Climate-Smart Pest Management: Implementation guidance for policymakers and investors

Overview of practice

Climate-smart pest management (CSPM) is a cross-sectoral approach that aims to reduce pest-induced crop losses, enhance ecosystem services, reduce greenhouse gas emissions and strengthen the resilience of agricultural systems in the face of climate change. Through the implementation of CSPM, farmers, extension workers, researchers, and public and private sector stakeholders will act in coordination to manage changing pest threats more effectively, and achieve more efficient and resilient food production systems.

GLOBAL ALLIANCE FOR CLIMATE-SMART AGRICULTURE

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KEY MESSAGES

1. Climate change is impacting the biology, distribution and outbreak potential of pests in a vast range of crops and across all land uses and landscapes
2. Up to 40% of the world's food supply is already lost to pests - reducing the impact of pests is more important than ever to ensure global food security, reduced application of inputs and unnecessary greenhouse gas emissions
3. CSPM involves the implementation of holistic approaches across the farm and landscape that aim to achieve the co-benefits of enhanced mitigation and strengthened resilience, and ultimately increase food security
4. CSPM seeks to support farmers, extension workers, scientists and public and private sector stakeholders to act in coordination and at scale to reorient pest management approaches and develop an appropriate enabling environment to manage evolving climate change-induced pest threats and invasions more effectively

Impact of climate change on crop pests

Climate change is causing global shifts in temperature, precipitation patterns and CO_2 and non-CO_2 greenhouse gas (GHG) levels, and an increase in unpredictable, extreme weather. As a result, it is having a significant impact on global crop yields and food security (Beddington et al. 2012, Challinor et al. 2014). **Climate change is also directly and indirectly influencing the distribution and severity of crop pests[1]**, including invasive species, which is further effecting crop production (Juroszek et al. 2011, Lamichhane et al. 2015, Macfadyen et al. 2016).

Although the effects of climate change can be beneficial, evidence suggests that **pest problems overall are likely to become more unpredictable and larger in amplitude** (Gregory et al. 2009). Predicting the direct effects of climate change on pests is complicated by the interacting influences of increasing atmospheric CO_2 concentrations, changing climatic regimes and altered frequency/intensity of extreme weather events (Gregory et al. 2009, Bebber et al. 2013). Projections are further challenged by the fact that climate change can exert its effects on pests indirectly. For example, the differing responses of host crops and pest natural enemies, as well as changes in efficacy of pest control strategies (e.g. biological control, synthetic pesticides), also affect pest responses (Barzman et al. 2015, Lamichhane et al. 2015). The influence that climate change has on human activities, such as land-use changes and crop management practices, should also not be ignored, as these can have an even greater effect on pest pressure than the direct effects of climate change alone (Hoffmann et al. 2008, Cock et al. 2013).

If changing climatic factors are examined in isolation, the following impacts on pests are just a few examples of what can transpire: (1) **Changing precipitation** (excessive or insufficient) can have substantial effects on crop–pest interactions. For example, warm and humid conditions favour many species, including plant pathogens (Hatfield et al, 2011), while crops suffering from water stress are more vulnerable to damage by pests (Rosenzweig et al. 2001); (2) **Increases in temperature** can augment the severity of diseases caused by pathogens, and can also reduce the effectiveness of pesticides (Lamichhane et al. 2015). Pest populations often increase as temperatures rise, which can lead to increased applications of pesticides and fungicides, with negative external effects on the environment and human health; (3) **Increasing CO_2 levels** can lead to crop yield increases. However, any gains in yield may be offset partly or entirely by losses caused by pests (Coakley et al. 1999) because higher CO_2 levels also stimulate pest incidence; (4) **Extreme weather events** can influence the interactions between crops and pests in an unpredictable way, potentially resulting in the failure of some crop protection strategies (Rosenzweig et al. 2001, Chakraborty et al. 2011). Droughts can reduce populations of beneficial insects, with knock-on effects on pollination and pest infestations, while strong air currents in storms can transport disease agents (and insect pests) from overwintering areas to areas where they can cause further problems. For example, Hurricane Wilma in Florida spread citrus canker widely, destroying 170,000 acres of commercially-grown fruit trees (Sutherst et al. 2011). Ecosystems that have been disturbed following extreme climatic events are also more susceptible/vulnerable to invasions of alien and native species (Masters et al. 2010).

With all of this taken into consideration, it has been concluded that a global **pattern of increasing latitudinal and altitudinal range of crop pests is anticipated**, either through direct effects of climate change on the pests themselves, or on the availability of host crops (Gregory et al. 2009, Barzman et al. 2015).

Up to 40% of the world's food supply is already being lost to pests (Oerke 2006), and, as climatic environments continue to change, and further intensify and/or create new pest threats, **farmers across the globe need to start adapting their farm and landscape management practices immediately**. Action should not be restricted to just farm level though. The impact of enhanced pest pressure and crop losses extends beyond the farm, to local and national food security, the economy and employment, and migration. Immediate action is needed on multiple levels and geographical scales to protect food and farmers, as well as economy and welfare on national and international scales, because pest-related yield losses due to climate change have so far gained little attention compared to human or animal health and its interaction with climate change.

[1] *Pests are defined as "any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products" (FAO, 2013. International Standard for Phytosanitary Measures 5)*

While science has directly addressed the issue of pest management in a changing climate, and the need to consider and revisit existing preventive agricultural practices and integrated pest management (IPM) strategies, information is often specific to a particular type of pest or geographic region. What is lacking is a clear concept that brings all of these recommendations and tools together under one umbrella with a strong focus on adapting to climate change and recognising the potential of pest management for climate mitigation. This approach needs to be embedded within a favourable enabling environment. Without the effective coordination of multiple stakeholders, the large-scale development and uptake of new and adaptive pest management approaches will be unsuccessful at worst and inefficient at best.

Overview of CSPM

The concept of CSPM (figure 1) is new and covers a number of **interdisciplinary approaches and strategies** that can be implemented immediately to begin the process of adapting crop production, strengthening the supporting functions (through extension and research) and creating the enabling environment (via the public and private sector). To be effective, CSPM should not be understood as a stand-alone approach, but as **part of a broader climate-smart agriculture (CSA) intervention,** in which pest management is one key component.

As figure 1 shows, through CSPM, farmers **will have the information and tools in hand** to immediately and proactively put into action practices (e.g. crop diversification, establishment of natural habitats, careful water management, etc.) that will enhance the health of his/her farm and surrounding landscape, and reduce its susceptibility to pest-induced disturbance. Moreover, through climate and pest monitoring, in combination with climate and pest risk forecasting information (e.g. as carried out by the Agrhymet Regional Centre), farmers will be able to proactively implement pest prevention practices (e.g. use of pest resistant varieties, careful selection of planting, pruning and harvesting times, push-pull techniques, etc.) in order to prevent the occurrence and/or build-up of expected pest problems. In cases where pest populations do reach economic injury levels, then CSPM enables farmers to make rapid, informed decisions regarding the most appropriate reactive pest control strategy.

Ensuring that CSPM operates efficiently is not the sole responsibility of the farmer. In many cases, farmers do not have the required support to be able to make informed proactive

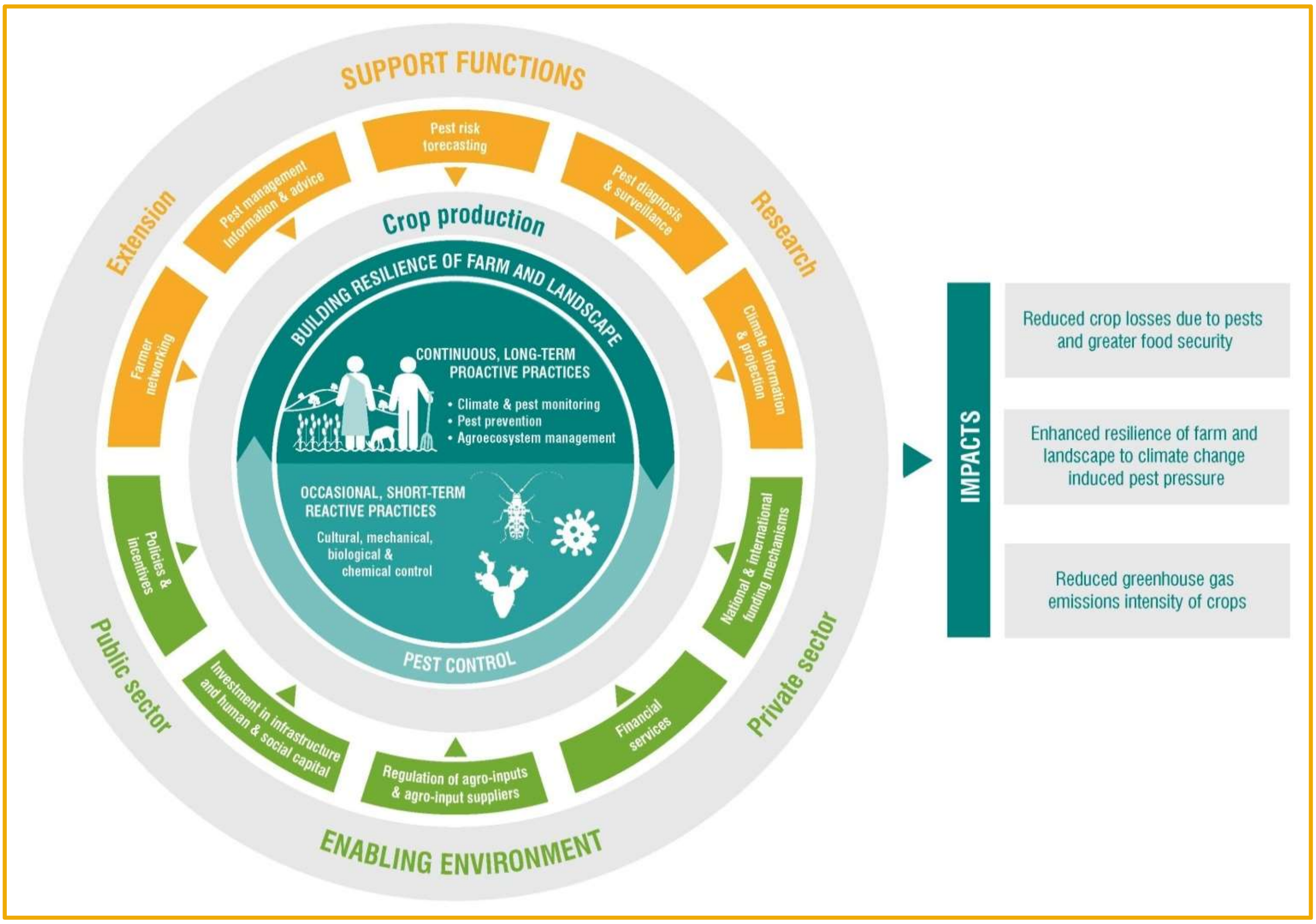

Figure 1. Climate-Smart Pest Management (CSPM) is an interdisciplinary approach aiming to increase resilience of farms and landscapes to changing pest threats, mitigate greenhouse gas emissions and contribute to food security

and reactive pest management decisions. For this reason, **CSPM fosters the coordinated support from extension and research**, and suggests approaches and practices to ensure that the services they provide are relevant, locally-adapted and accessible to all farmers, including those that are often marginalised (e.g. women, elderly, ethnic minorities, etc.). For example, conducting on the ground research to determine the likely impacts of climate change on crop/pest/natural enemy dynamics, and quantifying the consequences of these impacts, will facilitate the development of targeted adaptive responses that are currently lacking. In addition, the analysis of historical weather and climate data will allow pest risk forecasting to become a viable tool to guide proactive pest prevention strategies. An example of this is the service provided by the Desert Locust Control Organization for Eastern Africa (DLCO-EA).

CSPM also places a significant emphasis on **creating the necessary enabling environment to catalyse adoption of CSPM approaches**. For example, the development of appropriate policies and incentive-based systems that reward CSPM implementation is encouraged, together with the establishment of financial services that enable farmers to overcome adoption costs. Public and private sector investment is also a very significant prerequisite to enable supporting institutions to carry out their mandate (especially in developing countries), as well as to enhance the infrastructure required for effective exchange of information and knowledge between stakeholder levels.

The benefits of CSPM

Food security

CSPM leads to effective and cost-efficient management of new and existing crop pests, thereby reducing crop losses and increasing both food security and farmers' incomes.

Adaptation

CSPM decreases negative impacts on the broader ecosystem, making farming systems more resilient to climate change. At national and global levels, CSPM revitalises the important role of extension, research, and the public and private sectors for pest forecasting, surveillance, detection and control, which are vital services to increase resilience.

Mitigation

CSPM contributes to making agricultural production more efficient and promotes a rational use of agricultural inputs, thereby decreasing GHG emissions intensity of crop production.

Triple-wins

CSPM considers **adaptation and mitigation strategies simultaneously** wherever possible**.** For example, proactive practices like pest prevention, including mulching, minimum tillage and planting natural barriers, not only increase organic carbon sequestration in soil and biomass, but also increase resilience to certain pests (Hobbs et al. 2008, FAO 2010). This is also important because if adaptation strategies are devised in isolation from mitigation strategies then there is an increased risk of intensifying emissions (e.g. through enhanced used of agrochemicals). Together with the reduction in pest-induced crop losses that these practices bring, a triple-win effect of adapting to evolving pest threats, mitigating GHGs and ultimately improving food security can be achieved.

Delivery of Sustainable Development Goals

CSPM directly contributes to a number of SDGs: *SDG 1 – No Poverty* and *SDG 2 – Zero Hunger* (through its direct impact on crop production and income); *SDG 12 – Responsible Consumption and Production* (through reduction of food losses at the primary production stage); *SDG 13 – Climate Action* (through, among others, improving GHG efficiency per unit of food output); and *SDG 15 – Life on Land* (through conserving biodiversity and maintaining ecosystem services).

How is CSPM implemented?

In terms of CSPM at the farm and landscape level, many of the practices under the CSPM umbrella are not new for farmers. The issue is ensuring that these practices are improved in the context of a changing climate (e.g. through integration of local pest and climate forecasting into the farm management planning process). Implementation of CSPM practices can, however, be a challenge because **CSPM is highly context-specific** (Scherr et al. 2012, Beuchelt et al. 2013, FAO 2013, Neufeldt et al. 2013) and depends on the climatic, agricultural, ecological, social, economic and political environment, at the household, farm, community and national levels. Thus, the first step of any CSPM programme is to conduct a thorough appraisal of the local environment and perspectives.

Since there is no 'one size fits all' strategy for CSPM, the Toolbox on page 10 acts as a starting point to guide the process of selecting locally-adapted CSPM approaches. It is then important that these are **evaluated in the local context** in order to assess how well they will achieve their goals. The implications for other farm management decisions should also be considered. For example, changing to a pest-tolerant crop variety may require only minimal investment and knowledge, whereas changing crops because of a new pest invasion may involve investing in new seeding and harvesting equipment, implementing new crop rotation practices and sourcing new buyers and markets for the produce (Macfadyen et al. 2016). The toolbox also guides decisions at other stakeholder levels, including the planning of research agendas, the creation of policies and the channelling of investments. This in turn supports one of the aims of CSPM to establish an enabling environment and a variety support functions to facilitate CSPM uptake by farmers.

Since CSPM activities involve different stakeholders and institutions, and take place at a range of scales (Chakraborty et al. 2011), **interlinking CSPM activities and stakeholders is crucial to overcome barriers that hinder its implementation**. For example, enhanced linkages between extension, research and the public/private sector can help to provide the data and resources required to improve diagnosis of new and emerging pests, inform strategy and research, and reduce response time to these pest threats. One step further would be the development of a knowledge platform that collects data, information, tools, etc. from existing sources, makes them freely available and facilitates knowledge sharing and development of innovative solutions on a global level. Finally, CSPM is a dynamic and evolving approach and so **continual monitoring and evaluation** is also required to assess the implementation and short-term outcomes/impacts of CSPM interventions, and to allow continual re-evaluation of tools and approaches.

Contribution to CSA pillars

How does CSPM help us adapt to/increase resilience to climate change?

In taking a holistic, cross-sectoral and multi-stakeholder approach, CSPM can both efficiently and sustainably strengthen the resilience of farming systems, as the following examples of CSPM outcomes demonstrate:

The ability to predict and recognise future pest outbreaks. Because of upslope and poleward migration of pests, CSPM strongly emphasises the need to develop and implement more effective diagnostic processes for the identification of pests and their natural enemies in order to be able to make pest management decisions going forward (SciDevNet 2013, Lamichhane et al. 2016). Furthermore, quantitative modelling (climate data, population models, simulation models) allows multiple interactions to be investigated simultaneously (Coakley et al. 1999), but results need to be interpreted alongside social and ecological model outputs, in order to support countries in developing the most appropriate responses to future pest outbreaks.

The ability to suppress pest outbreaks and pathogen transmission. Pests are expected to respond to changing climate conditions faster than plants, so CSPM aims to ensure that pest management is ready to either prevent or withstand the pests that move into an area and manage those existing populations that are increasing in numbers. For example, migrant pests can be discouraged through the use of barriers, including biotic barriers (e.g. competition, predation and parasitism) (Patterson et al. 1999).

A healthier and more pest-resilient farm and landscape. Farmers following the approaches of CSPM will work proactively to increase the level of biodiversity across their farm and surrounding landscape as this has been shown to increase resilience of agroecosystems to climate change impacts (Altieri 2012, Altieri et al. 2015). For example, crop diversification, which enhances farm biodiversity, promotes a greater abundance of natural enemies that contribute to pest suppression (Lin 2011) and reduces the risks of pests becoming more severe as a result of climate change.

A revitalised climate-responsive extension systems. Due to the unpredictability of climate-induced pest outbreaks (and the lack of general models able to predict biological responses to pests) (Scherm 2004, Lamichhane et al. 2015), farmers must make vital decisions in response to unpredictable conditions and unknown risks. This is particularly true in the developing world where national plant protection infrastructures are often unable to execute activities like early pest detection. If farmers do not have access to the right information at the right time, this poses a great threat to crop production, agroecosystem functioning and livelihoods.

CSPM therefore aims to increase farmer resilience through the establishment of a climate-responsive national extension system, and through building functioning links between science and technology and farmers as a means to overcome the structural disconnect between research and end-users. For CSPM, a revitalised extension system must be able to fulfil the two twofold role of:

- Contributing to the early detection of changing pest threats, which requires that extension workers are skilled and linked to appropriate ICT-based reporting and diagnostic systems and services (figure 2) (Heeb L et al. 2016); and
- Repackaging and delivering farmer-friendly science-based pest management information directly into the hands of farmers (e.g. using ICT-based communication channels, such as mobile phones, radio, or television, which are cost-effective and versatile solutions) (Heeb L et al. 2016).

To enable extension systems to fulfil these roles, CSPM recognises that there must be quantitative investment (e.g. increasing the ratio of extension workers to farmers and promoting digital development) and qualitative investment (i.e. revisiting extension training programmes and investing in building climate literacy). In this process, it is also important to include private sector extension mechanisms, which already play an important role for semi-commercial and commercial-oriented smallholders. Repurposing extension services so that landscape considerations prevail over plot-based advice is also crucial.

How does CSPM mitigate GHG emissions?

Agricultural production, including pest control, is responsible for significant amounts of GHGs emitted into the atmosphere (Beddington et al. 2012). CSPM recognises that agricultural systems need to be modified to reduce these emissions (Rosenstock et al. 2016). Options to mitigate GHG emissions fall into three broad categories, namely: (1) reducing emissions, (2) enhancing removals (including carbon sequestration), and (3) avoiding emissions (Smith et al. 2008, Smith et al. 2014).

Reducing emissions. By decreasing avoidable yield losses, CSPM can directly contribute to a reduction in the emissions per unit of food produced, thereby decreasing the overall GHG emissions intensity of these systems. For example, controlling foliar

Increased resilience through ICT-enabled extension – The Plantwise example

A successful example of building the necessary institutional capacity of the extension service, backed-up with the required technology support system to contribute to early detection and provision of management advice for new pests, is the Plantwise approach, adopted by over 30 countries around the globe. National extension providers equip extension officers with handheld tablet devices, which are used to access pest-management information and can submit real-time GPS-tracked pest-observation records directly from the field. Figure 2 demonstrates how the presence of a viral disease of maize was documented by extension agents long before it was officially reported by the national authority responsible for pest reporting (Jenner et al. 2016), demonstrating the transformative power of ICT for both information delivery, pest surveillance and resilience.

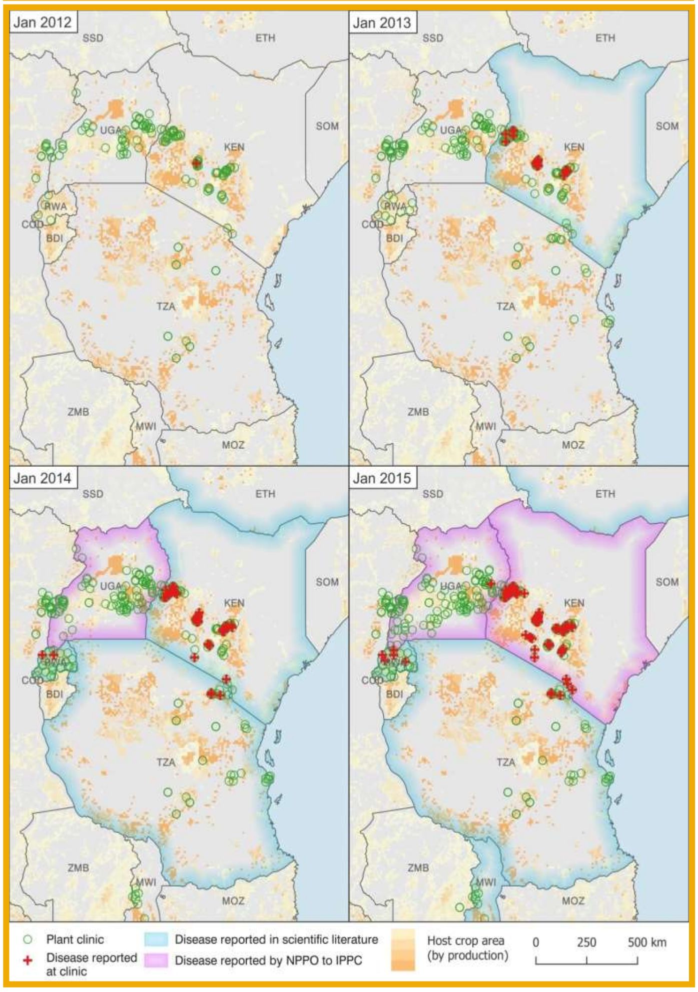

Figure 2. Spread of a plant disease in east Africa, 2012–2015, as recorded by data collected by extension workers, official National Plant Protection Organization reports recorded on the IPPC's International Phytosanitary Portal, and the scientific literature (Jenner et al. 2016)

disease in winter wheat in the UK through the use of resistant cultivars and fungicides, reduces the GHG emissions associated with each tonne of grain produced (Berry et al. 2008).

Enhancing removals. Efficient pest management can also contribute to the removal of GHGs from the atmosphere. For example, pest management approaches that lead to significantly higher crop yields also result in additional CO_2 assimilation by the plants (Kern et al. 2012). Furthermore, the long-term CSPM practices of maximising plant diversity and soil organic matter (e.g. through conservation agriculture) both contribute to carbon sequestration and enhancing plant resistance to insect pests (Altieri et al. 2003).

Avoiding emissions. CSPM can also lead to total avoidance of GHG emissions, due to the different approaches it uses compared with conventional pest management. For example, while the use of insecticides against soya bean aphid has led to annual emissions of between 6 and 40 million kg CO_2e in the US, the CSPM approach of adopting an economic threshold to limit pesticide application, coupled with the use of biological control agents (such as lady beetles) below this threshold can result in emission reductions of over 200 million kg of CO_2e (Heimpel et al. 2013). Also, CSPM can have a positive impact on indirect emissions (e.g. CO_2 emission due to agricultural expansion), as shown in the UK where it was estimated that 16% more land would be needed, if pests are not properly managed (Hughes et al. 2011). Both of these examples show how certain existing IPM practices can have benefits for climate mitigation and can be considered a part of CSPM.

How does CSPM increase productivity, farm livelihoods and food security?

The overarching goal of CSPM practices is the **sustainable increase of productivity and incomes**. This means bringing crop yields back to pre-infestation levels (or even augmenting them) and ensuring food production complies with national and international production standards (e.g. on pesticide residues), so that smallholders are able to supply high-value export supply chains and generate income.

A number of IPM-practices that can be considered under CSPM have been shown to increase crop yields, including selecting pest resistant crop varieties, intercropping, cover crops, climate-adapted push-pull techniques, mulching, and minimum tillage systems. However, **interventions may also come with trade-offs** (within CSPM, but also between CSPM and other CSA strategies). For example, drought-tolerant cassava planted to combat climate change has been found to be more susceptible to mealybug infestation (Thomson et al. 2010).

Challenges to adoption of CSPM

Uptake of more sustainable, climate-smart pest management practices remains slow (Bedmar Villanueva et al. 2016). **Barriers to uptake exist at both farm level and at the institutional level.** These are similar to the obstacles to IPM adoption as identified by Parsa et al. (2014)

Crop production (farm and landscape): Barriers that impede rates of adoption of CSPM practices include lack of sufficient knowledge about climate-smart practices, lack of resources, small land sizes, lack of awareness and potentially high associated costs (Abid et al. 2016, Bedmar Villanueva et al. 2016, Macfadyen et al. 2016). Other factors (not exhaustive) are willingness to pay for available technologies, risks associated with trying a novel approach, household demography, restricted access to markets, the availability of credit and the prevailing climatic condition and its unpredictability (Deressa et al. 2011, Below et al. 2012, FAO 2013, Belay et al. 2017, Khatri-Chhetri et al. 2017). The development of locally-adapted CSPM approaches at farm and landscape levels should therefore follow a participatory, bottom-up approach that engages the farming community, extension personnel and researchers. The establishment of public or private financial mechanisms (e.g. access to microcredit) should also be a priority as this can bolster capacity and incentive among farmers to adopt novel approaches.

Extension: To support farmers with the reorientation of pest management practices under climate change, extension services need to be effective, responsive, accessible and well-informed – but in many countries they are not. This indirectly limits farmers' adaptation capacity. Some documented reasons for these shortcomings include: lack of climate literacy, chronic understaffing, limited operational funds, weak linkages to other stakeholders (such as research), inconsistent dialogue between farmers and those who support them (CABI 2015, Bedmar Villanueva et al. 2016, Heeb et al. 2016). Public and private sector investments are needed to develop a well-connected, well-informed and responsive extension system that will enhance adoption rates of CSPM strategies across farms and landscapes. Digitalisation will be instrumental in this reform and has the potential to increase both efficiency and inclusiveness.

Research: Research institutes undertaking needs-based research are a necessary prerequisite to the development and implementation of novel and responsive CSPM strategies. However, in many countries a variety of barriers prevent this vital service from functioning as it should, such as reduced funds availability, a decline in relevant specialist expertise (Masters et al. 2010, Lamichhane et al. 2015), inadequate education and training in crop protection (Lamichhane et al. 2015), lack of research attention for specific sustainable management practices, and poor regional research collaboration and coordination (Machekano et al. 2017). Investing money and resources in capacity enhancement at national and international research institutions, and ensuring that these institutions are well-connected with extension, diagnostic facilities and climate information services, will help ensure that research is needs-based, collaborative and high-quality, and that research findings are not confined within the boundaries of scientific literature but are made available to all stakeholders.

Public sector: Government policies and regulatory instruments need to provide clear direction and guidance to all stakeholders to enable appropriate planning for climate change adaptation and mitigation, as well as the effective creation and targeting of resources and funds. However, challenges to making this a reality in many countries include the fact that existing policies are not informed by research evidence on local needs and constraints (Ampaire et al. 2017), a lack of funds, and a shortage of relevant expertise in the field of crop protection (Chakraborty et al. 2011, Liu et al. 2016). Awareness raising and knowledge transfer in the area of climate change impact and response approaches will help to enhance capacity at the government level for the development of well-informed and harmonised policies and regulatory instruments, addressing both adaptation and mitigation. Creating national special funds that enable the development of adaptation and mitigation plans would give substance to these policies. This in turn would stimulate financial sectors, businesses, civil society and international organisations to provide funding at multiple levels to put these plans into action.

Costs and benefits and funding for CSPM

The costs of implementing CSPM depend on the interventions required at the production- (farm and landscape), extension-, research-, public and private sector levels. These costs must be considered in relation to short- and long-term **monetary and non-monetary benefits**. At the farm level, adoption of CSPM can influence input costs and crop income. No cost–benefit analysis yet exists for CSPM but analyses of IPM (which overlaps to a certain extent with CSPM at the farm level) show that IPM increases crop yields by up to 41%, reduces pesticide use by an average of 31%, and in most cases increases net returns (Norton et al. 1994, Pretty et al. 2015). CSPM can also generate benefits by reducing negative external costs. For example, groundwater contamination by pesticides costs $2 billion/year in the US alone (Pimentel et al. 2005), and human health costs caused by pesticide application are substantial, if it is considered that for every 100 agricultural workers, between one and three suffer from acute poisoning, leading to many thousands of fatalities, of which 99% occur in developing countries (Chakraborty et al. 2011).

At the national level, **both the costs and the benefits of CSPM can be substantial**. Establishing a national extension system that is able to fulfil its role requires important public-/private-sector investments in human capital and infrastructure. Reversing the current decline in investments in extension is a priority for CSPM and a high pay-off public investment (such investments yield annual rates of return of 80%, on average) (Dercon et al. 2009, GFRAS et al. 2012). Funding for CSPM requires **joint efforts and coordination between public/private and domestic/international players**, as well as a cross-border approach. Concrete funding proposals under existing frameworks and finance channels, such as National Appropriate Mitigation Actions (NAMAs) and the Green Climate Fund (GCF), should be explored to kick-start CSPM.

Alternative ways to fund farm level CSPM practices are through **recognition in the food markets** (i.e. label production) or through public policies encouraging uptake through **regulatory instruments, such as incentive-based systems** (taxes or subsidies). Both systems are well established in Europe but require consumers' willingness to pay and a public sector able to compensate/penalise for positive or negative externalities (Lefebvre et al. 2015).

Interaction with other CSA practices

CSPM is **not a stand-alone approach.** It is linked to existing CSA practices and approaches at the farm and national levels. This is crucial because farmers who seek to adopt CSPM face multiple challenges well beyond pest management and need holistic mitigation-compatible adaptation solutions. Certain existing CSA practices (e.g. site-specific nutrient management, breeding for climate-resilient crops or crop diversification), are therefore highly relevant for the success of CSPM. In particular, attention should be given to CSPM alignment with:

- **Enabling advisory services for CSA**; a great deal of research-based knowledge and information aiming to mitigate pest risk is available but smallholder farmers lack access to this because of a structural disconnect between the relevant stakeholders (e.g. research institutions) and rural extension providers. Therefore, it is imperative to create an enabling environment that facilitates inclusive and cost-effective knowledge transfer and participatory technology development.
- **A gender-responsive approach to CSA**, because while women produce more than half of the food grown worldwide, they produce 20%–30% less yield than males, due to, among other factors, reduced access to agricultural information and inputs (World Bank et al. 2009, FAO 2011). Therefore, gender-responsive planning is a critical pillar for the success of CSPM.

Case study: Tuta absoluta, a threat to food security

The tomato leaf miner, Tuta absoluta, is a devastating pest of tomato. Originating from Latin America, it has spread to Europe, North Africa and the Middle East. Given its potential for crop destruction and rapid reproduction, it quickly became a key pest of concern in East Africa and elsewhere. Its primary host is tomato, but it also affects potato, aubergine, beans and others. In the Mediterranean Basin, global warming likely facilitated the establishment and spread of T. absoluta, which then became a major tomato pest in Italy (Ponti et al. 2013). Immediately, the National Plant Protection Service set up a T. absoluta working group and involved several research institutions to foster research on ecology and management strategies (EPPO, 2011). While developed countries often have the necessary awareness, capacities, financial means and biological data to detect new pests, develop models that predict potential distribution and devise sound policies and recommended management practices (as described in the CSPM approach), many farmers in developing countries, who rely on tomatoes for food security and income generation, are exposed to T. absoluta with very little or no support from the public sector. CSPM aims to address this by fostering a coordinated and multi-stakeholder action to create a favourable enabling environment, develop the necessary supporting functions, and contribute to a crop production system that is more resilient to such pest disturbances, so that farmers' vulnerabilities to climate change induced pest pressures are decreased.

		CSPM focal points	Climate Smart Pest Management Toolbox: Examples of underlying approaches	Contribution
	Production	Building resilience of farm and landscape	• **Climate and pest monitoring to be able to predict and respond rapidly to new, emerging and existing pests** • **Pest prevention approaches to discourage the establishment and development of pest populations** • **Agroecosystem management** to support ecosystem services and enhance resilience of farm and landscape to changes in climate and pest pressure	✓ Productivity ✓ Adaptation ✓ Mitigation
	Production	Pest control	• **Mechanical, cultural, biological and chemical** (last option) approaches to reduce pest damage and pest-induced crop losses	✓ Productivity ✓ Mitigation
SUPPORT FUNCTIONS	Extension and Research	Farmer networking	• Improve **farmer networks and organisations** and promote links to technology providers to enhance knowledge sharing and improve access to information about climate-smart pest management technologies and practices, thereby facilitating their uptake	✓ Productivity ✓ Adaptation
SUPPORT FUNCTIONS	Extension and Research	Pest management information and advice	• Conduct **participatory appraisal** of current extension system to identify structural weaknesses, understand linkages between extension system and other stakeholders and allow challenges to be prioritised and addressed in order to provide farmers with high quality extension support system • **Enhance accessibility of extension service for farmers** and ensure consistent and frequent engagement through methods that allow a two-way flow of information (transfer of pest-related information to farmers and subsequent collection of farmers' feedback for validating and adaptation of pest control strategies) • **Establish vibrant two-way linkages** between extension institutions and expertise (e.g. research, diagnostic facilities) • Develop **new climate-smart technologies and approaches** based on current needs and local contexts • Implement studies and develop methodologies to **assess GHG emission reduction potential** for pest management approaches • Establish interdisciplinary **knowledge creation** (with local validation), **knowledge exchange and knowledge management systems** for climate-smart pest management information to ensure sound recommendations for farmers and allow information sharing within and between national and international stakeholders	✓ Productivity ✓ Adaptation ✓ Mitigation
SUPPORT FUNCTIONS	Extension and Research	Pest risk forecasting	• **Conduct basic research to determine likely impacts of climate change on pest establishment, development, phenology, behaviour, interactions with host and natural enemies, etc. in specific agricultural settings** • **Develop models of pest outbreak potential and impact to enable informed and climate-responsive pest management decision-making** • **Develop/implement early warning systems to support prevention and rapid response to new and existing pests to limit in-country and cross-border spread and intensification**	✓ Productivity ✓ Adaptation
SUPPORT FUNCTIONS	Extension and Research	Pest diagnosis and surveillance	• **Develop tools for, and improve, the monitoring of existing pests as well as the surveillance for and identification of new pests to enable rapid and targeted short-term responses and long-term adaptation planning** • **Implement effective data collection system for pest surveillance, linked to national/international diagnostic support services, to enable fast detection of new and emerging pests, assess current pest management practices used by farmers and inform development of short- and long-term management approaches**	✓ Productivity ✓ Adaptation
SUPPORT FUNCTIONS	Extension and Research	Climate information and projection	• **Enhance availability and accuracy of climate information (down-scaled historical, monitored and predicted) to enable farmers to make informed decisions, better manage risk, take advantage of favourable climate conditions and adapt to change**	✓ Adaptation
ENABLING ENVIRONMENT	Public and Private sector	Policies and incentives	• Develop public policies and regulatory instruments such as incentive-based systems that **reward climate smart pest management practices** (e.g. food labels, taxes, subsidies) to incentivize and reward/penalise farmers who adopt/do not adopt climate smart pest management practices (e.g. subsidising climate-smart crop rotations, taxing use of highly hazardous agrochemicals)	✓ Adaptation ✓ Mitigation
ENABLING ENVIRONMENT	Public and Private sector	Investment in infrastructure, and human and social capital	• **Identify knowledge gaps** and implement training for decision makers to promote awareness, inclusiveness, ownership, sustainability and effective development and uptake of climate smart pest management policies • Invest in **training programmes** and infrastructure (e.g. ICTs) to enhance efficiency and impact of national extension systems and research institutions • **Build structures that enhance connectivity of farmers, e.g. producer organisations,** to enable smallholders to access the information, technologies and resources necessary to adapt to climate change and potentially access new markets	✓ Productivity ✓ Adaptation ✓ Mitigation
ENABLING ENVIRONMENT	Public and Private sector	Regulation of agro-inputs and agro-input suppliers	• Monitor/regulate **agro-input suppliers and build climate-literacy to** increase outreach of reliable climate smart pest management knowledge (especially in developing countries, where agro-input suppliers are primary source of information for many farmers due to lack of formal extension system) • Implement effective **regulatory procedure to register and control available agro-inputs** and monitor the quality of those products once on the market	✓ Productivity ✓ Adaptation ✓ Mitigation
ENABLING ENVIRONMENT	Public and Private sector	Financial services	• Establish, and enhance access to, **financial mechanisms**, including climate insurance, crop insurance, access to micro-credit, etc. to increase farmers' capacity to invest in farm- and/or landscape-level changes in their production systems	✓ Productivity ✓ Adaptation ✓ Mitigation
ENABLING ENVIRONMENT	Public and Private sector	National and international funding mechanisms	• Establish **national special funds** for developing and implementing local adaptation plans that include of climate smart pest management • **Apply for international funds** (e.g. GCF and bilateral donors) for implementation of projects/programmes to achieve (I)NDC targets and piloting of climate smart pest management approaches as proof of concept and to catalyse adoption by farmers	✓ Productivity ✓ Adaptation ✓ Mitigation

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PRATICE BRIEFS ON CSA

The Practice Briefs intend to provide practical operational information on climate-smart agricultural practices.

Please visit www.climatesmartagriculture.org for more information.

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