Multifunctional Field Margins

Assessing the benefits for nature, society and business

ARCADIS Design & Consultancy for natural and built assets

syngenta

Bioversity International

Acknowledgment

The coordinators of this paper would like to thank the many experts and organizations who contributed to this paper.

Contributors

Annelisa Grigg	UN Environment WCMC
Dietmar Stoian	Bioversity International
Eva Zabey	World Business Council for Sustainable Development (WBCSD)
Gregor Pecnik	Arcadis
Johan Lammerant	Arcadis
Linfeng Wang	Syngenta
Madlaina Michelotti	Syngenta
Marina Prada	Syngenta
Paula Rodriguez Castaneda	Bioversity International
Sarah Jones	Bioversity International
Simon Attwood	Bioversity International
Varun Vats	Syngenta
Vincent Johnson	Bioversity International

Coordinators

Gianpiero Menza	Bioversity International
Romano De Vivo	Syngenta

Editorial consultation

Carey Sargent	O public relations GmbH
Liz Wilson	Syngenta

Contents

Citation: This paper should be referenced as follows: Syngenta, Arcadis, and Bioversity International, (April 2018), 'Multifunctional Field Margins' Assessing the benefits for nature, society and business; a position paper.

Foreword

Arcadis

All businesses depend on and impact natural capital. Many organizations do not fully appreciate their relationship with natural capital, and therefore are missing out on opportunities for improved performance or failing to address potentially significant risks. The total global amount of natural capital continues to decline as cumulative levels of exploitation and pollution start to exceed environmental tipping points. Most of what remains, and many of its related benefits, are undervalued even though they have the potential to impact every organization. Proactive management of natural capital provides opportunities, whereas a lack of management generates risks, ultimately impacting on shareholder value. Utilizing natural capital to improve business performance and the environment is surely a win-win that every company should strive for.

The agro-industry sector relies more on healthy ecosystems than most others. Increasingly, integrating natural capital into the decision making processes for implementing farm management practices is a response the sector should have to respond to the risks it faces.

Syngenta's Multifunctional Field Margin approach is a great example of how measures to enhance biodiversity in agricultural landscapes contribute to increased natural and social capital benefits for the farmer communities and society as a whole, thus improving the quality of life.

Arcadis believes that ecosystem restoration ambitions can only be achieved by involving all stakeholders, including the business sector. That's why we've joined forces with Syngenta to develop this important paper.

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The food we eat and how we produce it are inextricably bound together – poor diets are now the world's number one health risk while agriculture is the main driver of land degradation and biodiversity loss.

This discussion paper seeks to find solutions to these challenges by highlighting and valorizing the benefits of agricultural biodiversity for business, nature and society, using the case study of multifunctional field margins in food production landscapes. Field margins and other natural rural features such as watercourses offer extended opportunities to farmers to use and manage their land to boost biodiversity. Farming practices based on optimizing biodiversity can increase yields and reduce dependence on external inputs such as pesticides.

The paper is based on fruitful interactions coordinated by Syngenta and Arcadis with many different experts. Bioversity International provided input as part of its overall strategy to engage with private sector agri-food companies to develop biodiversity-based practices, tools and approaches on how to mainstream agrobiodiversity in their business models and operations. Tools include ways to assess the socio-economic and environmental benefits of enhancing agricultural biodiversity, providing an evidence-base that will drive new investments in support of a global move towards sustainable food systems.

As the world grapples with the complex challenges of meeting the Sustainable Development Goals, a key challenge remains on how to produce enough nutritious food to feed a growing population on a planet with depleting resources. A transformational change is needed and mainstreaming agricultural biodiversity in sustainable food systems is a critical part of that change.

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It is farmers and farming communities who mainly shape our agricultural landscapes.

While landscapes vary by geography, topography, and farming approaches, they are mostly a rich mosaic of cultivated and uncultivated areas, separated by linear features such as hedges and watercourses. These natural dividing lines provide an ideal framework for the field margins that, in the hands of farmers, can benefit nature, society and business.

Well-managed field margins or other uncropped areas near fields can boost biological diversity on farms and hence are one of the most important environmental assets farmers can provide, in addition to producing food. We believe when farmers combine this approach with good practices, crop technologies and connected green corridors, they are the true custodians of land and landscapes.

This paper examines how agricultural biodiversity can be enhanced by the use of multifunctional field margins to produce natural, social and economic benefits. It also recommends some design principles and protocols to establish and manage field margins for biodiversity benefits, and makes a first attempt at ascribing a monetary value to the most important outcomes.

Together with Arcadis and Bioversity International, we call on all stakeholders to collaborate to improve both the agricultural protocols proposed and the valuation method, and to strive to answer the many challenging questions ahead to encourage farmers to adopt biodiversity enhancing practices.

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Executive summary

Improving agricultural biodiversity (ABD) is critical for sustainable land management. There are many ways in which it is possible to achieve such improvements as part of good agricultural practice. Greater adoption of economically, environmentally and socially sustainable agricultural practices requires greater collaboration among a wide range of stakeholders inside and outside agricultural value chains, from breeders, farmers, food processors and consumers to scientists, policy makers, conservation experts and providers of extension or advisory services, inputs and financial services.

Value-chain stakeholders need to be aware of the potential value and sustainability of proposed biodiversity enhancements, demonstrated by common criteria in a monitoring, evaluation and learning system based on scientific design principles and sound evidence.

This discussion paper considers how best to assess the benefits of boosting ABD through multifunctional field margins (MFFMs). MFFMs enhance ABD by providing habitat and wildlife corridors that connect landscapes. They facilitate the movement of seeds and animal species, reduce soil erosion, and attract pollinators and predatory invertebrates as natural pest control that could improve crop yield and/or quality. Society benefits from multiple ecosystem services[1] as well as aesthetic value.

Syngenta and other stakeholders encourage farmers to establish and manage MFFMs on field margins, field corners, and buffer zones that may have limited access for large-scale farm machinery and are less suitable for crop production.

The paper presents evidence from selected MFFM projects linked to Syngenta's Good Growth Plan[2] – a public commitment to making agriculture more sustainable by 2020 and beyond. The plan places particular emphasis on MFFMs, establishing them on marginal farmland along field boundaries and waterways.

MFFM projects have made a significant contribution[3] to The Good Growth Plan target of enhancing biodiversity on 5 million hectares of farmland[4].

Extensive interviews of selected MFFM projects' stakeholders across nine countries and three land-use types[5] and a review of scientific literature have been used to document 20 natural and environmental benefits, along with 15 social capital benefits.

The assessment referred to in this paper is based on Syngenta's decade of experience in enhancing agrobiodiversity through MFFMs and on Arcadis's expertise in the field of natural capital and biodiversity.

As well as interviews and a literature review already mentioned, Syngenta sought scientific inputs from several researchers and advice from practitioners[6].

1 Ecosystem services: the benefits people obtain from ecosystems. Ecosystem services are grouped into four broad categories: provisioning, such as the production of food and water; regulating, such as the control of climate and disease; supporting, such as habitat and food sources for pollinating insects; and cultural, such as spiritual and recreational benefits. – adapted from the Millennium Ecosystem Assessment, (2005).

2 Syngenta launched The Good Growth Plan in 2013 to improve the sustainability of agriculture and company commercial performance through six commitments to be achieved by 2020. – Syngenta Good Growth Plan, (2013).

3 The MFFM projects contributed 5 million benefited hectares out of a total of 5.6 million benefited hectares reported in the last four years (2014–2017) within the Biodiversity commitment of The Good Growth Plan. As such, MFFM projects represent approximately 90% of total benefited hectares reported by Syngenta. – Syngenta Biodiversity Commitment, (2013).

4 Syngenta measures progress towards its "Help biodiversity flourish" commitment of The Good Growth Plan – to enhance biodiversity on 5 million hectares of farmland – by tracking the number of hectares of farmland where biodiversity conservation practices have been established and the number of hectares that have benefited from them. There is a separate commitment within The Good Growth Plan on soil to support the establishment of "healthy, functional, and resilient ecosystems". – Syngenta Biodiversity Commitment, (2013).

5 Grassland, woodland, tropical forests.

6 Syngenta has hosted two workshops with stakeholders to explore how to help biodiversity flourish in agricultural landscapes. The first workshop, in June 2015, brought together academic and scientific experts working on agriculture and biodiversity. This workshop concluded that agriculture is a key driver of land conversion and biodiversity loss, making agricultural landscapes and their ecosystems an important part of the conservation agenda. The second workshop, in September 2015, brought together stakeholders from across the food value chain to discuss the outcomes of the first workshop and to consider for practical actions to be taken. Stakeholders in the second workshop, for instance, emphasized developing a clear case for a return on investment for farmers in order for them to act on their farmlands for biodiversity benefits.

The resulting insights have allowed us to develop new guidelines on the design, implementation, monitoring and management of MFFMs, and to show which approaches are likely to achieve highest business value for farmers while enhancing biodiversity and providing broader societal benefits. We have also gained insights into how private sector commitments[7] can enhance the use and conservation of biodiversity in agricultural landscapes, bringing benefits to farming communities, businesses, nature, and society as a whole.

However, some challenging questions remain:

1. How to increase MFFM practices in agricultural landscapes?
2. How to improve the assessment of benefits derived from MFFMs?
3. How to conduct an integrated valuation of both natural and social capital benefits?
4. How to extrapolate farm-level data and findings to landscape or sub-national level?
5. How to identify and address synergies and trade-offs?
6. How to communicate benefits and the underlying evidence to stakeholders?

We hope this paper will stimulate a constructive discussion about the benefits of biodiversity and how they can be valued in a simple and compelling manner. Improving measurement and valuation (and monetization) will lead to a better understanding of the impact of MFFMs on farming and food production, allowing companies to integrate such analysis in their risk assessment and management systems. We believe the approach proposed could help guide evaluation of the impacts of other agricultural biodiversity measures.

Emerging findings should enhance policy development and business practices, lead to sector innovations, and improve collaboration to refine this approach and scale it up. Monetization of natural and social capital benefits could generate interest from the financial sector leading to investment.

The paper, therefore, can help to meet the grand challenge of moving towards more environmentally and socially sustainable agriculture and the challenge of contributing towards the UN Sustainable Development Goals[8] (SDGs) and the Aichi biodiversity targets[9].

[7] Includes all commitments about biodiversity enhancement that are formulated across the entire portfolio of agri-food value chains.

[8] UN Sustainable Development Goals (SDGs) are the product of extensive multi-stakeholder negotiations involving a wide range of sectors. They set out a framework of 17 Goals to tackle the world's most pressing social, economic, and environmental challenges in the lead-up to 2030. – United Nations, (2015).

[9] Aichi biodiversity targets are a set of 20 targets that UN Convention on Biological Diversity member states will be expected to use to frame their agendas and political policies to conserve biodiversity. – United Nations Convention on Biological Diversity, (2010).

Promoting biodiversity through multifunctional field margins

1

Agrobiodiversity[10] – the variety of plants, animals and micro-organisms essential to plant breeding and food quality and diversity – has declined considerably over the last century[11]. Stakeholders including business recognize this and are seeking the most effective ways to reverse the trend.

MFFMs offer one of the most valuable opportunities for enhancing biodiversity in agricultural landscapes, while maintaining crop productivity.

The edges of arable fields are ideal, often being less fertile, less productive or inaccessible to modern farm machinery, and so considered less valuable for crop production (see Figure 1).

An example is hedgerows and other buffers such as grasses and trees planted alongside water courses to reduce erosion and runoff from fields. They reduce farmers' costs by preventing the loss of topsoil and nutrients, and societal cost-incurring events such as sedimentation, water contamination and damage to fish and wildlife, as well as increased water treatment costs and flood risk[12]. They can also provide walking paths or recreational spaces and habitats for wild biodiversity (e.g. spiders, birds, crops' wild relative plants). In this way, MFFMs provide natural capital and social capital benefits[13].

[10] FAO defines agrobiodiversity/agricultural biodiversity as the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. – FAO, (1999a).

[11] According to FAO, more than 90% of crop varieties have disappeared from farmers' fields. Loss of forest cover, coastal wetlands, other 'wild' uncultivated areas, and the destruction of the aquatic environment exacerbate the 'genetic' erosion of agrobiodiversity. With this decline, agrobiodiversity is disappearing; the scale of the loss is extensive. – FAO, (1999b).

[12] Woodland Trust, (2014).

[13] Natural capital is a stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, and minerals) that yield a flow of benefits to people. Social capital is a stock of resources and relationships provided by people and society – WBCSD Natural Capital Protocol, (2016) and WBCSD Social Capital Protocol, (2017a).

Promoting biodiversity through multifunctional field margins continued

Figure 1
Multifunctional field margins

While sustainable agriculture is slowly being adopted around the world, there is huge untapped potential.

We believe concerned stakeholders should work together to identify programs encompassing a variety of local partnerships and environmental and cultural approaches. Companies should strive to agree specific program targets and define protocols for implementation and reporting on progress.

An essential first step towards building this far-reaching collaboration is to present the scientific evidence that demonstrates the 'capital' value that MFFMs add[14]. Putting together sound evidence on how MFFMs benefit the health and competitiveness of rural communities should include quantifying the benefits that MFFMs deliver, and defining the business case for farmers and others in associated agri-food value chains: what returns can producers expect in terms of better access to markets, increased income or reduced environmental risks, and increased ecosystem service delivery?

More insight into and evidence for such benefits will increase community acceptance and support for establishing MFFMs and similar practices.

[14] Kleijn D. and Sutherland W.J., (2003).

Research on benefits of MFFMs

2

Gathering evidence about the benefits of MFFMs starts with assessing the socio-economic and environmental impacts of relevant existing projects. The coordinators developed methods based on the following approach:

- Reviewing the relevant literature on agrobiodiversity's role and benefits in food production systems, and the contribution of field margins to natural and social capital. Since agrobiodiversity is a relatively rare term, the coordinators used various search terms, e.g. "mixed cropping", "intercropping", "on-farm biodiversity", "hedgerows", "ecological corridors", "field margins", etc. for research.
- Interviewing a selection of stakeholders and partners of local Syngenta biodiversity projects (see Table 3B in Appendix 3).
- Identifying MFFMs design principles and selecting those relevant for building a set of global protocols (that can be adapted to local contexts).

Literature review

A review of 74 scientific papers was carried out, looking specifically at how MFFMs might help in:

a) Restoring, preserving, and enhancing biodiversity
   - Reintroducing local plant species, and associated invertebrates, small mammals and birds
   - Boosting the number of pollinating insects
   - Increasing the number of pest-controlling invertebrates
   - Increasing earthworm populations and activity
   - Providing food and habitats sources for birds, reptiles, amphibians, and small mammals
   - Establishing ecological corridors to connect important patches of habitats
   - Conserving genetic diversity

b) Improving water management, including optimized fertilizer and pesticide management
   - Reducing runoff and protecting watercourses and ponds from siltation and contamination
   - Improving the efficiency of water use by crops in dry landscapes
   - Decreasing flood risk by increasing the water retention capacity of soil

c) Reducing soil erosion and improving soil management
   - Reducing the loss of soil, which is a key natural resource for agriculture and food security
   - Improving soil condition by increased earthworms and other biota

d) Reducing air pollution and increasing carbon sequestration

e) Increasing the resilience of agro-ecological systems to climate change

f) Providing food, forage, fodder and wood

g) Functioning as windbreaks

h) Improving overall landscape attractiveness, supporting recreational and cultural values

i) Contributing to product branding (biodiversity-friendly farm products)

While plenty of information about gains in biodiversity[15] exists, the benefits for stakeholders are less clearly defined (see Tables 2 and 3 which describe natural and social capital benefits of different design principles of MFFMs as identified from the literature review.) This might be because most research was driven by the need to restore biodiversity in agricultural areas and so has only focused on ecological benefits, and by the fact that this type of research is principally carried out by natural scientists, rather than economists or other social scientists.

Assessing the links between agrobiodiversity and ecosystem services can make the benefits of conserving agrobiodiversity for businesses and other stakeholders more apparent.

For example, our review found evidence that ecological corridors provide more suitable habitats and migration corridors for pollinators and natural pest predators, and so can mitigate operational risks that may reduce yields[16]. They also increase aesthetic value, providing opportunities for recreation and tourism[17], increasing the value of the adjacent farmland[18]. Establishing a network of ecological corridors can enhance reputation in terms of biodiversity-friendly farming practices and create new market opportunities for farmers and for local communities[19].

However, few studies go as far as valuing these benefits. If the aim is to move from a subsidy-based or regulatory-obligations-driven system to a self-sustaining or market-based system, more evidence demonstrating the direct economic benefits of MFFMs and ecological corridors is required.

Interviews with MFFM projects' stakeholders

A sample of nine MFFM projects[20] (see Appendix 2) representing around 60% of Syngenta's portfolio of projects[21] was selected, covering different environments. The objectives of the interviews related to each project were to:

- Gain an understanding of the key features of each project, and identify specific needs that drove implementation as well as the business case behind each of them.
- Understand how the process of site identification and project implementation takes place, including involved stakeholders.
- Gather first insights on how multiple stakeholders monitor and measure natural and social capital benefits.

The interviews with stakeholders revealed useful information. It became clear, for example, that the drivers for implementing MFFMs vary considerably and are dependent on the local context. The matrix below (Table 1) summarizes main drivers and motivators to implement MFFMs within the nine projects.

Different drivers for implementing MFFMs included: legal compliance; subsidies and financial incentives; farm productivity enhancement; environmental risk reduction; market access; reputation; landscape connectivity; socio-economic benefits; and others (e.g. scenic beauty, tourism).

15 Based on the peer review of the benefits of different type of field margins by the European Crop Protection Association, (2014). The report was commissioned by the ECPA and prepared by Cambridge Environmental Assessments (CEA), part of ADAS UK Ltd., and provides a summary of up-to-date information and descriptions of different types of field margins. The report shows that field margins can be multifunctional in character, not only providing semi-natural habitat for biodiversity, including pollinators for crops and the predators for agricultural pests, but also reducing the effects of runoff and soil erosion.

16 Aizen et al., (2009); Alebeek et al., (2006); Alison, (2010); Bianchi et al., (2006); Bullock et al., (2008); Carreck and Williams, (1997); Carreck and Williams, (1998); Corbet et al., (1991); Hackett and Lawrence, (2014); Hartridge and Pearce, (2001); Hatt et al., (2017); Helenius and Backman, (2004); Holzschuh et al., (2009); Lee and Heimpel, (2005); Klein et al., (2007); Losey and Vaughan, (2006); Martin et al., (2015); Morse and Calderone, (2000); Pierce et al. (2015); Pimentel et al., (1992); Robinson et al., (1989); Sutherland et al., (2001); Tscharntke et al., (2012); Letourneau DK, et al., (2011).

17 Hedgelink; Marshall and Moonen, (2002); Tieskens et al., (2017); Vandaele, (2010) in TEEB case studies.

18 WBCSD (2017b) "a call-to-action" report on landscape connectivity.

19 WBCSD (2017b) "a call-to-action" report on landscape connectivity.

20 In total these nine projects represent 3.15 million hectares of farmland benefited out of 5.6 million hectares of farmland benefited so far by Syngenta, and are taken from four continents. – Syngenta Biodiversity Commitment, (2013).

21 The portfolio is the projects and the number of benefited hectares of the MFFMs implemented in the first four years of The Good Growth Plan. The nine projects were selected as the most material ones in the diverse regions.

Iphiclides podalirius
The flaming butterfly is a large butterfly characterized by the pale yellow color streaked with black of its wings, which gives it its name. The flaming butterfly is found through most of Europe, and as far as Asia Minor. They use MFFMs for habitat and food sources.

Research on benefits of MFFMs
continued

Table 1
Main drivers for implementing MFFMs in nine projects[22]

MFFM project	**Drivers for implementing MFFMs**			
	Compliance	**Incentive**	**Productivity**	
Brazil Greener Soy	Helps growers comply with restoration requirements (Brazilian Forest Code)			
Colombia Ecoaguas			Reduces the risk of lower yields (e.g. restoration of riparian habitats ensures water provision)	
Canada Operation Pollinator				
USA Conservation Seed Program				
China GroMore			Helps in pest control and enhances pollination for rice production	
Korea Operation Pollinator			Helps in establishing habitat for beneficial insects to improve productivity by supporting pollination	
Germany Operation Pollinator		Helps comply with rural development and subsidies requirements through 'ecological focus areas', of which MFFMs are a part		
Belgium Regional Landscape			Controls pest population	
UK Operation Pollinator				

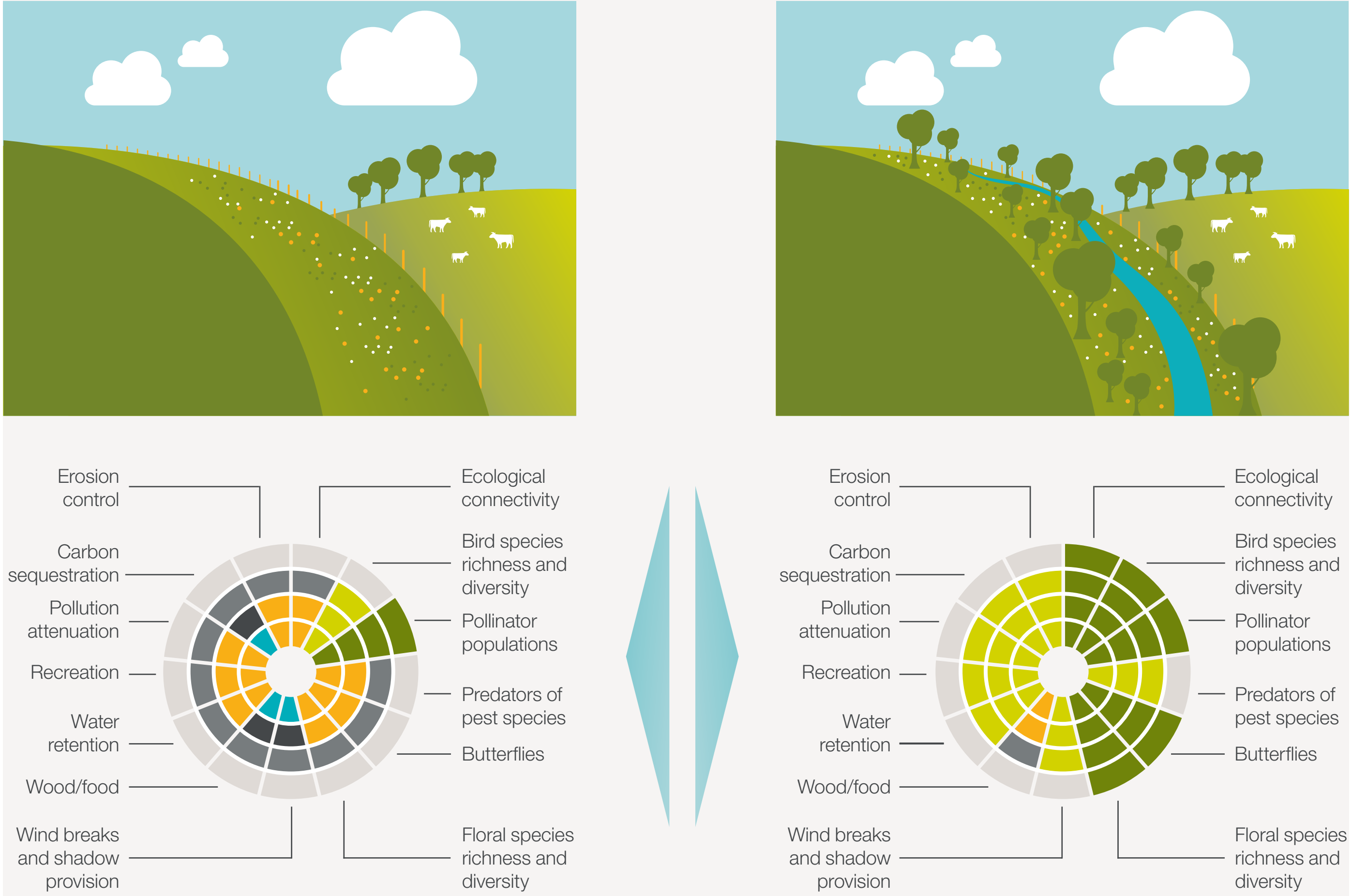
[22] Please view this table along with Table 2A in Appendix 2; which describes the main characteristics and benefits of MFFM projects assessed in the study (such as restoration of riparian forests, conservation of pollinator habitats, creation of habitats for wildlife or ecological corridors for natural pest control).

Environmental concerns	Reputational	Landscape connectivity	Market access	Socio-economic benefits
Conserves biodiversity, improves water quality in rivers and control of floods		Facilitates landscape-level connectivity	Helps producers improve market access	
Conserves biodiversity, facilitates water provisioning, and improves crop pollination		Supports restoration of riparian habitats	Helps producers improve market access	Supports local communities' development (e.g. jobs, gender equality and productivity enhancement)
Benefits pollination, controls erosion and floods, and reduces diffuse water pollution and pesticide drift		Restores riparian habitats		
Creates biodiverse habitats around commercial fields, and improves water quality				Stimulates engagement with local conservation and hunting organizations
Facilitates pollination and natural pest control through connected ecological corridors				Saves cost through reduced pesticide use. Ensures stable or increased rice yields and additional income (e.g. harvestable field margins)
Facilitates pollination and natural pest control through connected ecological corridors		Acts as ecological corridors for pest control invertebrates, helping facilitate natural pest control	Provides pollination, helping improve apple yield and quality	Encourages and also supports orchard farmers to adopt integrated pest management
Helps in increasing biodiversity. Benefits pollination, controls erosion and floods, and reduces diffuse water pollution and pesticide drift	Improves ecological value alongside productive agriculture	Facilitates ecological corridors for deer		
	Improves ecological value alongside productive agriculture		Increases access to local markets by offering 'biodiversity friendly' labeled products (e.g. apples and pears)	Increases aesthetic value of the landscape enhancing attractiveness for recreation and tourism
Increases the quality of habitat, pollination and natural pest control				Builds farmers' capacity to implement and manage MFFMs

Research on benefits of MFFMs
continued

Identifying and selecting design principles

Figure 2
Graph showing relative biodiversity density of MFFMs and associated benefits[23]



Note:

Representation of different colors in circle graphic:

Dark green:	high added value
Light green:	good added value
Orange:	poor added value
Blue:	no added value

[23] Data available from literature review.

The literature review also demonstrated how benefits are linked to specific field-margin characteristics, design or management practices[24]. For instance, there may be MFFMs with basic ecological features and relatively poor outcomes or those with more complex features and higher biodiversity performance.

Figure 2 shows associated natural and social capital benefits of different types of MFFMs, on a comparative basis. This figure was created for illustrative purposes and it depicts the more ecological features and biodiversity richness MFFMs have, the more benefits they provide. A set of MFFMs are shown in the figure (e.g. from MFFM on the left hand side with no ecological feature and less biodiversity richness to MFFM on the right hand side with a few ecological features (a water course) and more biodiversity richness (more trees and vegetation)). Respective natural and social capital benefits of these MFFMs are shown next to the circle graphics at the bottom of the figure. Different colours in the circle graphics illustrate the degree of added value or benefits these MFFMs provide.

Additional details on the associated benefits of MFFMs[25] and how inputs affect outcomes at the farm level and beyond to the local community can be found in the Table 3A in Appendix 3.

For example, natural capital benefits such as supporting pollinator species can increase when certain design principles are used: arranging uncropped land in strips rather than in blocks, promoting strips with higher plant richness and less soil disturbance, providing pollen-rich flower mixes and implementing less invasive land management techniques all support this goal. Table 2 provides more detail on how different design principles facilitate natural capital benefits.

Orthetrum brunneum (female)
The species is present in Europe and North Africa. It is frequently found in many types of stagnant and common water habitat. Females lay their eggs on the surface of the water. It is a generalist predator and feed on a wide variety of insects, including pests. Riparian MFFMs offer habitat to it, mainly stream water.

[24] Farmers implementing MFFMs need to consider various implementation and management costs of the chosen measures. Implementation costs refer to the steps that farmers must take to establish MFFMs. For example, for flower margins, farmers need to set aside some of their farmland from production and invest in the appropriate seed mixtures and the machinery needed to sow it. The choice of location, generally marginal lands, and seed mixture, will depend on an analysis of the local conditions of the farm, including climate and target species for biodiversity restoration. Management costs refer to the costs incurred by the farmers in the years subsequent to establishing the margins. Farmers need to invest time on the proactive and targeted management of MFFMs to ensure the expected benefits.

[25] The topic of MFFMs is so vast that further research could be carried out for a thorough assessment of benefits across different domains, synergies amongst benefits, trade-offs amongst different elements, and differences based upon farm and landscape and regional typologies. Field margins such as hedgerows, wildflower strips and extensively used meadows provide multiple ecosystem services through their ability to contribute to biodiversity, encourage beneficial insects and pollinators, reduce erosion or regulate the water balance. To date, however, little research has been conducted on their influence on the landscape. For example, one project, 'QuESSA', was implemented in the European Union to investigate the contribution of different types of field margins to ecosystem services at field to landscape levels, in various crops, management and agro-climatic contexts. – QuESSA, (2013–17).

Table 2
Natural Capital benefits provided through the implementation of MFFMs design principles

Natural Capital benefits	Design principles
Reintroducing local species and supporting genetic diversity[26] Margins with higher plant diversity support higher densities of invertebrate species. It is assumed that high genetic variation in multifunctional field margins allows for more rapid adaptation to climate change.[27]	– Arrange uncropped land in strips rather than in blocks. It is beneficial to combine at least three different types of sown margins: wildflower mixtures only, grass seeds and wildflower seeds, and pollen- and nectar-rich plants. Different compositions support different species. – Field margins with greater richness of plant species and less soil and vegetation disturbance will support a wide variety of species groups. – Regular mowing, cultivation or re-seeding is required to maintain highly diverse habitats.
Pollinator species[28] Pollination is one of the most important natural capital benefits provided to agriculture by natural habitats.	– In general, 0–5% uncropped land used to establish pollinator margins could increase the number of bee groups. – Interfacing grass strips with woodlands or hedgerows enhance parasitoid wasp species' diversity and abundance. – Mowing promotes nectar-producing wildflowers and is beneficial for pollinators. – Pollen- and nectar-rich flower mixtures should be preferred as they support high insect abundances and diversity. – Connect fragmented landscapes by corridors to benefit bee populations.
Natural pest-controlling species[29] Restoring habitat can increase natural enemy populations and thus effectively suppress pests. Predators in natural ecosystems provide an estimated 5–10 times increase in pest control.	– Complex landscapes comprising dense networks of non-crop habitats provide favorable conditions and requirements for natural enemy populations, supporting greater populations and species richness than in systems lacking multifunctional field margins. Hence, mosaic landscapes should not be alternated. – Sown wildflower strips and un-ploughed habitats support high abundance and diversity of overwintering beetles.
Earthworm populations and activity[30] Multifunctional field margins increase soil abundance of soil macro fauna, including earthworms, woodlice and beetles.	– Less invasive crop management systems (e.g. Integrated Pest Management with a focus on the use of non-invasive species) decrease the mortality of macro-detritivore populations. – An increase of surface litter layer increases litter-feeders (like earthworms), which increase the surface area available for microorganisms. So residue should be left on the ground.
Food sources and nesting sites[31] Uncropped areas and non-farmland habitats offer supplementary food resources to many farmland birds and mammals.	– Grow vegetation on waste ground, rough grassland and scrub to provide nesting, foraging or roosting resources for birds, small mammals and invertebrates. – Land management regime need to consider seasonality and species.[32]

26 Haaland et al., (2010); Hackett and Lawrence, (2014); Stevens et al., (2002); Vickery et al., (2009).
27 Dicks, L.V., et al., (2014).
28 Aizen et al., (2009); Alebeek et al., (2006); Bianchi et al., (2006); Bullock et al., (2008); Carreck and Williams, (1997); Carreck and Williams, (1998); Hackett and Lawrence, (2014); Hartridge and Pearce, (2001); Hatt et al., (2017), Helenius and Backman, (2004); Holzschuh et al., (2009); Lee and Heimpel, (2005); Klein et al., (2007); Losey and Vaughan, (2006); Martin et al., (2015); Morse and Calderone, (2000); Pierce et al.; Pimentel et al., (1992); Robinson et al., (1989); Sutherland et al., (2006); Tscharntke et al., (2012).
29 Letourneau DK, et al., (2011).
30 Erisman et al., (2016); Smith et al., (2008a); Wardie, D.A. & van der Putten, W.H., (2002).
31 Fuller et al., (2004); Hackett and Lawrence, (2014); Siriwardena et al., (2006); Vickery, (2009); Whittingham, (2007).
32 For example, according to field trials conducted by the Royal Society for the Protection of Birds the survival rate of farmland birds such as skylarks improves significantly with undrilled patches, also known as 'Skylark Plots', and wider-spaced drill rows. This happens mainly because of enhancing the diversity, abundance and availability of arable plant and invertebrate food, and the provision of nesting habitats. For instance, in the treatment plots, skylark territory densities were higher and the number of skylark chicks reared was nearly 50% greater than in conventional wheat crops. However, in fields with skylark plots and 6m-wide grass margins, there were very high densities of territorial skylarks but nesting success was reduced due to high levels of nest predation in the crop near to the field margins. – Royal Society for the Protection of Birds.

Natural Capital benefits	Design principles
Migration corridors[33] Multifunctional field margins can act as ecological corridors when connected to each other, forming a biodiversity corridor.	– Optimal design depends on the species for which migration is envisaged. Corridor variables such as habitat types, corridor width and maximum distances from forest patches; all need to be considered while designing a corridor. – Retain or install hedgerows which can also function as corridors for many species, reducing habitat fragmentation. Hedgerows provide shelter to many invertebrate, bird and mammal species. – Prepare the ground along a 1.5m wide strip to provide good soil conditions and as little competition from other vegetation as possible. – Trim the newly planted hedge in at least the first two years to encourage bushy growth, allowing the hedge to become taller and wider at each cut. – Prevent livestock and grazing animals from damaging the corridor.
Soil quality[34] Soil structure and fertility provide essential ecosystem services. Soil pore structure, soil aggregation and decomposition of organic matter are influenced by the activities of soil micro and macro fauna, which are supported by the presence of MFFMs as food and habitat sources.	– Minimize soil cultivation and develop a substantial surface litter layer. – Use cover crops to support on-farm retention of soil and nutrients between crop cycles. – Field margins could also be used as wind breakers if positioned properly, thereby helping in reducing wind induced soil erosion.
Erosion prevention[35] Multifunctional field margins can help erosion control by reducing water and sediment discharge, and controlling floods.	– Retain or install hedgerows and riparian vegetation to reduce erosion and runoff among fields. The width of a buffer depends greatly on what resource is to be protected. Furthermore, the necessary width for an individual site may be less or more than the average recommendations, depending on soil type, slope, land use and other factors.[36] – Buffers composed of grasses, trees and shrubs can lower levels of sediment run-off.
Water pollution and flood attenuation, and water retention[37] More complex plant community composition and, to some extent, species richness, reduces leaching of inorganic nitrogen from grasslands.	– There are many factors that influence the effectiveness of buffers. These include slope, buffer width, rainfall, the rate at which water can be absorbed into the soil, type of vegetation in the buffer, the area of impervious surfaces, and other characteristics specific to the site, amount of vegetation and leaf litter and soil type.[38] – Use a network of grass strips next to watercourses and ditches, to provide a physical barrier to restrict the flow of pollutants and prevent them from entering watercourses. – Plant perennial vegetation in natural ecosystems to regulate the capture, infiltration, regulation, retention and flow of water across landscapes. – Use native species of plants and grasses in margins, wherever possible.
Carbon sequestration[39] Carbon sequestration potential increases with increasing margin width and depends on plant diversity.	– Understand the value of carbon sequestration and storage in soil in the field margins. – The use of wide field margins with high species richness (including trees, shrubs and grasses) provides the greatest carbon sequestration potential.[40]

33 Merckx et al., (2009).
34 Bailey et al., (1999); Costanza et al., (1997); Pimentel et al., (1992); Power, (2010); Smith et al., (2007); Zhang et al., (2007).
35 Foster, (2006); Kort et al., (1998); Le Bissonais, (2004); Power, (2010); Vandaele, (2010); Woodland Trust (2014).
36 Scientific studies have shown that efficient buffer widths range from three meters for bank stabilization and stream shading, to over 90 meters for wildlife habitat. For instance, in order to prevent most erosion, vegetated buffers of nine meters to 30 meters have been shown to be effective – Yale School of Forestry and Environmental Studies, (2005).
37 Haycock and Pinay, (1993); Power, (2010); Stoate et al., (2009); Woodland Trust (2014).
38 For instance, buffers, especially dense grassy or herbaceous buffers on gradual slopes, intercept overland runoff, trap sediments, remove pollutants, and promote ground water recharge. To provide an example, widths for effective sediment removal vary from only five meters in relatively well drained flat areas to as much as 30 meters in steeper areas – Yale School of Forestry and Environmental Studies, (2005).
39 De Deyn et al., (2008); Lynch, (2015); Pimentel et al., (1997).
40 A spatial analysis of the L'Ormière River watershed, Quebec, Canada reveals that one hectare of riparian forest would be able to sequester 587 tonnes of CO_2 equivalent, over a period of 25 years. – Agriculture and Agri-Food Canada, (2008).

Research on benefits of MFFMs continued

Table 2 continued
Natural capital benefits provided through the implementation of MFFMs design principles

Natural Capital benefits	Design principles
Windbreaks[41] Wind breaking field margins help in reducing wind speed, control wind-blown soil erosion, provide shade and alter the microclimate in the sheltered area.	– The most important factors in windbreak design for wind protection are height, density, orientation, and length. A continuous row of trees and/or shrubs is placed to provide wind protection.[42]
Product branding[43] Farmers may have greater market access with biodiversity-friendly products. Farmers may obtain specific certifications if they help develop landscape-scale wildlife corridors.	– Comply with the requirements of given certification schemes for biodiversity-friendly farming associated with using MFFMs.[44]
Wood and food provisions[45] Field margins can provide fruit and firewood to local communities. Also, traditionally, hedgerows have been the source of local foods, medicines and drink.	– Plant hedges and trees that can provide firewood. – Plant fruit trees, local (non-commercial) food crops and medicinal plants.

Similarly, design principles such as introducing environmental conservation practices, engaging local communities and promoting eco-agriculture can support social capital benefits such as improving air and an increase in recreational opportunities and tourism. See Table 3, below, for more detail.

Table 3
Social capital benefits provided through the implementation of MFFMs design principles[46]

Social Capital benefits	Design principles
Air pollution attenuation[47] MFFMs can absorb or remove air pollutants.	– A series of small woods or shelter belts can be more effective than one large wood as the woodland edge is especially effective at capturing airborne pollutants, depending on a range of local factors (i.e. positioning, sources of pollutants).
Recreational opportunities and tourism[48] Field margins provide access to the countryside as they can be used as footpaths, supporting recreational walking and hunting opportunities.	– Riparian corridors and forests can act as recreational areas if public access permits. – Inclusion of hedgerows in a landscape provides cover and breeding sites for quarry species such as pheasants and partridges and facilitates hunting.

[41] Donnison, (2011); Ucar and Hall, (2001).
[42] For instance, a study done in L'Ormière River watershed, Quebec, recommends 10 windbreaks per farm with three tree rows spaced nine meters apart to effectively break the wind in farms – Agriculture and Agri-Food Canada, (2008).
[43] Scherr and McNeely, (2008).
[44] Major voluntary sustainability standards, such as those promoted by Rainforest Alliance and Fairtrade, include 'biodiversity' requirements.
[45] Hedgelink; Scottish Natural Heritage.
[46] Almost all interventions are generating multiple benefits – if so, synergies and/or trade-offs. For example, MFFMs provide habitats for pollinating insects, but also provide food sources for birds and small mammals, create high-quality vegetative buffer strips alongside watercourses to reduce runoff, and increase the resilience of agro-ecological systems to climate change contributing to higher yield and quality and to better livelihoods of farmers. The paper focuses on a few social capital benefits, where information on benefits and design principles were available.
[47] CNT, (2010); Horton et al., (2016); Woodland Trust.
[48] Marshall and Moonen, (2002); Tieskens et al., (2017); Vandaele, (2010) in TEEB case studies.

Social Capital benefits	Design principles
Farmers' livelihoods and wellbeing[49] Biodiversity enhancement helps conserve ecosystem services for farming that are critical to farmers' livelihood.	– Corridors need to be designed with the needs of desired game bird populations in mind if hunting can be used to generate additional income. – In addition to some of the uses of field margins mentioned before, they can also be used to conserve crop wild relatives[50], fodder and forage crops, medicinal plants, condiments, ornamental and forestry species used by humankind, producing additional income to farmers.
Knowledge acquisition and education[51] Multifunctional field margins can play a role in extending or enhancing educational opportunities by providing farmers chances to learn about their benefits and how they can increase agricultural yields if margins are managed properly. They can also stimulate nature-based school trips.	– Encourage collaboration between experts and other stakeholders. – Create a greater appreciation for the ecosystem services and the relationship between agricultural and non-agricultural landscapes. – Environmental agricultural schemes should consider value added for farmers when implementing and managing MFFMs. (Farmers are learning an additional skill when implementing MFFMs.) – Farmers are more likely to maintain long-term stewardship and protection if they are part of a well-connected group/network and when their insights are valued and included.
Local community benefits[52] Multifunctional field margins could help reduce conflict, maintain property rights and resolve both landscape-scale and system-scale issues.	– Engage local communities in the design of field margins. Positive biodiversity projects with a greater long-term potential occur when participation is active. Create a greater sense of connectedness amongst stakeholders. – Social equity can be improved by identifying synergies between the benefits for local livelihoods, agricultural economics and biodiversity[53]. – Consider how MFFMs can contribute to diversifying food offers and diets when choosing species composition. For example, plant fruit trees, local food crops and medicinal plants, spices, ornamental and forestry species.
Landscape aesthetics[54] Multifunctional field margins provide an improved aesthetic value.	– Carefully consider species and structural diversity that will provide aesthetic value all year round. Aesthetic value of landscapes can vary significantly with the growing season. – Flower strips around fields provide an improved aesthetic value, e.g. strips near main roads. – Create ecological corridors along already existing landscape features like ditches and waterways. Widening and maintaining buffer zones provides higher scenic beauty.
Cultural and historical heritage[55] Field margins can provide and protect traditional landscape features with important cultural roles and landscape heritage.	– Engage with local farmers and communities to raise awareness about the value of multifunctional landscapes and/or ecological corridors to protect cultural heritage and enhance biodiversity.
Agribusiness benefits[56] Multifunctional field margins can help businesses obtain/maintain their social license to operate.	– Promote eco-agriculture and other biodiversity-friendly farming practices. – Meet social capital conditions (i.e. building trust and social connectedness) via bonding, and linking with people.

[49] Marshall and Moonen, (2002); Pretty and Smith, (2004); Scherr and McNeely, (2008); Sutherland and Darnhofer, (2012).
[50] Crop wild relatives are defined as wild plant species that are more or less genetically related to crops but, unlike them, have not been domesticated. In other words, crop wild relatives are all those species found growing in the wild that to some degree are genetically related to food. – Bioversity International, (2011).
[51] Horton et al., (2016); Pretty and Pervez Bharucha, (2014); Pretty and Smith, (2004); Sutherland and Darnhofer, (2012).
[52] Evans et al., (2006); Pretty and Pervez Bharucha, (2014); Pretty and Smith, (2004); Scherr and McNeely, (2008).
[53] An important impetus for economic approaches to nature conservation was achieved via the "ecosystem services-human wellbeing" nexus that was made popular by the Millennium Ecosystem Assessment. – Boyd and Banzhaf, (2007) and Millennium Ecosystem Assessment, (2005).
[54] Hietala-Koivu, Lankoski and Tarmi, (2004); Marshall and Moonen, (2002); Tahvanainen et al., (2002).
[55] Marshall and Moonen, (2002); Scherr and McNeely, (2008); Tieskens et al., (2017).
[56] Pretty and Smith, (2004); Scherr and McNeely, (2008).

A Global MFFM Protocol

3

The investigation described above provided further insights into how design principles affect outcomes, and showed how such practices can help farmers and society to realize natural and social capital benefits. This approach will lead to applying this knowledge at scale, and to proposing a global protocol for establishing MFFMs and to monitor and evaluate the multiple benefits arising.

A protocol can provide both guidance on key design principles and evidence that demonstrates MFFMs' multiple benefits. A protocol maintaining a good balance between scientific soundness and pragmatism – starting from a standard global approach, but allowing for regional differences (see Appendix 3 for an example) – can be used to monitor the efficacy of MFFMs.

Efficacy can be measured by the extent to which design principles have been applied: protocols are supported scientifically so one can assume that if practices comply, they may generate the expected benefits. If this type of monitoring is enhanced with existing data on benefits, it should garner essential information that can be used to further refine the design principles for biodiversity measures.

An example global protocol is proposed below to showcase its aim and benefits.

Aim of a Global MFFMs Protocol

The protocol aims to provide a smart, efficient way to monitor the efficacy of implemented measures and allow for practices that can be connected to clear design principles and benefits that have already been established in scientific literature. The protocol should provide guidance on how to design, establish and manage MFFMs as well as a checklist for monitoring how well they are being put into practice.

The protocol should mainly serve the following purposes:

1. Implementation: provide guidance on key design principles for MFFMs to achieve specific or combined benefits in terms of biodiversity and natural capital. This is useful to implement new or to upgrade existing projects.
2. Monitoring and evaluation: efficacy of implementation[57] of MFFMs could be monitored by means of process-based indicators (checking for implemented process). These indicators if possible could be combined with existing qualitative (e.g. farmers' perceptions) or quantitative (e.g. yield data) data on benefits. The outcomes allow for reverse-engineering that is a continuous refining of design principles based on practical experience.

The protocol could be based on the following key characteristics:

– Starts from a standard approach globally and allows for regional or local variations.

– Provides a good balance between scientific soundness and pragmatism, allowing on-the-ground implementation by local partners and stakeholders.

– Aligns with the Natural and Social Capital Protocols[58] conceptual model on business impacts and dependencies on natural and social capitals, and related opportunities and risks. It is driven by enhancement opportunities (net-positive impact) and risk reduction or avoidance.

– Promotes the key role of design principles in achieving benefits and reducing risks.

– Allows for comparing different types of interventions (such as MFFM typologies) and for deciding on trade-offs between different types of social and natural capital benefits.

– Accounts for contextual factors, such as landscape, farming practices and cultural context.

– Ensures continuous improvement, which is central to monitoring and lessons learned.

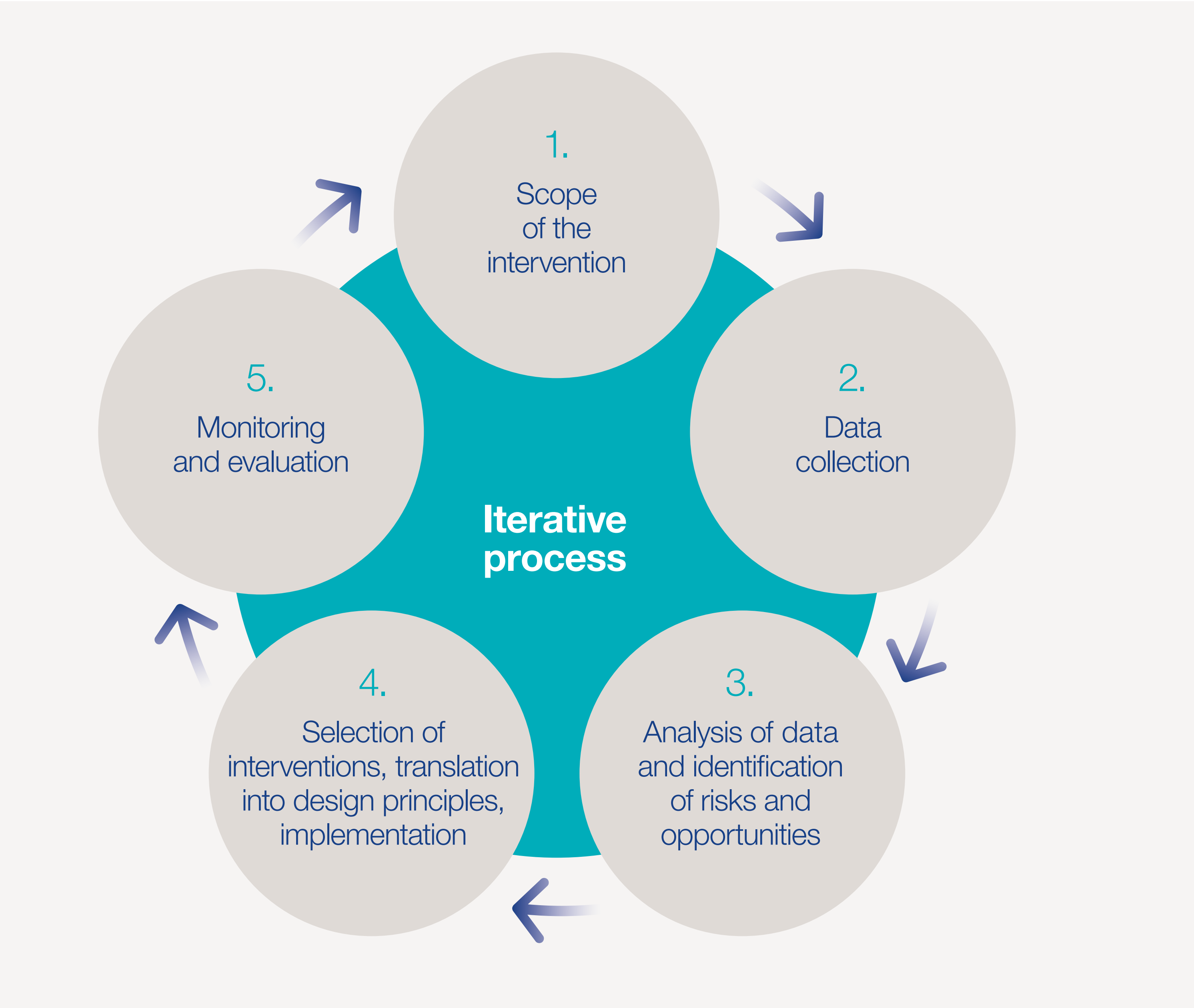
The use of the Global Protocol in practice

In order to implement a new MFFM project, data collection and analysis and a proper assessment are needed. This includes a description of the location and characteristics of involved farms as well as the landscape type and distinctive elements. This information provides the necessary insight and data for identifying the relevant risks and opportunities. Risks relate to degradation of the local ecosystem threatening farming operations, today or in the near future. These risks can be operational in nature, such as a water shortage or lack of natural pollinators. Opportunities may be market related, for example the shift of consumer preferences towards more biodiversity-friendly products (linked to certification). Certain trends may imply both opportunities and risks, including increasing legal requirements to restore habitats alongside water courses, or decreasing willingness of lenders to support unsustainable farming.

57 Efficacy is referred to in terms of achieving the targeted biodiversity and/or natural capital benefits, but also in terms of socio-economic benefits such as yields.

58 The Natural Capital Protocol offers a standardized framework for businesses to better identify, measure and value their impacts and dependencies on nature. Similarly, the Social Capital Protocol provides a harmonized approach for businesses to measure and value their interactions with society. It helps companies identify best practices, boost the positive impacts of their operations, and improve business credibility by integrating the consideration of social impacts and dependencies into performance management and decision-making. – WBCSD Natural Capital Protocols, (2016) and WBCSD Social Capital Protocols, (2017a).

Figure 3
Conceptual model behind the MFFMs Protocol



1. **Scope**

Setting goals and boundaries by identifying needs, type of intervention, process and resources.

2. **Data collection**

Identifying the biodiversity enhancement opportunities by collecting relevant data.

3. **Analysis of data**

Verifying that the selected design principles represent the most appropriate solution.

4. **Implementation**

Developing, piloting and implementing MFFMs, with the support of local stakeholders.

5. **Monitoring and evaluation**

Evaluating success in terms of benefits provided by implemented MFFMs.

Addressing these risks by restoring ecosystem resilience in the agricultural landscape will automatically create opportunities in the form of more stable and sustainable production, or better market access.

It is also necessary to define clear objectives based on this risk and opportunity identification – examples include 'increase level of natural pollinators' and 'reduce erosion' – and then select the right type or set of intervention measures and the appropriate design principles for implementing them based on the definition of these objectives.

The targeted benefits are assumed to be generated when the appropriate design principles have been implemented at the appropriate place and time[59]. No monitoring of results is required, apart from smart data-mining, that is, collecting already existing qualitative and quantitative information. The benefits reduce the identified risks and enhance potential opportunities.

The global MFFM implementation protocol responds to the need for a standard global approach that allows for adaptation and incorporation of local knowledge and helps farmers address their needs. The protocol is periodically reviewed and adapted to the local situation in consultation with relevant stakeholders. The tool can later be adapted and used as an assessment protocol to evaluate the effectiveness of the implemented biodiversity enhancement practice.

This is illustrated in Figure 3 where the steps 1 to 5 allow for the local adaptation of the Global Protocol.

[59] For example, properly placed and managed field margins can reduce chemical runoff from crop fields, thereby protecting water from contamination and limiting soil erosion and improving the levels of soil biodiversity. To achieve these benefits, vegetative buffer strips need to be properly designed, located, established, and managed.

The valuation challenge

4

While the protocol described above will help to identify biodiversity gains as well as natural and social capital benefits of MFFMs, it will not be sufficient to trigger or accelerate a real behavioral change in the field. The long-term success should become evident where incentives are offered, such as making the business case for such measures to stakeholders, not least to the farmers themselves.

It is important to have clear insights into both the societal and business value of MFFMs. Better understanding the impacts of MFFMs on farming and local society will facilitate design of interventions and incentives that lead to gains in biodiversity as well as natural and social capital, increased business value for farmers and increased societal value. It will also give companies a better idea of how to strengthen commercial offers and marketing strategies.

A first approach

The business value, or the benefits to the farmer or farmer communities of MFFM, is a combination of direct economic benefits such as increased crop yields and better access to markets and other monetary incentives, and indirect benefits generated by ecosystem services including revenue from additional activities such as hunting or tourism, or increased resilience of the agricultural ecosystems towards droughts or peak precipitation[60]. The societal value is a combination of social capital benefits for local farming communities such as increased welfare due to increased income, and wider benefits provided by improved supplies of a multitude of ecosystem services.

While farm interviews have started providing evidence on the positive impacts of MFFMs on crop yields (see Appendix 4), placing a value on indirect business benefits and wider societal benefits is much more challenging.

Monetary valuation might offer a first approach. In addition to qualitative and other forms of quantitative valuation, economic measures are considered a suitable way to support decision-making because they provide a common denominator for assessing and comparing various benefits. While several studies have estimated the benefits of pollination to the economy in monetary terms, less information is available on how to make these benefits accessible at the farm level.

An initial and rapid attempt to ascribe a monetary value to some benefits of MFFMs is described below. It is intended as a pragmatic approach towards presenting the value of ecosystem services provided by MFFMs in economic terms and translating the qualitative benefits of MFFMs into more tangible benefits for growers, local communities and society[61].

The model focuses on valuing the impact of selected ecosystems services associated with the implementation of MFFMs based on relevance, the availability of reliable data from existing literature and coordinators' experience. The valuation was also based on the principles of the Natural Capital and Social Capital Protocols.

In a first step, the coordinators selected pilot projects, focusing on the same nine MFFM projects previously used in the benefit assessment (see Appendix 2).

In a second step, the coordinators identified natural and social capital benefits across the nine projects (see Appendix 5 for a list of 20 natural and 15 social capital benefits, as per Table 5A). They identified the benefits of MFFMs to growers participating in selected projects through interviews that used a specially designed checklist to ensure the data was captured in a standardized manner.

[60] A timescale for generating these benefits is hard to predict: many will take more than a year, and some will be apparent for many years.
[61] During the study it was possible to understand how MFFMs benefit different stakeholders. Table 3B in Appendix 3 summarizes some of these findings.

Table 4
Classification of pilot projects based on their dominant land type[62]

Land type[63]	Description
Grassland	Land area generally dominated by perennial grasses. Grasslands are generally distinguished from “forest” as ecosystems having a limited tree canopy cover.
Woodland	Land area with woody vegetation structure, which may only cover a small percentage of the entire land surface. For example, land area with scattered tree groups or trees.
Tropical forest	Land area with tree crown cover of more than 10–30%, with the potential of trees to reach a minimum height of 2–5 meters at maturity.

As part of the third step, and to simplify the analysis, the coordinators classified pilot projects according to their dominant land type as presented in Table 4 above.

The fourth step estimated monetary values for the selected natural and social capital benefits highlighted in step 2. Finding monetary values for the benefits provided by MFFMs is challenging, and suitable data are not always available. For the assessment, estimates were made of monetary value per unit area of selected ecosystem services provided by MFFMs, sourced from online databases and scientific literature. See Appendix 5 for a full description of sources and calculation methods used to value ecosystem services in this assessment.

The fifth step performed monetary valuations based on the number of implemented hectares in each of the nine projects using the monetary values selected. This allowed the calculation of an estimated monetary value for the benefits provided to farmers and local communities by ecosystem services. The calculated values do not represent the cumulative value that projects may have over time.

[62] IPCC, (2006).

[63] Land types are selected based on their proximity to the landscape types of selected nine MFFM projects. Limited literature was available on the market and non-market values of MFFMs and so information from studies of other landscape types had to be adapted. Studies also vary in the way they define and classify MFFMs as well as how they sampled, monitored, aggregated, calculated and modeled simulations.

[64] The monetary valuation carried out here is based on our selection of relevant ecosystem services for all the nine projects and the availability of respective economic coefficients. Analysis does not reflect ranges of fluctuation in values and instead applies an uniform approach providing information for a single point in time. Additionally, the coordinators focused on total revenue generation and the cost of implementation and management of MFFMs is not considered.

Table 5

The monetary value of natural and social capital benefits from MFFMs (see Table 5A in Appendix 5 for description and reference sources of the selected monetary values)

Projects	Ecosystem services[65,66]						Calculations
	Individual economic coefficients (USD/Hectare)						
	Habitat	Provisioning	Regulating			Cultural	
Land use type	Pollination services provision[67]	Water filtration and storage	Climate regulation	Soil erosion prevention	Carbon sequestration	Recreation and aesthetics	Economic coefficient USD/Hectare
Grassland (flowers, grasses, shrubs)	937	60	40	44	367	193	1,641
Woodland	937	n.a.	7	13	241	7	1,205
Tropical forest	937	27	2,044	15	241	867	4,131

Based on the analysis above, the coordinators estimated the average economic coefficients for MFFMs[68] as follows:

– Establishment of MFFMs with flowers, grasses, and shrubs margins: 1,600 USD/ha/year

– Establishment of MFFMs with tree rows: 1,200 USD/ha/year

– Restoration of connectivity in tropical forest: 4,100 USD/ha/year

Despite its advantages, the valuation approach has limits (see Appendix 5 for a list of key limitations for monetary valuation of MFFMs benefits). It cannot for example account for the trade-offs of dedicating arable land to MFFMs. The coordinators nonetheless believe that the approach can serve as a starting point for more in-depth discussion and refinement of a method for valuing MFFMs.

65 A small number of ecosystem services were selected for monetary analysis, based on the availability of their economic coefficients (the estimation of the economic value of ecosystem services is limited by existing biological, geographical, and economic data) and their relevance in the selected projects. For instance, some ecosystem services were not considered in the analysis even if coefficients were available, as these services were deemed to be less common to the majority of implemented projects.

66 The coordinators followed The Economics of Ecosystem and Biodiversity (TEEB) categories of ecosystem services that ecosystems provide.

67 In Table 5A in Appendix 5, the coordinators describe why the same coefficient is used for the three land use types for pollinating services.

68 These are approximate coefficients, as accuracy of the estimation of the economic value of ecosystem services is limited by existing biological, geographical, and economic data (studies with the global scope were therefore preferred and considered wherever possible). Furthermore, projects have different characteristics and locations, and available coefficients were adapted to project criteria, to the best extent possible. Also, reviewed studies vary widely in the scope and methods used.

Next steps

Concerned stakeholders continue to improve design principles, global MFFM implementation protocols, and the processes of identifying benefits and their evaluation. The results should be used to improve collaboration between value chain actors and stakeholders from outside of the chain, including civil society organizations focused on biodiversity conservation and socio-economic development.

The aim is to invite stakeholders to engage in cooperative work to help enhance biodiversity and investigate how biodiversity enhancement can generate natural and social capital benefits for society and business alike, and how benefits could be valued in a simple and robust manner.

This paper provides a ‘baseline’ framework to start discussions on evaluating MFFMs’ benefits, though the coordinators anticipate the need for a more sophisticated model, taking into account factors such as landscape features, trade-offs with crop yields, farming practices and cultural context. The development of such a model will require that the coordinators try to answer these pressing questions:

- How can one perform an integrated, scalable valuation of both social and natural capital benefits of MFFMs?
- How can one extrapolate data and results from the farm to the landscape level?
- How can the natural and social capital benefits of MFFMs best be shared with farmers and other value chain stakeholders?

The objective is to invite **the expert community** (research institutes, universities, consultants, think-tanks, practitioners, etc.) to help the coordinators address these key questions and collaborate in identifying the most suitable way to tackle the valuation challenge.

The upscaling of this approach will require support from multiple stakeholders, who work together to identify and address challenges of accounting natural and social capitals while also taking into consideration social, economic, and environmental constraints and opportunities along agri-food value chains. Interested companies could engage with governments, academics and civil society organizations to roll-out their respective impact assessments. Actors need to understand the potential value and sustainability of any proposed biodiversity enhancement measures, using common criteria in an evaluation system based on scientific design principles and sound evidence[69].

The dialogue should be inclusive of all stakeholders and particularly of farmers and local environmental organizations, academia, aid agencies, governments, communities, and businesses to share collective learning and seek input. All parties are invited to take part, share ideas and best practices and bring their expertise to this critical conversation and valuation effort.

[69] To begin, Syngenta and Arcadis, through the WBCSD, had presented a preview of this paper at the Natural Capital Forum, last year. A teaser/business case of this paper was also launched on WBCSD website, to strengthen dialogue and engagements with NGOs and other interested stakeholders on the natural and social capitals evaluation of MFFMs. – WBCSD, (2017c).

6 Appendices

Appendix 1
Progress on Syngenta's Good Growth Plan biodiversity target

Syngenta has measured progress towards its 5 million-hectare target by tracking the number of hectares of farmland where biodiversity conservation practices have been established and the number of hectares that have benefited from them. There is debate about how much farmland should be devoted to enhancing biodiversity. After consultation with scientists and conservation experts[70], Syngenta believes that 3% is a suitable conversion ratio for measuring farmland benefited by MFFMs. Our assumption is that improvements in agro-biodiversity may be seen when a minimum of 3% of farmland is devoted to managed margins. Nonetheless, having more than 3% dedicated to well-managed field margins is better

The conversion ratio may vary from location to location so the exact percentage of farmland devoted to managed biodiversity should be determined at local level based on local conditions.[71] This depends on a range of factors, like the composition of the surrounding landscape, the type of non-crop vegetation planted, the target species, spatial configuration, the crop and the quality of habitat management, and environmental protection goals for a given landscape[72].

[70] In 2015, a small survey was carried out by Syngenta to better understand how MFFMs are perceived by agronomists. A questionnaire was distributed to 1,000 experts from Italy and the UK, and 175 responses were received (124 from Italy and 51 from the UK). These two countries were chosen to provide a snapshot of implementation perceptions in northern and southern Europe. Amongst this sample, the majority stated that approximately 5% of farmland was not directly cultivated and that 3% of farmland should be managed to enhance biodiversity.

[71] Studies suggest that different species need different percentages of field margin habitat to flourish (e.g. Holland et al., 2013).

[72] For accounting purposes, Syngenta reports three hectares of established MFFM as 100 hectares of land that has benefitted from managed margins. On this basis, Syngenta has reported 5.6 million hectares of improved farmland since 2013. – Syngenta Good Growth Plan, biodiversity commitment (2013).

Appendix 2
Tables on MFFM projects

Table 2A
Syngenta's MFFM projects assessed in the study

Biodiversity project	Project characteristics and benefits
Brazil Greener Soy The Greener Soy project helps growers comply with restoration requirements.	Restoring riparian forests conserves biodiversity and improves water quality in rivers; restoration along watercourses provides corridors.
Colombia Ecoaguas The project helps growers create rich habitats in field margins, riparian zones alongside rivers and corridors for wildlife.	Restoring riparian forests (lowland) and creating MFFMs in smallholder coffee areas (highlands). Benefits include biodiversity conservation, water provisioning, pollination, and local community benefits.
Canada Operation Pollinator The project transforms marginal farm areas into improved habitats for bees and other pollinators. Syngenta contributes through the seed mixture.	MFFMs in plain agricultural lands benefit biodiversity conservation and pollination. Restoring riparian habitats benefits biodiversity conservation, water quality, and provides ecological corridors.
USA Conservation Seed Program Donation of corn seeds to wildlife organizations to create enhanced, biodiverse habitat around commercial fields.	Donation of seeds of discontinued varieties to create habitats for wildlife. Benefits include increased biodiversity and improved water quality. Donated seeds and harvested plants may not be resold.
China GroMore The project encourages paddy rice farmers to adopt integrated pest management and establish habitat for beneficial insects.	MFFMs in rice fields act as ecological corridors for pest-control invertebrates. Benefits include increased natural pest control, biodiversity conservation, reduced pesticide use and stable or increased yields.
Korea Operation Pollinator The project helps growers implement conservation agriculture practices.	MFFMs in apple orchards benefit pollination.
Germany Operation Pollinator The project aims to promote and advocate the implementation of MFFMs in agricultural landscapes.	MFFMs along a range of crop fields (e.g. canola and milling weed) enhance biodiversity and act as ecological corridors for deer.
Belgium Regional Landscape The project improves ecological value alongside productive agriculture in the Regional Landscape of Haspengouw and Voeren in Belgium's South Limburg.	MFFMs along fruit orchards (apple, pear). Benefits include increased pollination, natural pest control and biodiversity.
UK Operation Pollinator The project increases the amount of pollen, nectar and nesting sites on the farm by providing grower agronomic advice and support.	MFFMs in agricultural land that benefit pollination, soil quality and natural pest control. Syngenta provides instructions and covered 25% of the seed pack cost.

Appendix 3
A Sample MFFM Protocol[73]

Practical guidelines for the application of local protocols

The guidelines below provide a summary of the practical guidance to help farmers implement and manage field margins for pollination benefits and provide detailed information on what to do, how and when.

Planning[74]

1. Identification of low yielding areas on farms

- Look for uncropped areas.
- Use areas of the farm that are low in fertility or show otherwise poor growth (e.g. compacted soils or those with low water storage capacity).
- Plan well ahead.[75]

2. Look for the best sites

- Margins must be a minimum of 3% of the overall farmland.
- Consider placing them along features such as hedges, banks, forest fringes, ditches or watercourses.
- Flower mixes need sun and shelter.
- Where possible, choose a dry, well-drained site.

3. Fit with the farm

- Ensure access to these areas for management.
- Margins should be considered as a long-term element of farm strategy and where possible should be connected to ecological infrastructures at a landscape level.

Preparation

1. Prepare seed bed

- Plough and press or disc followed by a power-harrow to create a firm and fine seed bed, which is required to avoid weed pressure.

2. Sowing

- Select appropriate seed mixes suitable to the local environment.
- Choose sowing dates according to local conditions.
- Be aware that small seed can settle in the bag or drill; regularly mix as you drill. A final roll after sowing should firm the seed soil contact.
- Margins, like crops, need management. Effectively managed margins will last for many seasons.

Management (in the first year)

- Cutting/mowing will remove annual weeds[76]. Newly established wildflower habitats are likely to need cutting to aid establishment and remove undesirable weed species. Mowing should ideally take place when the weeds start to compete with the sown plant species.
- Actual timing of cuts will depend on soil conditions, growth and constraints from agri-environmental schemes and rural development plans. If in the first season growth is excessive, an additional cut within five to eight weeks may be needed.
- Cut to a height of 10–15 cm.

Management in subsequent years

- A cut to 15 cm at the end of the flowering season will support the establishment of a dense margin that will push out unwanted weed species in subsequent years.
- To provide overwintering habitat for specific species (e.g. butterflies) cut only 50% of the margin and alternate in the following year.

Removal of cuttings

- Removal of cuttings is recommended for grass-based mixes, as it helps light reach the smaller, shyer perennial species and stops sward getting too dense. If the cuttings cannot be removed, try to spread the cutting as thinly as possible to avoid smothering the plants below.
- Removal is not necessary for clover-based mixes as the cut sward will wilt away.

[73] This is a sample protocol and is adapted from the Syngenta Operation Pollinator Growers guidelines from the UK. – Syngenta UK, (2014).
[74] In general, the abundance and richness of insect pollinators due to MFFM can vary within the year and between years. Therefore, it might be important to consider that planning could help farmers to take advantage of the MFFM. The coordinators recognize that seasonality is an important criteria in planning MFFMs, however in order to keep the protocol at the higher level and more broadly applicable the coordinators have decided not to consider it here.
[75] For instance, in the UK January is recommended for spring planting and June for autumn planting – Syngenta Operation Pollinator Growers guidelines. – Syngenta UK, (2014).
[76] The involvement of local experts is important to optimize the right mix of plants to be considered for field margins. Sometimes smallholders may prefer edible crops to other plants.

Appendix 3
A Sample MFFM Protocol[73] continued

Table 3A
MFFMs and associated benefits and impacts

Inputs	Changes at farm level	Changes beyond farm level	Impacts on farmer	Impacts on local community
– Technologies (i.e. seed mixture). – Training to establish, manage and monitor MFFMs. – Marketing and financial support.	– Increase crop yield and quality. – Enhance agrobiodiversity knowledge. – Provide habitat for local species and food sources for pollinating insects, birds and reptiles. – Improve water management and reduce field runoffs. – Prevent soil erosion and loss.	– Enhance market access (due to better yield and crop quality). – Help comply with sustainability schemes and legal or agri-food value chain requirements. – Provide access to subsidies. – Support climate change mitigation and adaptation. – Provide migration corridors for wildlife.	– Ensure stable or increased farmer incomes and wellbeing. – Support recreational and tourism activities. – Reduce exposure to climate change risks.	– Help improve local community livelihood. – Food security. – Facilitate recreational and tourism opportunities. – Preserved ecosystem services.

Table 3B
Various stakeholders and their interest in MFFMs

Stakeholders	Interest
Farmers	Productivity gains, higher farm income, prevention of soil erosion, enhanced pollination.
Environmental non-governmental organizations	Increased biodiversity in agricultural landscapes, sustainable farming for the environment, promotion of local plant species, improved water quality.
Agri-food chain partners	Procurement of biodiversity-friendly products.
Universities and research institutes	Training and education of farmers to enhance biodiversity in agricultural landscapes.
Community at large	Sustainable food production, improved water quality, tourism, and recreation benefits.
Governmental bodies	Preservation and management of biodiversity in agricultural landscapes.

[73] This is a sample protocol and is adapted from the Syngenta Operation Pollinator Growers guidelines from the UK. – Syngenta UK, (2014).

Appendix 4
Farm monitoring

Syngenta has started collecting evidence on the positive impacts of MFFMs on crop yields through an external third-party organization, Market Probe-Kynetec.

Approximately 3,700 farmers cultivating 20 crop types in 36 countries were interviewed. Of these, 80% (around 3,000) shared information on biodiversity and soil conservation practices.

The findings reinforce the importance of biodiversity conservation and restoration. The majority of respondents are familiar with biodiversity conservation (80% in Latin America and 68% in Europe, Africa and the Middle East). Moreover, on average, growers have 6% non-cropped land at the global level (3% in Asia Pacific, 6% in Europe and Africa and 11% in Latin America). For a majority of the growers, none or only a small percentage of this land is managed for biodiversity conservation. Thus, the percentage of non-cropped land that is managed for biodiversity is often very limited.[77]

Finally, many farmers implementing biodiversity conservation practices report higher yields in several countries, which is a promising initial confirmation of the potential social capital benefits gained. For instance, the analysis for different countries and crops highlights an overall higher yield on the reference farms (with MFFMs) compared to the controls (without MFFMs).

[77] Syngenta elaboration on Market Probe-Kynetec data, Internal report, (2017).

Appendix 5
Natural and Social Capital benefits and monetary evaluation of MFFMs

Table 5A
Natural Capital and Social Capital benefits identified across nine projects

		Land use classification								
		Grassland							Wood-land	Tropical forest
	Country projects:	S. Korea	China	USA	Canada	Germany	Belgium	UK	Colombia	Brazil
Natural Capital benefits	Reintroduction of Local Species	×	×	×	✓	✓	✓	✓	✓	✓
	Pollinators	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ecosystem Disturbance Moderation	×	×	×	×	×	×	×	×	×
	Waste Treatment	×	×	×	×	×	×	×	×	×
	Nutrient Cycling	×	×	×	×	×	×	×	×	×
	Nursery Service	×	×	×	×	×	×	×	×	×
	Ornamental Resources	×	×	×	×	×	×	×	×	×
	Natural Pest Predators	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Earthworm Populations and Activity	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Food Sources and Nesting Sites	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Migration Corridors	×	×	×	×	×	✓	×	✓	✓
	Pest Control	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Soil Quality and Erosion Prevention	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Water Filtration and Storage	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Water Quality	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Flood Control	×	×	✓	×	×	✓	✓	✓	✓
	Wind Breaks	×	×	×	×	×	✓	×	✓	✓
	Genetic Diversity	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Climate Regulation	×	×	×	×	×	×	×	×	✓
	Carbon Sequestration	✓	✓	✓	✓	✓	✓	✓	✓	✓
Social Capital benefits	Employment	✓	✓	×	×	×	✓	×	✓	✓
	Yield	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Gender Equality	✓	✓	×	×	×	×	×	✓	×
	Recreational Activities	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Tourism and Aesthetics	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Raw Material Provision	×	×	×	×	×	×	×	×	×
	Spiritual	×	×	×	×	×	×	×	×	×
	Medicinal Resources	×	×	×	×	×	×	×	×	×
	Genetic Resources	×	×	×	×	×	×	×	×	×
	Air Quality Regulation	×	×	×	×	×	×	×	×	×
	Knowledge Acquisition and Education	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Local Community Benefits	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Landscape Aesthetics	✓	✓	×	✓	✓	✓	✓	✓	✓
	Cultural and Historical Heritage	✓	✓	×	×	×	×	×	✓	✓
	Product Branding/Market Access	×	×	×	✓	✓	×	✓	×	✓

Identification of benefits

Table 5A opposite illustrates the natural capital and social capital benefits identified across the nine projects and linked to the specific field margin characteristics, design or management practices identified through the literature review.

Below, six of the identified benefits (highlighted in Table 5A) were selected for monetary valuation based on their relevance and the availability of reliable monetary values from existing literature (see below).

Pollination services provision
Soil erosion prevention
Water filtration and storage
Recreation and aesthetics
Carbon sequestration
Climate regulation

Table 5B
Description of selected monetary values

Ecosystem service	Description	Monetary value $/ha/year	Description
Pollination services provision	Pollinators' diversity and abundance supports crop production for calorie benefits and dietary nutritional value. Pollinator margins in farmlands contribute to food and nutritional security. In addition, sustainable intensification contributes to pollination enhancement.	937[78]	Average coefficient of five global studies obtained from the assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production.
Soil erosion prevention[79]	Tree and plant root systems in forests and woodlands prevent soil erosion from wind and water. Dense foliage intercepts rainfall, preventing compaction and erosion of bare soil. Similarly, grassland covers an area with its roots, stabilizing the soil and contributing greatly to control erosion.	Tropical forest: 15[80] Woodland: 13[80] Grassland: 44[80]	
Water filtration and storage	This ecosystem function refers to the increment of filtering, retention, and storage of water in soil caused by the deep-reaching roots of various trees, bushes, and grass. It is assumed that the dense vegetation provides copious root systems and a relatively smaller amount of vegetation provides fewer roots.	Tropical forest: 27[80] Woodland: n/a[80] Grassland: 60[80]	
Climate regulation	Regulation of local weather and climate, caused by water vapor released through the leaves during metabolism of trees, bushes, and grass, resulting in different levels of humidity and precipitation increments. For instance, it is assumed that the forest provides a large number of plants, therefore it greatly increases the humidity and precipitation of the surrounding areas. On the other hand, grasses have smaller leaves but cover an area more completely, and therefore prevent the loss of moisture and maintain precipitation level.	Tropical forest: 2,044[80] Woodland: 7[80] Grassland: 40[80]	

[78] The five following global studies (with their respective coefficients) were used to calculate the mean coefficient for pollination services:
- Bauer and Wing (2014), (1,010-1,891 $/ha)
- Bauer and Wing (2014), (439-526 $/ha)
- Lautenbach et al. (2012), (717-1,760 $/ha)
- Gallai et al. (2009), (624 $/ha)
- Gallai et al. (2009), (473-1306 $/ha)

[79] Secretariat of the Convention on Biological Diversity (SCBD), (2001); and Brink et al., (2009).
[80] De Groot, R. et al., (2012).

Ecosystem service	Description	Monetary value $/ha/year	Description
Recreation and aesthetics	Forests, woodlands and grasslands have important recreational benefits, as they are places where people can come to rest, relax, refresh and enjoy the scenery of natural areas and landscapes. Attractive scenery of forests with dense vegetation and animals engages people through activities such as hiking, riding, camping, jogging, etc. Most studies reviewed relied on contingent valuation method (surveys and interviews) to calculate the recreational and aesthetic value of an ecosystem.	Tropical forest: 867[80] Woodland: 7[80] Grassland: 193[80]	
Carbon sequestration	Agriculture carries a significant potential to reduce greenhouse gas emissions and increase carbon sequestration while still helping to meet food security objectives. For example, improving the efficiency and productivity of food production systems through better management practices and improved input technologies can go a long way to reducing emissions. For this analysis, the coordinators have considered carbon sequestration and storage above ground in forest lands and in below ground biomass and grasslands margins, primarily because of emissions factors available.	Tropical forest and Woodland: 241[81] Grassland: 367[82]	The coefficient for carbon sequestration is derived from the change of plant biomass in a hectare of land over the period of a year. This biomass (3.29 and 5 C t/ha/year respectively) is multiplied by 3.67 to convert it into CO_2 equivalent tonnes/ha/year. A price of 20 $/t is used to obtained the economic coefficient.

80 De Groot, R. et al., (2012).
81 Carbon sequestration coefficient for tropical forest and woodland landscape types is taken from the IPCC, (2003a).
82 Carbon sequestration coefficient for grasslands landscape types is taken from the IPCC, (2003b).

Appendix 5
Natural and Social Capital benefits and monetary evaluation of MFFMs continued

Table 5C
The monetary value of Natural and Social Capital benefits in the case of implemented hectares

Based on selected ecosystem services the below table (Table 5C) summarizes the monetary value created by nine MFFM projects on the basis of their implemented hectares.

Projects			Calculations	
Land use type	Implemented hectares	Benefited hectares	Ecosystem services economic coefficient (USD/Hectare)	Total economic value (USD)
Grassland	7,929	273,860	1,641	13,011,489
Woodland	414	66,126	1,205	498,870
Tropical forest	4,947	2,818,054	4,131	20,436,057
	13,290	3,158,040		33,946,416

Key limitations of the monetary valuation of Natural and Social Capital benefits from MFFMs

The coordinators would like to highlight some of the limitations of the monetary values used in the proposed valuation and found in the literature:

– Limited literature was available on the market and non-market values of MFFMs. As such, information from other studies of landscapes had to be adapted. Studies also varied in the way they defined and classified MFFMs as well as how they sampled, monitored, aggregated, calculated and modelled simulations.

– Accuracy of the estimation of the economic value of ecosystem services is limited by the scope and availability of biological, geographical, and economic data. Studies with global scope were preferred and considered where possible.

– Knowledge gaps limited the capacity to accurately adapt available coefficients to the project level. Projects have different characteristics and locations.

– Literature was limited, especially on the social capital benefits of ecosystem services: a number of factors are not accounted for in most of the studies that were reviewed. These include: price fluctuation of crops; additional agricultural income and jobs created; and positive environmental and human capital effects from reduced use of agricultural inputs.

– Some ecosystem services were not considered in our calculations even if coefficients were available, as these services were deemed to be less common to the majority of implemented projects. Evidence based on counterfactuals is a major challenge. Ideally, farms with MFFMs would be compared with control farms without MFFMs. In practise, such conditions do not exist and so findings from control groups need to be interpreted with caution.

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Editorial completion April, 2018

Arcadis, Bioversity International and Syngenta

Printed on paper from certified forests

ISBN: 978-3-033-06849-0