where it is difficult to switch crops, having a clear understanding of where agricultural commercialisation activities fit within livelihood strategies which may also be invested in off-farm activities will be necessary for understanding the implications for people's ability to withstand climate impacts.

4.4.3 Medium-scale commercial farming

1. Medium-scale farmers who find that the area they live in becomes less conducive over time to the cultivation of commercial (mono) crops from which they derive a living face the biggest adaptation challenge. Those living in areas in which conditions will become more propitious for the cultivation of crops with greater commercial potential may be presented with greater opportunities. Much may hinge on the ability of farmers, in combination with the presence of enabling conditions (or lack therein), to switch to a different commercially viable crop which does better under changing environmental conditions (**work stream 2**).

2. The adaptive capacity of medium-scale farmers may, like smallholder counterparts, be adversely

affected by restrictions on access to commons and other productive resources, as a result of land enclosure. In some instances, large-scale commercialisation may be the cause of enclosure, and this can have especially adverse effects on nomadic/transhumant pastoralism. Given the adaptive potential inherent in the mobility of livestock, it would be important to investigate the extent to which, in the country contexts in which APRA will operate, one commercialisation pathway diminishes the adaptive capacity of those involved in another pathway. This consideration is highly relevant to **work streams 1 and 2**.

4.4.4 Smallholder farming

1. The concern, from a climate perspective, is that smallholder farming activities, whether for commercialisation or subsistence purposes, are the most exposed to changes in rainfall and rainfall variability because of much greater reliance on rainfed agriculture. This has large implications for work streams 1 and 2 because it is fundamental to both the outcomes and pathways of commercialisation at the heart of APRA.

2. Smallholder farming is perhaps the key pathway to focus on given that questions of poverty, women and girls' empowerment, food and nutrition security are the most important outcomes for APRA. All of these impinge upon vulnerability and/or resilience to climate impacts and may be adversely affected by them. Some sources maintain that smallholder farming is dominated by women; and yet they are frequently uninterested in or lack incentives to engage with commercialisation activities. This is at least in part because they are more concerned with ensuring that there is enough food for the household, rather than trying to produce it for the market. Some commentators would take the position that women are not involved in commercialisation activities precisely because these are governed by a patriarchal division of labour in which men seek either to profit from their own labour or to sell it, whilst it falls to women to occupy themselves with the unpaid work associated with reproducing labour (Akram-Lodhi 2016; O'Laughlin 2009). From this point of view, it is precisely the underlying logic of commercialisation which prevents women from becoming more involved in agricultural commercialisation. More empowering commercialisation pathways would have, from this perspective, to explore ways to move away from this conundrum, and as such this concern is intimately connected to **work stream 2**.

3. At the same time, becoming more involved in the cultivation of commercially viable crops is apt to increase vulnerability to climate impacts. Commercialisation pathways may therefore need to consider the extent to which women transitioning

into more commercialised agriculture would have access to the information and support to help them (work stream 2)

4. It will be important for commercialisation pathways to take into account and build upon locally-held, agro-ecological knowledge, if an important source of adaptive capacity is not to be lost. Given that commercialisation has in some cases replaced local practice with ones that potentially increase vulnerability to climate impacts, this is a crucial factor. Nevertheless, there is some evidence that the introduction of modern technologies associated with commercialisation can be added or otherwise incorporated into existing agro-ecological systems in ways which sometimes can enhance adaptive capacity, at least across the short-medium term (**work streams 1 and 2**).

5. Commercialisation pathways which do not take sufficiently into account the agro-environmental conditions in which they are being applied may end up contributing to heightened vulnerability to climate impacts. It would be useful in **work streams 1 and 2** to investigate the prospects for such uses in the case study countries that APRA will focus on. It will also be important to understand, in the context of **work stream 3**, the extent to which the policy environment is likely to favour or dismiss commercialisation strategies which are more responsive to agro-environmental considerations.

4.5 Crosscutting themes

The crosscutting themes are not simply relevant to the work streams, but also intersect between themselves. Some of the key intersections are outlined below:

1. Empowerment of women and girls – dimensions of social difference: Climate impacts are experienced differentially, and one of the key differentiators is gender. As we have seen, there are existing constraints on the involvement that women have in commercialisation activity across many sub-Saharan African countries. To some extent, this may shield them from direct impacts upon commercial agriculture, but not from the impacts upon subsistence agriculture. Women in the act of, or seeking to, become more involved in commercialisation activities may also be at a disadvantage in relation to access to information and assistance with regard to dealing with climate impacts.

2. Policy processes and political economy: The political economy of agricultural commercialisation has profound implications for vulnerability and resilience to climate impacts. Perhaps nowhere is this more evident than in the extent to which

commercially lucrative but environmentally problematic commercial agriculture shapes the parameters within which commercialisation pathways can exist.

3. Rural transitions, non-farm rural economies and rural-urban links: The extent to which farmers engage in off-farm livelihood activities, and are increasingly moving towards these in some circumstances, is very important to understand because it frequently entails fundamental shifts in the vulnerability profiles of those engaged in this type of transition. This is especially the case when people migrate from rural to urban areas, where they may be exposed to climate hazards with which they are unfamiliar. In some cases, off-farm diversification is a by-product of successful agricultural commercialisation: it tends to be wealthier households that have potential to diversify off the farm. To the extent that they diversify into livelihood activities which are much less sensitive to climate impacts than agricultural counterparts, then they can reduce their vulnerability to climate impacts. As such, commercialisation leading to diversification can be a promising adaptation strategy. However, for those pursuing diversification activities because they are struggling to make ends meet on the farm, the prospects for poverty reduction can be less than the prospects for poverty reproduction, with concomitant implications for compounding vulnerability to climate impacts.

4. Science, technology and innovation for commercialisation: Clearly, technologies such as early-maturing, or drought-resistant varieties of seed could be highly useful in the context of commercialisation, and the prospects for the introduction of such technology is highly relevant to considerations of resilience in the face of climate impacts. Against this, concerns have been voiced about dependency upon patented seeds which potentially threaten the existence and viability of, as well as access to, seed varieties which can contribute to adaptive capacity, and stifle innovation.

ANNEXE 1 COUNTRY-LEVEL CLIMATE PROJECTIONS FOR DFID APRA COUNTRIES

A1 Ethiopia

According to Admassu et al. (2013), Ethiopia is highly vulnerable to climate change because a large proportion of the population is dependent on agriculture for employment and income; agriculture, including own-farm labour, employs over 85 percent of the population and smallholders are producing on more than 90 percent of total cropped land. The agricultural production in the country is mainly subsistence mixed crop and livestock in the highlands, and nomadic pastoralism in the lowlands. Teff, a main cash crop for smallholders, is known for climate adaptability, fetching relatively high prices, easy storability, and easy marketing due to cultural preferences (ibid.).

Highest value of production agricultural commodities 2005–07	Most important food commodities (for consumption) 2003–05
Wheat	Roots and tubers
Maize	Maize
Teff	Wheat
Coffee	Teff
Sorghum	Sorghum
Source: Adapted from Admassu et al. (2013).	

The authors report that Ethiopia is already experiencing rising temperatures; it is anticipated that continued rising temperatures will lead to evapotranspiration thereby leading to water deficits (ibid.).

Simulation results for agricultural commodities in Ethiopia: Admassu et al. report implications for agricultural commodities according to climate scenario projections as follows:

Rainfed maize, which is an important food crop for the majority of Ethiopians, is expected to have higher yields in the eastern highlands at the edge of the Great Rift Valley and in the northern central highlands (25 percent increase), and some new patches of suitable growing areas in eastern parts of Amhara and Tigray. However,

models show an equal amount of existing maize land is expected to become marginalised or no longer suitable for maize, and a marked decrease is expected in the maize yield over the southwestern and eastern part of central Ethiopia.

Rainfed wheat, which is both a food and cash crop, is expected to face future losses in all zones.

Sorghum, overall, is expected to increase in yield in current major producing areas, and suitable areas will expand. However, the prediction is not uniformly positive. A large area in the western and northwestern parts of the country will see a decrease in yields. This is expected to be offset by a 25 percent increase in central Ethiopia and in parts of the north. Newly emerging suitable areas for growing sorghum 'are all in fragile agro environments; tremendous work would be required to rehabilitate the degraded areas' (ibid.: 170).

Davis et al. (2016) provide climate scenarios for coffee, a major part of Ethiopian agriculture. There are around 15 million coffee farmers; coffee is a huge proportion of export earnings and is a key economic driver for the country. Coffee in Ethiopia is already suffering from climate change (Davis 2016). Researchers note that since the 1960s, there has been a mean annual temperature increase of 0.28 degree Celsius per decade, shorter wet seasons, and an increasing number of hot days with implications for wild coffee and coffee production (Davis et al. 2012, 2016). Davis et al. (2016) found through mixed methods research, specifically through interviews with multi-generation family farms in Ethiopia, that farms that have been productive for decades are now already defunct. The research team anticipates an alarming decline in suitable areas, with a drastic reduction in the areas that are well suited for coffee growing. At the same time, upland areas will become more suitable as other areas disappear. For example, the research anticipates that Harare will not be producing any coffee by the end of the century. Growing coffee in newly suitable areas will require reforestation and initiatives on the part of public policy as well as farmer investment (Davis 2016; Davis et al. 2016).

A2 Kenya

According to Odera et al. (2013), maize and beans are the most important crops in Kenya, grown in 37.5 percent and 17.0 percent, respectively, of harvested areas.

Highest value of production agricultural commodities 2006–08	Greatest harvest area of agricultural commodities 2006–08
Maize	Maize
Tea	Beans
Potatoes	Pigeon peas
Beans	Coffee
Sugar cane	Tea
Source: Adapted from Odera et al. (2013).	

Climate model results for agricultural commodities in Kenya: The authors (ibid.) report implications for agricultural commodities according to climate scenario projections as follows:

For **rainfed maize**, an important crop for its common use and value, projections are varied depending on the model that is used. The most optimistic project anticipates yield increases in most areas, whereas another model predicts losses in part of Rift Valley Province, and a third model predicts losses in Coast Province. All models predict newly suitable areas where previously it had been too dry.

Wheat is anticipated to see losses in areas north of Mount Kenya and east of Mount Elgon. The four different climate models predict yield increases in Central Rift Valley and Central Provinces. However, it is projected that maize will do better than wheat under climate change.

The climate models for Kenya are not in wide agreement because some scenarios would mean little change in rainfall while others anticipate a wetter future for Kenya. In short, this is because it is not known whether and to what extent the current trajectory of carbon emission and temperature rise will continue or change; therefore models are run that assume different outcomes. In some countries, the models make similar projections, but in Kenya there is wide variability between the different models (ibid.).

A3 Tanzania

According to Kilembe et al. (2013), the Tanzanian economy depends on agriculture and has seen an increase in production since 2000, mainly owing to newly cultivated areas rather than more intensive production. Since 2010, government has invested in providing subsidies for smallholders for inputs including fertilisers, seeds, and agrochemicals (ibid.).

Harvest area of leading agricultural commodities 2006–08	Most important food commodities (for consumption) 2003–05
Maize	Cassava
Sorghum	Maize
Rice	Fermented beverages
Beans	Potatoes
Cassava	Other vegetables
Source: Adapted from Kilembe et al. (2013).	

Climate and crop model projections in Tanzania:

According to Kilembe et al., climate model projections for Tanzania are not in wide agreement. One model predicts substantial increases in rain and temperature increases of one degree. Another projects no significant change in rainfall except for increases around Lake Victoria and an increase of 2.1 degrees in temperature. Another finds the converse for rain, no significant change except for decreases around Lake Victoria, and the same for temperature, a 2.1 degree increase. In other words, while there is not agreement, the models do all suggest that there will be either no change or an increase overall.

Because the climate projections are variable, the crop model projections are also not in wide agreement.

For **rainfed maize**, ‘without significant geographic agreement across models, it is not possible to focus on particular strategies at this point’ (ibid.: 333).

The models agree for **sorghum**, predicting losses in yields, including in the main sorghum-growing areas of the country. All models predict some increase in provinces along the border with Kenya.

For **rice**, models predict both gains and losses, but do not agree on geographic areas.

Cassava is projected to remain largely unchanged (ibid.).

Watts (2016) provides climate scenarios for **coffee**, an important crop in Tanzania. According to Watts, 2.4 million peoples' livelihoods are reliant on coffee. His research finds that since the 1960s, yields have declined by 50 percent for coffee. Since 2001, the coffee berry borer has spread and by the 2060s it is anticipated that yields will reach critically low levels (ibid.).

A4 Ghana

According to Nutsukpo et al. (2013), the agricultural sector in Ghana includes crops, livestock, and fisheries, all contributing to national food security. Ghanaian agriculture is rainfed, with only 4 percent of its irrigation potential developed (Ghana, MOFA 2009). As the backbone of the national economy, agriculture provides employment to over 50 percent of the country's workforce and supplies over 70 percent of the national food requirements. The potential impacts of global climate change (such as unpredictable rainfall, increasing temperatures, and longer dry periods) add to the vulnerability of Ghanaian agricultural production systems. Although the general consequences of climate change are becoming better known, great uncertainty remains about how climate change will affect specific locations (Nutsukpo et al. 2013: 141).

Cocoa is the most important cash crop, followed by cassava and maize, which are also important food crops. In the north, the two most important food and income crops are groundnuts and sorghum (ibid.).

Highest value of production agricultural commodities 2006–08	Greatest harvest area of agricultural commodities 2006–08	Most important food commodities (for consumption) 2003–05
Cassava	Cocoa beans	Cassava
Yams	Cassava	Yams
Plantains	Maize	Plantains
Cocoa beans	Groundnuts	Roots and tubers
Taro coco yams	Sorghum	Maize
Source: Adapted from Nutsukpo et al. (2013).		

Crop model projections in Ghana: Nutsukpo et al. report the following from climate scenario modelling:

Maize is projected to have a general decrease in yield across the country.

Rice is projected to have losses as well, but not as severe as for maize.

Groundnuts are projected to have a reduction in yields across the country to varying degrees. However, all models show a possible increase in some areas of Northern Ghana (ibid.).

Läderach et al. (2011) provide climate scenarios for cocoa, a cash crop that contributes 3.4 percent of Ghana's GDP. Läderach et al. find that rainfall will decrease, except for coastal areas and the temperature will increase. Coffee is currently grown in the Eastern, Central, Ashanti, Western and south of Brong Ahafo regions, but 'by 2030, suitable areas start shifting, affecting mainly the southern area of Brong Ahafo, and Western regions in Ghana', which will see the most drastic decline; Central, Ashanti and Eastern regions in Ghana will remain suitable but will become less ideal (ibid.: 13–14). The authors predict that by 2050 coffee will mainly be grown 'between the Central and Ashanti regions and in the mountain ranges of the Kwahu Plateau between the Eastern and Ashanti regions' (2011: 14). Few areas will gain: the Bas-Sassandra region and southern parts of Western region. Higher altitudes, between 450 and 500 MASL, are expected to become more suitable (ibid.).

A5 Malawi

According to Saka et al. (2013), Malawi is highly dependent on agriculture: it makes up 50 percent of its GDP and is the main livelihood for the densely populated country. Maize is the staple food crop; productivity is low.

The rainfed nature of smallholder farming makes agricultural production prone to adverse weather conditions such as droughts and floods. Drought years have most often resulted in poor crop yields and sometimes in total crop failure, leading to serious food shortages, hunger, and malnutrition. Flooding also disrupts food production, destroys household and community assets, and causes loss of life for both livestock and people (ibid.: 120).

Climate and crop model projections in Malawi: According to Saka et al., climate models are not in agreement regarding rainfall. They do agree that temperature will increase, though they vary in the projected amount.

Highest value of production agricultural commodities 2005–07	Greatest harvest area of agricultural commodities 2006–08	Most important food commodities (for consumption) 2003–05
Cassava	Maize	Maize
Maize	Groundnuts	Cassava
Potatoes	Beans	Potatoes
Sugar cane	Potatoes	Bananas
Tobacco	Cassava	Plantains
Source: Adapted from Saka et al. (2013).		

Likewise, the projected picture for **maize** is unclear. One predicts decline for most of the northern and central regions, while the Shire Highlands in the south are projected to increase. Two models predict gains in the northern and central regions, and a mixed prediction for the south with some areas increasing and others decreasing. Another shows maize yields declining in most parts of Malawi. The models do not agree with each other on rainfall, which in turn means there is not agreement on what may happen to rainfed maize production (ibid.).

A6 Mozambique

The following table shows the major crops grown in Mozambique:

Highest value of production agricultural commodities 2005–07	Greatest harvest area of agricultural commodities 2006–08	Most important food commodities (for consumption) 2003–05
Cassava	Maize	Cassava
Maize	Cassava	Maize
Tobacco	Pulses	Wheat
Potatoes	Seed cotton	Rice
Coconuts	Sorghum	Sorghum
Source: Adapted from Maure et al. (2013).		

Climate and crop model projections in Mozambique:

According to Maure et al., climate models are not in agreement regarding rainfall. They do agree that temperature will increase, though they vary in the projected amount.

Likewise, for **maize**, the crop models are not in agreement; some show areas gaining and others show the same area with losses. There is some indication that northern Mozambique may fare better (ibid.).

A7 Zambia

According to Kanyanga et al., Zambia has a ‘relatively large and impoverished rural population that largely relies on rainfed agriculture’ (2013: 255). Rural populations are especially dependent on maize; the monoculture farming system could mean a failure in the maize crop ‘would essentially mean total crop failure for the country’ (ibid.: 282).

Most important food commodities (for consumption) 2003–05	Greatest harvest area of agricultural commodities 2006–08	Most important food commodities (for consumption) 2003–05
Maize	Maize	Cassava
Cassava	Cassava	Maize
Fermented beverages	Seed cotton	Wheat
Vegetables	Groundnuts	Rice
Wheat	Pulses	Sorghum
Source: Adapted from Kanyanga et al. (2013).		

Climate and crop model projections in Zambia:

According to Kanyanga et al., climate models differ dramatically in their results for rainfall. They do agree that temperature will increase, though they vary in the projected amount, and the crop models are in relative agreement.

Maize yield gain is expected in ‘Western Province, the eastern half of North Western Province, Copper Belt Province, and most of Northern and Luapula Provinces. Some of these yield gains exceed 25 percent. But we also note losses in Southern Province and parts of Eastern Province, and others scattered throughout the country’ (ibid.: 275). In other words, ‘all four models show a yield gain of sometimes more than 25 percent in the northern region and a yield loss of sometimes more than 25 percent over the rest of the country’ (ibid.: 283). The areas that are projected to decrease in yield are those where maize is currently being grown (ibid.).

A8 Zimbabwe

According to Mugabe et al., ‘the commodities of significance to the poor, who are most vulnerable to climate change, are maize, sorghum, millet, and groundnuts. Maize is the staple food of Zimbabwe and is grown by all small-scale farmers for food security’ (2013: 295).

Most important food commodities (for consumption) 2003–05	Greatest harvest area of agricultural commodities 2006–08
Maize	Maize
Sugar	Seed cotton
Wheat	Sorghum
Cassava	Millet
Fermented beverages	Groundnuts
Source: Adapted from Mugabe et al. (2013).	

Climate and crop model projections in Zimbabwe:

According to Mugabe et al., climate models are not in agreement for rainfall. They do agree that temperature will increase, though they vary in the projected amount.

For **maize**, the crop models are in relative agreement that yields are projected to improve in the most traditional maize-growing areas, with some areas of declining yield, and scattered areas of suitability loss. Three of the crop models show areas of yield losses of greater than 25 percent in southern Zimbabwe.

For **sorghum**, the models show losses for nearly the entire country (ibid.).

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2. Enteric fermentation refers to the digestive process of ruminant animals, such as cattle and other common livestock, which produces methane (CH₄), a potent greenhouse gas.
3. See Toulmin (2011) for global discussion on (a) the main global climate threats by region and type of farm, (b) direct and indirect climate change impacts, (c) risk management strategies, including diversification, contract farming arrangements, and insurance, and (d) opportunities and measures to help smallholders adapt including research and technology, information and communication, local resource rights, bridging local knowledge and modern science, investment in social infrastructure, and market engagement.
4. For an additional review of climate change and agriculture in sub-Saharan Africa, see Phiiri et al. (2016). See also Clements (2009).
5. Viswanathan et al. (2012) provide a brief discussion of climate change implications for agriculture in Asia.
6. See also Syngenta's website for an example of private sector research and involvement: www4.syngenta.com/what-we-do/the-good-growth-plan/progress.
7. Because this review is focused on vulnerability to climate change, a thorough discussion of the social impacts – particularly for women – of commercial agriculture in Africa is beyond its scope, consider the following sources: Stockbridge (2007); for a review of key gender issues that arise across three different models of agricultural commercialisation – plantation, contract farming and small- and medium-scale commercial farming – the authors highly recommend Dancer and Tsikata (2015); see also Hossain and Jaim (2011).
8. While it is beyond the scope of this paper to comprehensively cover commercialisation in Africa, Kirsten et al. (2013) provide a valuable resource on the literature and various models of commercialisation. The authors draw lessons learned from the literature, as well as trends in commercialisation in sub-Saharan Africa and includes discussion on the implications of climate change. In particular, on pages 6–7 agricultural commercialisation policies in Zambia, Malawi, Kenya, Namibia, and Tanzania are summarised.
9. Newsham and Bhagwat define locally-held knowledge as 'knowledge strongly connected to a place and culture, contested, changed and transmitted intergenerationally through learning and practice, and through (sometimes-imposed) exposure to other ways of knowing – most commonly science' (2016: 230). They propose it as a more accessible framing of ideas found in other terms such as 'indigenous', 'hybrid' and 'endogenous' knowledge.

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