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The impact of interventions in the global land and agri-food sectors on Nature's Contributions to People and the UN Sustainable Development Goals¹

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Abstract

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Interlocked challenges of climate change, biodiversity loss and land degradation require transformative interventions in the land management and food production sectors to reduce carbon emissions, strengthen adaptive capacity, and maintain or increase food production to 2050. However, deciding which interventions to pursue and understanding their relative synergies with and trade-offs against social and environmental goals has been difficult without benefit of direct comparisons across a range of possible actions. This study examined a series of 40 different mitigation and adaptation options implemented through land management, value chain or risk management measures for their relative impacts across 18 Nature's Contributions to People (also known as ecosystem services) and 17 Sustainable Development Goals. We find that a relatively small number of interventions show significant positive synergies with both SDGs and NCPs, including increasing soil organic matter, improved cropland, grazing land and livestock production, sustainable sourcing, reducing postharvest waste and losses, and disaster risk management. Several interventions show strong negative impacts on either SDGs, NCPs or in some cases, both, including bioenergy, afforestation, and some risk sharing measures, like commercial crop insurance. Our results demonstrate that better understanding of benefits and trade-offs of comparative policy approaches can help decisionmakers choose the most effective, or at the very minimum, the less negative interventions for implementation in specific contexts.

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1. Introduction

The world currently faces a series of interrelated problems; climate change, biodiversity and ecosystems loss, land degradation, and poverty, among others, highlighting the need for transformative solutions that cut across these challenges. This has highlighted hopes that changes in how we use land might be able to co-deliver multiple benefits, such as reduced greenhouse gas emissions, increased adaptive capacity to current and future climate changes, improved land health and quality, and improved access to and productivity of agriculture to reduce food insecurity and poverty. However, a major dilemma is how to access these multiple benefits without undue adverse side effects on other social development goals or on natural ecosystems.

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Numerous potential options have been suggested to address these land challenges, and this study assesses 40 of the response options examined in the most recent IPCC report (on climate change and land) by discussing possible co-benefits and adverse side effects. These response options encompass different land use, value chain or risk management practices commonly proposed to meet diverse land challenges, ranging from mitigation to adaptation to land degradation and food security. These options were evaluated against their implications for nature, including biodiversity and water, and against their impacts on people, such as poverty reduction efforts or gender equality measures. We do so by assessing the 40 practices against 18 identified Nature's Contributions to People (NCP), a new term for ecosystem services used by the

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Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES

2019), and the 17 UN Sustainable Development Goals (SDGs), in order to identify those that result in least trade-offs and most co-benefits.

The 40 practices considered in this study were categorized into those that rely on a) land management, b) value chain management and c) risk management (Figure 1). The land management practices can be grouped according to those that are applied in agriculture, in forests, on soils, in other/all ecosystems and those that are applied specifically for carbon dioxide removal (CDR). The value chain management practices can be categorised as those based demand management and supply management. The risk management options are grouped together. Smith et al. (2019) provides further details on each of the response options and how they were evaluated.

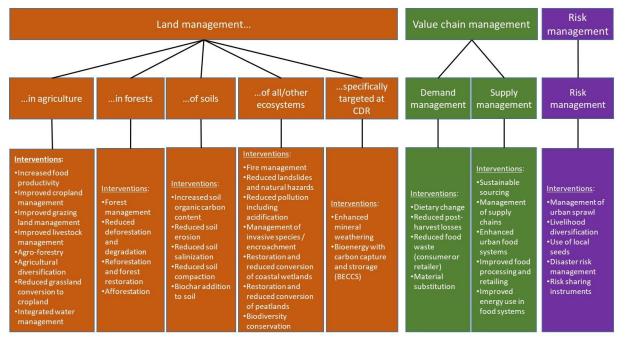


Figure 1. Broad categorisation of practices categorised into three main classes and eight subclasses.

How the different options impact progress toward the SDG can be a useful shorthand for looking at the social impacts of policy choices, and similarly, looking at how these response options increase or decrease the supply of ecosystem services/NCP can be a useful shorthand for a more comprehensive environmental impact. Such evaluations are important as response options may lead to unexpected trade-offs (adverse side effects) or potential co-benefits with social goals and important environmental indicators like water or biodiversity. These synergies and co-benefits associated with some response options may increase their cost-effectiveness or attractiveness. Because many of these synergies are not automatic and are dependent on well-implemented and coordinated activities in appropriate environmental contexts, often requiring institutional and

enabling conditions for success and participation of multiple stakeholders, it is important to identify these interactions early on in decision-making processes (IPCC 2019).

In defining co-benefits and adverse side effects, we use the IPCC AR5 WGIII definitions: co-benefits are "positive effects that a policy or measure aimed at one objective might have on other objectives, thereby increasing the total benefits for society or the environment" while adverse side-effects are "negative effects that a policy or measure aimed at one objective might have on other objectives, without yet evaluating the net effect on overall social welfare." Both co-benefits and adverse side-effects can be biophysical and/or socio-economic in nature and "are often subject to uncertainty and depend on, among others, local circumstances and implementation practices" (IPCC 2019).

Assessing policy options against their co-benefits and adverse side effects needs to account for impacts on both natural and human systems. The importance of assessing a range of climate change response options and policies against the SDGs in particular was emphasized in the IPCC 1.5 report, especially Figure SPM4 (IPCC 2018). In this approach, mitigation options were compared for their potential positive effects (synergies) or negative effects (trade-offs); negative effects from mitigation options across energy supply and demand and land were particularly noted for SDG 1 and 2 (zero poverty and no hunger) and SDG 6 and 15 (clear water and sanitation and life on land), while positive effects were noted on SDG 3 (good health) and SDG 7 (affordable and clean energy). However, as many commentators have pointed out, it is insufficient to judge progress against SDGs alone, as many of the planetary support systems that make sustainable development possible might be degraded through economic development, hence there is a need for indicators of ecosystem change and health as well beyond some of the SDGs specifically focused on ecosystems (SDG 14 and 15) (Griggs et al. 2013).

We chose to examine NCP as indicators of ecosystem benefits and services. Ecosystem services have become a useful concept to describe the benefits that humans obtain from ecosystems, while NCP is a newer approach championed by IPBES, defined as "all the contributions, both positive and negative, of living nature (i.e., diversity of organisms, ecosystems and their associated ecological and evolutionary processes) to the quality of life of people" (Díaz et al. 2018). However, IPBES has stressed NCP are a particular *way to think* of ecosystem services, rather than a replacement for the concept (Pascual et al. 2017; Díaz et al. 2018). Many mitigation actions may have positive impacts on adaptation or food production (Carpenter et al. 2009) but may also come with a decline in ecosystem provisioning, or adversely impact biodiversity (Foley et al. 2005), which is why it is important to specifically assess them. Global climate models are increasingly incorporating some ecosystem services/NCP indicators to understand vulnerability to change or loss in future climate scenarios (Schröter et al. 2005).

1 Table 1. List of NCPs and SDGs

NCPs (Díaz et al. 2018; IPBES 2019)	SDGs (UN 2017)
NCP 1: Habitat creation and maintenance	SDG 1: No poverty
NCP 2: Pollination and dispersal of seeds and	SDG 2: Zero Hunger
other propagules	
NCP 3: Regulation of air quality	SDG 3: Good health and well-being
NCP 4: Regulation of climate	SDG4: Quality education
NCP 5: Regulation of ocean acidification	SDG5: Gender equity
NCP 6: Regulation of freshwater quantity,	SDG 6: Clean water and sanitation
flow and timing	
NCP 7: Regulation of freshwater and coastal	SDG7: Affordable and clean energy
water quality	
NCP 8: Formation, protection and	SDG 8: Decent work and economic growth
decontamination of soils and sediments	
NCP 9: Regulation of hazards and extreme	SDG9: Industry, innovation and infrastructure
events	
NCP 10: Regulation of organisms detrimental	SDG10: Reduced inequality
to humans	
NCP 11: Energy	SDG 11: Sustainable cities and communities
NCP 12: Food and feed	SDG 12: Responsible production and
	consumption
NCP 13: Materials and assistance	SDG 13: Climate action
NCP 14: Medicinal, biochemical and genetic	SDG 14: Life below water
resources	
NCP 15: Learning and inspiration	SDG 15: Life on land
NCP 16: Physical and psychological	SDG 16: Peace and Justice, strong institutions
experiences	
NCP 17: Supporting identities	SDG 17: Partnerships to achieve the goals
NCP 18: Maintenance of options	

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2. Materials and methods

- 4 Practices available to address the land challenges of climate change mitigation, climate change
- 5 adaptation, desertification and land degradation and food security were collated from Chapters 2
- 6 to 5 of the IPCC Special Report on Climate Change and Land (IPCC, 2019). A thorough
- 7 literature review was conducted to gather evidence on the intersections between each of these 40
- 8 practices and the 17 SDGs and 18 NCPs. Some of the categories may appear similar to each
- 9 other, such as SDG 13 on "climate action" and an NCP titled "climate regulation". However,
- 10 SDG 13 includes targets for both mitigation and adaptation, so options were weighed by whether
- they were useful for one or both. On the other hand, the NCP "regulation of climate" does not

include an adaptation component, and refers to specifically to "positive or negative effects on emissions of greenhouse gases and positive or negative effects on biophysical feedbacks from vegetation cover to atmosphere, such as those involving albedo, surface roughness, long-wave radiation, evapotranspiration (including moisture-recycling) and cloud formation or direct and indirect processes involving biogenic volatile organic compounds (BVOC), and regulation of aerosols and aerosol precursors by terrestrial plants and phytoplankton" (Díaz et al. 2018).

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For the evaluation process for NCP, we considered that NCP are about ecosystems, therefore options which may have overall positive effects, but which are *not* ecosystem-based are not included; for example, improved food transport and distribution could reduce ground-level ozone and thus improve air quality, but this is not an ecosystem-based NCP. Similarly, energy efficiency measures would increase energy availability, but the 'energy' NCP refers specifically to biomass-based fuel provisioning. This necessarily means that the land management options have more direct NCP effects than the value chain or governance options, which are less ecosystem-focused.

In evaluating NCP, we have also tried to avoid 'indirect' effects – that is a response option might increase household income which then could be invested in habitat-saving actions, or dietary change would lead to conservation of natural areas, which would then led to increased water quality. These can all be considered *indirect* impacts on NCP, which were not evaluated². Instead, the assessment focuses as much as possible on *direct* effects only: for example, local seeds policies preserve local landraces, which *directly* contribute to 'maintenance of genetic options' for the future. Therefore, the NCP interactions should be considered a conservative estimation of effects; there are likely many more secondary effects, but they are too difficult to assess, or the literature is not yet complete or conclusive. Further, many NCP may trade-off with one another (Rodriguez et al 2006), so supply of one might lead to less availability of another – for example, use of ecosystems to produce bioenergy will likely lead to decreases in water availability if mono-cropped high intensity plantations are used (Gasparaos et al 2011). These interactions between NCPs are not mapped directly in our assessment.

For our assessment of SDGs, the literature was particularly uneven. Because many land management options only produce indirect or unclear effects on SDG, we did not include these where there was no literature. Therefore, the value chain and risk management options appear to offer more direct benefits for SDGs. Further, it is noted that some SDG are internally difficult to assess because they contain many targets, not all of which could be evaluated (e.g., SDG 17 is about partnerships, but has targets ranging from foreign aid to debt restructuring to technology

 $^{^2}$ The exception is NCP 6, regulation of ocean acidification, which is by itself an indirect impact. Any option that sequesters CO_2 would lower the atmospheric CO_2 concentration, which then indirectly increases the seawater pH. Therefore, any action that directly increases the amount of sequestered carbon is noted in this assessment, but not any action that avoids land use change and therefore indirectly avoids CO_2 emissions.

- 1 transfer to trade openness). We attempted to conduct literature searches for all key indicators per
- 2 SDG (UN 2018), but found many more well represented in the literature than others.
- 3 Additionally, some SDG contradict one another for example, SDG 9 to increase
- 4 industrialisation and infrastructure and SDG 15 to improve life on land; more industrialisation is
- 5 likely to lead to increased resource demands with negative effects on habitats. Therefore, a
- 6 positive association on one SDG measure might be directly correlated with a negative measure
- 7 on another, and the table needs to be read with caution for that reason. The specific caveats on
- 8 each of these interactions can be found in the supplementary material tables (SM Table 1-6).

3. Results

- In the sections below, we provide the primary interactions arising from the extensive literature
- review and represent them visually in Tables 2-7, while textual descriptions of interactions and
- 13 literature can be found in SM Tables 1-6. In all tables, colours represent the direction of impact:
- positive (blue) or negative (brown), and the scale of the impact (dark colours for large impact
- and/or strong evidence to light colours for small impact and/or less certain evidence).
- Supplementary tables show the values and references used to define the colour coding used in all
- tables. In cases where there is no evidence of an interaction or at least no literature on such
- interactions, the cell is left blank. In cases where there are both positive and negative interactions
- and the literature is uncertain about the overall impact, a note appears in the box. In all cases,
- 20 many of these interactions are contextual, or the literature only refers to certain co-benefits in
- 21 specific regions or ecosystems, so readers are urged to consult the supplementary tables for the
- specific caveats that may apply.

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3.1 Interactions of the options on NCP supply

- Tables 2-4 summarise the impacts of the response options on NCP supply. Examples of
- synergies between response options and NCP include positive impacts on habitat maintenance
- 27 (NCP 1) from activities like invasive species management and agricultural diversification. For
- 28 example, the latter improves resilience through enhanced diversity to mimic more natural
- 29 systems and provide in-field habitat for natural pest defences (Lin 2011), while invasive species
- 30 management has strong direct links to improved habitats and ecosystem diversity (Richardson &
- 31 van Wilgen 2004).

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- Overall, several response options stand out as having co-benefits across 10 or more NCP with no
- 34 notable adverse impacts on ecosystems: improved cropland management, agroforestry, forest
- 35 management and forest restoration, increased soil organic content, fire management, restoration
- 36 and avoided conversion of coastal wetlands, and use of local seeds.

- 38 Other response options may have strengths in some NCP but require trade-offs with others. For
- 39 example, reforestation and afforestation bring many positive benefits for climate and water

- 1 quality but may trade-off with food production. Several response options, including increased
- 2 food productivity, bioenergy and BECCS, and some risk sharing instruments (like commercial
- 3 crop insurance), have significant negative consequences across multiple NCP. While BECCS
- 4 may deliver on climate mitigation, it results in a number of adverse side-effects that are
- 5 significant with regard to water provisioning, food and feed availability, and loss of supporting
- 6 identities if BECCS competes against local land uses of cultural importance (IPCC 2019).

Table 2. Impacts on Nature's Contributions to People of integrated response options based on land management

Integrated response options based on land management	Habitat creation and maintenance	Pollination and dispersal of seeds and other propagules	Regulation of air quality	Regulation of climate	Regulation of ocean acidification	Regulation of freshwater quantity, flow and timing	Regulation of freshwater and coastal water quality	Formation, protection and decontamination of soils and	Regulation of hazards and extreme events	Regulation of organisms detrimental to humans	Energy	Food and feed	Materials and assistance	Medicinal, biochemical and genetic resources	Learning and inspiration	Physical and psychological experiences	Supporting identities	Maintenance of options
Increased food productivity																		
Improved cropland management																		
Improved grazing land management																		
Improved livestock management																		
Agroforestry																		
Agricultural diversification																		
Avoidance of conversion of grassland to cropland																		
Integrated water management													+ or -					
Y 1.0																		
Improved forest management and forest restoration									+ or -				+ or -					

	Reduced deforestation and degradation											
	Reforestation					+ or -						
	Afforestation				+ or -	+ or -						
9											•	
	Increased soil organic carbon content											
	Reduced soil erosion											
	Reduced soil salinisation											
	Reduced soil compaction											
	Biochar addition to soil											
10												
	Fire management											
	Reduced landslides and											
	natural hazards											
	Reduced pollution including acidification											
	Management of invasive											
	species / encroachment											
	Restoration and avoided											
	conversion of coastal wetlands							+				
	Restoration and avoided							or -				
	conversion of peatlands											
	Biodiversity conservation							+ or -				
11												
	Enhanced weathering of minerals											

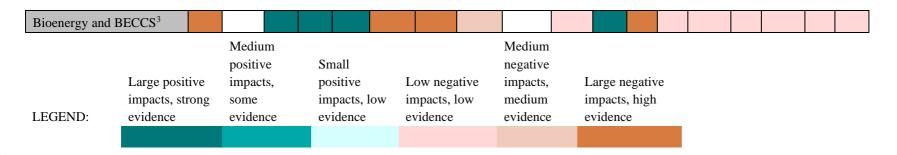


Table 3. Impacts on Nature's Contributions to People of integrated response options based on value chain management

Integrated response options based on value chain management	Habitat creation and maintenance	Pollination and dispersal of seeds and other propagules	Regulation of air quality	Regulation of climate	Regulation of ocean acidification	Regulation of freshwater quantity, flow and timing	Regulation of freshwater and coastal water quality	Formation, protection and decontamination of soils and	Regulation of hazards and extreme events	Regulation of organisms detrimental to humans	Energy	Food and feed	Materials and assistance	Medicinal, biochemical and genetic resources	Learning and inspiration	Physical and psychological experiences	Supporting identities	Maintenance of options
Dietary change																		
Reduced post-harvest losses																		
Reduced food waste (consumer or retailer)										_								
Material substitution																		

³ FOOTNOTE: Note that this refers to large areas of bioenergy crops capable of producing large mitigation benefits (> 3 GtCO2 yr⁻¹). The effect of bioenergy and BECCS on NCPs is scale and context dependent, and smaller scale and more sustainable bioenergy would lessen these negative impacts (IPCC 2019).

Sustainable sou	rcing															
Management of	supply															
chains																
Enhanced urbar	n food															
systems																
Improved food																
processing and	retail															
Improved energ	gy use in															
food systems																
	Large pos	sitive	Medium positive impacts,		Sma	all itive	Lo	w negati	Medium negative impacts,	La	rge ne	gative	e			
LEGEND:	impacts, s evidence	_	some evidence	e	-	acts, lov dence		pacts, lo	medium evidence		pacts, idence					

Table 4. Impacts on Nature's Contributions to People of integrated response options based on risk management

Integrated responsed on risk management of sprawl	nanagement	Habitat creation and maintenance	Pollination and dispersal of seeds and other propagules	Regulation of air quality	Regulation of climate	Regulation of ocean acidification	Regulation of freshwater quantity, flow and timing	Regulation of freshwater and coastal water quality	Formation, protection and decontamination of soils and sediments	Regulation of hazards and extreme events	Regulation of organisms detrimental to humans	Energy	Food and feed	Materials and assistance	Medicinal, biochemical and genetic resources	Learning and inspiration	Physical and psychological experiences	Supporting identities	Maintenance of options
Livelihood dive	ersification																		
Use of local see	eds																		
Disaster risk m	anagement																		
Risk sharing in	struments																		
LEGEND:	Large positi impacts, str evidence		Medium positive impacts, some evidence		Small positiv impact eviden	s, low	Low n impact eviden		Med nega impa med evide	tive acts, ium	Large impact	s, hig							

21 22 3.2 Interactions of the options with Sustainable Development Goals 23 Tables 5-7 summarise the impact of the integrated response options on the UN SDGs. Some of the synergies between response options and SDGs in the literature include positive poverty 24 25 reduction impacts (SDG 1) from activities like improved water management or improved 26 management of supply chains, or positive gender impacts (SDG 5) from livelihood 27 diversification or use of local seeds. For example, women play important roles in preserving 28 and using local seeds, which can empower them to take more active roles in agricultural 29 production (Ngcoya and Kumarakulasingam 2017; Bezner Kerr 2013). 30 31 Overall, several response options have co-benefits across 10 or more SDG with no adverse 32 side effects on any SDG: increased food production, improved grazing land management, 33 agroforestry, integrated water management, reduced post-harvest losses, sustainable 34 sourcing, livelihood diversification and disaster risk management. 35 36 Other response options may have strengths in some SDG but require trade-offs with others. 37 For example, use of local seeds bring many positive benefits for poverty and hunger 38 reduction, but may reduce international trade (SDG 17). Other response options like 39 enhanced urban food systems, management of urban sprawl, or management of supply chains 40 are generally positive for many SDG but may trade-off with one, like clean water (SDG 6) or decent work (SDG 8), as they may increase water use or slow economic growth. Several 41 42 response options, including avoidance of grassland conversion, reduced deforestation and 43 degradation, reforestation and afforestation, biochar, restoration and avoided conversion of 44 peatlands and coastlands, have trade-offs across multiple SDG, primarily as they prioritise

land health over food production and poverty reduction. Several response options, such as bioenergy and BECCS and some risk sharing instruments, such as crop insurance, trade-off

over multiple SDG with potentially significant adverse consequences.

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Table 5. Impacts on the UN SDG of integrated response options based on land management

Integrated response options based on land management	GOAL 1: No Poverty	GOAL 2: Zero Hunger	GOAL 3: Good Health and Wellbeing	GOAL 4: Quality Education	GOAL 5: Gender Equality	GOAL 6: Clean Water and Sanitation	GOAL 7: Affordable and Clean Energy	GOAL 8: Decent Work and Economic Growth	GOAL 9: Industry, Innovation and Infrastructure	GOAL 10: Reduced Inequality	GOAL 11: Sustainable Cities and Communities	GOAL 12: Responsible Consumption and Production	GOAL 13: Climate Action	GOAL 14: Life Below Water	GOAL 15: Life on Land	GOAL 16: Peace and Justice Strong Institutions	GOAL 17: Partnerships to achieve the Goal
Increased food productivity																	
Improved cropland management																	
Improved grazing land management																	
Improved livestock management																	
Agroforestry																	
Agricultural diversification										+ or -							
Avoidance of conversion of grassland to cropland																	
Integrated water management																	
Improved forest management and forest restoration																	

	Reduced deforestation and											
	degradation	+ or -										
	Reforestation	+ or -										
	Afforestation											
52						'				·	'	
	Increased soil organic carbon											
	content											
	Reduced soil erosion											
	Reduced soil salinisation											
	Reduced soil compaction											
	Biochar addition to soil											
53												
	Fire management											
	Reduced landslides and natural											
	hazards											
	Reduced pollution including											
	acidification											
	Management of invasive species / encroachment											
	Restoration and avoided		+									
	conversion of coastal wetlands	+ or -	or -									
	Restoration and avoided											
	conversion of peatlands											
	Biodiversity conservation		+									
		+ or -	or									
54		1 01										
ĺ	Enhanced weathering of											
	minerals											

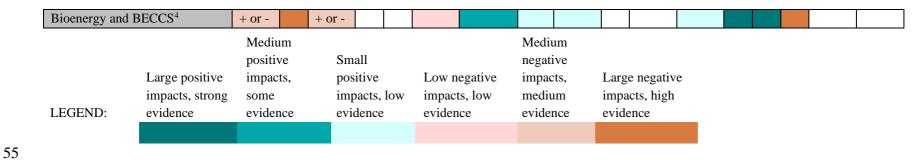


Table 6. Impacts on the UN SDG of integrated response options based on value chain interventions

Integrated response options based on value chain management	GOAL 1: No Poverty	GOAL 2: Zero Hunger	GOAL 3: Good Health and Wellbeing	GOAL 4: Quality Education	GOAL 5: Gender Equality	GOAL 6: Clean Water and Sanitation	GOAL 7: Affordable and Clean Energy	GOAL 8: Decent Work and Economic Growth	GOAL 9: Industry, Innovation and Infrastructure	GOAL 10: Reduced Inequality	GOAL 11: Sustainable Cities and Communities	GOAL 12: Responsible Consumption and Production	GOAL 13: Climate Action	GOAL 14: Life Below Water	GOAL 15: Life on Land	GOAL 16: Peace and Justice Strong Institutions	GOAL 17: Partnerships to achieve the Goal
Dietary change																	
Reduced post-harvest losses																	
Reduced food waste (consumer or retailer)																	
Material substitution																	
Sustainable sourcing																	

⁴ FOOTNOTE: Note that this refers to large areas of bioenergy crops capable of producing large mitigation benefits (> 3 GtCO2 yr⁻¹). The effect of bioenergy and BECCS on NCPs is scale and context dependent, and smaller scale and more sustainable bioenergy would lessen these negative impacts (IPCC 2019).

Management of	supply chains											
Enhanced urban	food systems											
Improved food p	processing & retail											
Improved energ	y use in food											
systems												
		Mediu	ım				3.7.12					
		positiv		Sm	all		Medi negat					

Table 7. Impacts on the UN SDG of integrated response options based on risk management

Integrated response options based on risk management	GOAL 1: No Poverty	GOAL 2: Zero Hunger	GOAL 3: Good Health and Well-being	GOAL 4: Quality Education	GOAL 5: Gender Equality	GOAL 6: Clean Water and Sanitation	GOAL 7: Affordable and Clean Energy	GOAL 8: Decent Work and Economic Growth	GOAL 9: Industry, Innovation and Infrastructure	GOAL 10: Reduced Inequality	GOAL 11: Sustainable Cities and Communities	GOAL 12: Responsible Consumption and Production	GOAL 13: Climate Action	GOAL 14: Life Below Water	GOAL 15: Life on Land	GOAL 16: Peace and Justice Strong Institutions	GOAL 17: Partnerships to achieve the Goal
Management of urban sprawl																	
Livelihood diversification																	
Use of local seeds		+ or -															
Disaster risk management																	
Risk sharing instruments											·	+ or -					

	LEGEND:	Large positive impacts, strong evidence	Medium positive impacts, some evidence	Small positive impacts, low evidence	Small negative impacts, low evidence	Medium negative impacts, medium evidence	Large negative impacts, high evidence
60							

3.3 Interactions between SDGs and NCPS

 Overall, across both categories of both SDGs and NCPs, 16 of 40 options that were evaluated deliver at least some co-benefits and have no significant adverse side-effects for the full range of NCPs and SDGs (Table 8, blue shading). This include many agriculture- and soil-based land management options, some ecosystem-based land management options, reduced post-harvest losses, sustainable sourcing, improved energy use in food systems, livelihood diversification and disaster risk management. Only three options (afforestation, bioenergy and BECCS and some types of risk sharing instruments, such as crop insurance) have potentially adverse side-effects for five or more NCP or five or more SDGs (Table 8, brown shading).

Table 8. Sums of co-benefits and adverse side-effects

	Positive Co-	Positive Co-	Adverse	Adverse
	benefits for	benefits for	Side Effects	Side Effects
	NCPs	SDGs	for NCPs	for SDGs
Increased food productivity	2	12	4	
Improved cropland management	10	9		
Improved grazing land management	9	10		
Improved livestock management	7	8		
Agroforestry	13	10		
Agricultural diversification	8	~7		~1
Avoidance of conversion of grassland to cropland	9	3	1	3
Integrated water management	~6	14	~1	
Improved forest management and forest restoration	~17	16	~2	
Reduced deforestation and degradation	15	8	1	~4
Reforestation	~15	~6	~2	~2
Afforestation	~11	4	~3	3
Increased soil organic carbon content	10	9		
Reduced soil erosion	7	7		
Reduced soil salinisation	4	5		
Reduced soil compaction	6	4		
Biochar addition to soil	5	3		3
Fire management	11	5		
Reduced landslides and natural hazards	6	4		
Reduced pollution including acidification	5	7		

Management of invasive species	8	6	1	
/ encroachment				
Restoration and avoided	~16	~6	~1	~3
conversion of coastal wetlands				
Restoration and avoided	10	3	2	4
conversion of peatlands				
Biodiversity conservation	~9	~9	~1	~2
Enhanced weathering of	4	2	1	
minerals				
Bioenergy and BECCS	4	6	12	~5
Dietary change	4	9		2
Reduced post-harvest losses	5	12		
Reduced food waste (consumer	5	11		2
or retailer)				
Material substitution	2	5	1	2
Sustainable sourcing	8	12		
Management of supply chains	2	14		1
Enhanced urban food systems	8	14		1
Improved food processing & retail		11		1
Improved energy use in food		7		
systems				
Management of urban sprawl	9	11		1
Livelihood diversification	2	13		
Use of local seeds	10	~12		~2
Disaster risk management	2	14		
Risk sharing instruments	1	~8	7	~5

Notes: Columns are sums of categories of co-benefits and side effects from Tables 2-7 and do not indicate magnitude of effect (e.g. large, medium or small benefits). ~ indicates a mixed effect.

Blue indicates presence of co-benefits with no adverse side effects.

Brown indicates presence of significant adverse side effects

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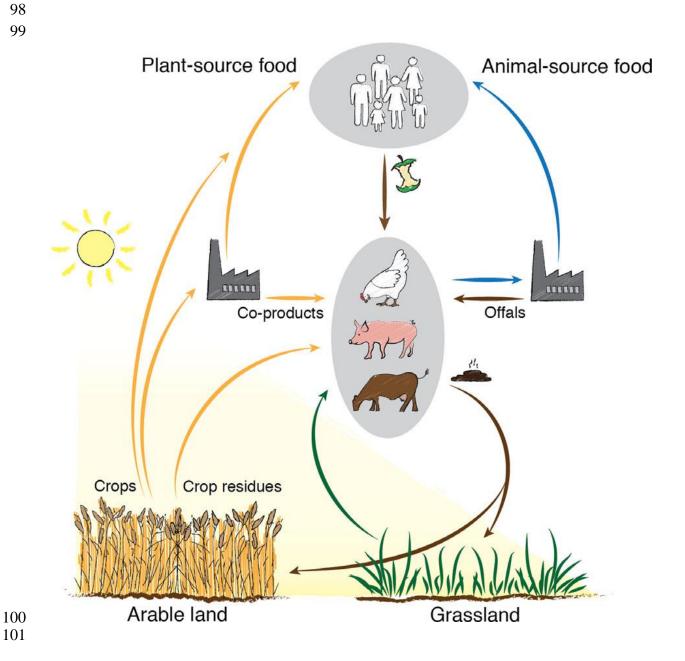
options stand out as being particularly good across a range of SDGs, but few NCPs: increased food productivity, dietary change, reduced food loss and waste, management of supply chains, enhanced urban food systems, improved food processing and retail, and improved energy use in food systems, livelihood diversification, disaster risk reduction and risk sharing instruments. Conversely, some options deliver co-benefits for many NCPs but few SDGs:

Some interactions between NCPs and SDGs are also suggested by Table 8. Some response

avoidance of grassland conversion, reduced deforestation and degradation, reforestation and afforestation, restoration and avoided conversion of coastal wetlands and peatlands.

Notably, some options deliver a balanced set of co-benefits across both SDGs and NCPs: improved cropland management, improved grazing land management, improved livestock management, agroforestry, agricultural diversification, improved forest management, nearly all soil management options, reduced landslides and reduced pollution, management of invasive species, biodiversity conservation, and use of local seeds. Such interactions and synergies are noted in Figure 2.

Figure 2. Possible new figure showing interactions between NCP and SDG for a particular response option (improved cropland management??) that would look something like the below in terms of form



4. Discussion

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Decisionmakers are increasingly asking for policy options that will help them meet agreed-upon global goals like the Paris Agreement or the SDGs. Our assessment across an extended literature review has been as comprehensive as possible (forty options times 18 NCPs and 17 SDGs) and robust (literature in the thousands of documents) to provide some direction to such policymaking. Below we discuss the primary findings, limitations of the study, and some future research directions.

Our findings of co-benefits and adverse side effects should be combined with attention to how the response options deliver across objectives such as mitigation, adaptation, land degradation or food security. Smith et al. (2019), which assesses the 40 options against these specific challenges, found that nine of the options deliver medium to large benefits for all four land challenges: increased food productivity, improved cropland management, improved grazing land management, improved livestock management, agroforestry, improved forest management, increased soil organic carbon content, fire management and reduced postharvest losses. For mitigation only, five options have large potential (> 3 GtCO₂e yr⁻¹) without adverse impacts on the other land challenges: increased food productivity, reduced deforestation and degradation, increased soil organic carbon content, fire management and reduced post-harvest losses. Sixteen practices have large adaptation potential (>25 million people benefit), without adverse side-effects on other land challenges: increased food productivity, improved cropland management, agroforestry, agricultural diversification, improved forest management, increased soil organic carbon content, reduced landslides and natural hazards, restoration and reduced conversion of coastal wetlands, reduced post-harvest losses, sustainable sourcing, management of supply chains, improved food processing and retailing, improved energy use in food systems, livelihood diversification, use of local seeds, and disaster risk management.

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4.1 Co-benefits for people and nature

There are a range of potential synergies and co-benefits provided by the assessed response options. For example, there are positive co-benefits between response options and important SDGs including positive poverty reduction impacts from activities like increased food productivity and livelihood diversification. Table 9 indicates the strongest positive relationships between options and specific SDGs, providing a possible template for what the better response options for each SDG might be.

Table 9. Better response options for certain SDGs

SDGs	Better Response options
SDG 1: No poverty	Increased food productivity, increased soil
	organic carbon, livelihood diversification,
	disaster risk reduction
SDG 2: Zero Hunger	Increased food productivity, increased soil
	organic carbon, agroforestry, agricultural

	diversification, reduced soil erosion and
	salinisation, reduced post-harvest losses,
	•
	enhanced urban food systems, management
CDC 2. Co. d books and soull be in	of supply chains, disaster risk management
SDG 3: Good health and well-being	Agricultural diversification, reduced
	pollution, reduced post-harvest losses,
	management of supply chains, management
	of urban sprawl, disaster risk reduction
SDG4: Quality education	Disaster risk reduction, livelihood
	diversification, risk sharing instruments
SDG5: Gender equity	Livelihood diversification, use of local
	seeds, disaster risk management
SDG 6: Clean water and sanitation	Integrated water management, increased
	soil carbon, restoration of wetlands, dietary
	change, reduced losses and waste,
	management of urban sprawl, disaster risk
	management
SDG7: Affordable and clean energy	Afforestation, bioenergy, reduced losses and
	waste,
SDG 8: Decent work and economic growth	Reduced losses and waste, enhanced urban
	food systems
SDG9: Industry, innovation and	Sustainable sourcing
infrastructure	
SDG10: Reduced inequality	Dietary change, reduced losses,
	management of urban sprawl
SDG 11: Sustainable cities and	Reduced food waste, enhanced urban food
communities	systems, management of urban sprawl,
	disaster risk management
SDG 12: Responsible production and	Dietary change, reduced losses and waste,
consumption	enhanced urban food systems, management
•	of urban sprawl, use of local seeds
SDG 13: Climate action	Increased food productivity, integrated
	water management, reduced deforestation,
	reforestation and afforestation, increased
	soil carbon content, biochar, biodiversity
	conservation, bioenergy & BECCS, dietary
	change, reduced food waste, management of
	urban sprawl
SDG 14: Life below water	Reduced wetland conversion, biodiversity
SECTION WILL	conservation, bioenergy &BECCS
SDG 15: Life on land	Increased food productivity, improved
	cropland, grazing and livestock
	management, agroforestry, avoided
	managomoni, agrororosti j, avoidod

	grassland conversion, integrated water
	management, reduced deforestation,
	reforestation and afforestation, increased
	soil carbon, reduced soil erosion,
	salinisation and compaction, fire
	management, avoided wetland and peatland
	conversion, biodiversity conservation,
	dietary change, reduced losses and waste,
	management of urban sprawl
SDG 16: Peace and Justice, strong	Enhanced urban food systems, use of local
institutions	seeds, disaster risk reduction
SDG 17: Partnerships to achieve the goals	

Examples of positive co-benefits between response options and NCPs include positive ecosystem impacts on habitat maintenance from activities like reduced land conversion (across forests, grasslands, wetlands and peatlands) fire management. Table 10 indicates the strongest positive relationships between options and specific NCPs, providing a possible template for what the better response options for each NCP might be.

Table 10. Better response options for certain NCPs

NCPs	Better response options
NCP 1: Habitat creation and maintenance	Increased food productivity, agroforestry,
	integrated water management, improved
	forest management, reduced deforestation,
	reforestation, increased soil carbon, reduced
	soil erosion, fire management, restoration
	and avoided conversion of wetlands and
	peatlands, biodiversity conservation
NCP 2: Pollination and dispersal of seeds	Reduced deforestation, biodiversity
and other propagules	conservation
NCP 3: Regulation of air quality	Reduced soil erosion, bioenergy,
	management of urban sprawl
NCP 4: Regulation of climate	Reduced deforestation, reforestation,
	increased soil carbon, restoration of
	wetlands and peatlands, bioenergy, dietary
	change, reduced waste
NCP 5: Regulation of ocean acidification	Bioenergy & BECCS
NCP 6: Regulation of freshwater quantity,	Integrated water management, reduced
flow and timing	deforestation, increased soil carbon,
	reduced soil compaction, restoration and
	avoided conversion of wetlands and
	peatlands,

NCP 7: Regulation of freshwater and coastal water quality NCP 8: Formation, protection and decontamination of soils and sediments	Integrated water management, reduced deforestation, increased soil carbon, reduced soil erosion, salinisation and compaction, reduced pollution, restoration and avoided conversion of wetlands and peatlands, Improved cropland and grazing land management, improved forest management, increased soil carbon, reduced soil erosion,
	salinisation, and compaction, biochar, reduced landslides, , restoration and avoided conversion of wetlands and peatlands, management of urban sprawl
NCP 9: Regulation of hazards and extreme	Fire management, reduced landslides,
events	restoration and avoided conversion of
	wetlands, disaster risk reduction
NCP 10: Regulation of organisms	Improved cropland management,
detrimental to humans	agroforestry, agricultural diversification,
	increased soil carbon, use of local seeds
NCP 11: Energy	Bioenergy and BECCS,
NCP 12: Food and feed	Increased food productivity, improved cropland, grazing land and livestock
	management, agroforestry, agricultural
	diversification, integrated water
	management, increased soil carbon, dietary
	change, reduced loss and waste, enhanced
	urban food systems, use of local seeds, risk
	sharing instruments
NCP 13: Materials and assistance	Increased soil carbon, material substitution, sustainable sourcing, use of local seeds
NCP 14: Medicinal, biochemical and genetic	Increased soil carbon, biodiversity
resources	conservation, use of local seeds
NCP 15: Learning and inspiration	Use of local seeds
NCP 16: Physical and psychological	Improved forest management, Biodiversity
experiences	conservation
NCP 17: Supporting identities	Biodiversity conservation, use of local seeds
NCP 18: Maintenance of options	Biodiversity conservation, use of local seeds

The strong synergies between positive co-benefits with both NCPs and SDGs on a number of response options is an important finding that indicates there are potentially win-wins that do not require the degradation of natural capital and ecosystems to achieve poverty and

development objectives (Miteva 2019). However, all too often such options are not implemented in an integrated manner, and the synergies are not managed for explicitly, which can result in lost opportunities (IPCC 2019).

4.2 Study limitations

The literature assessed points to general directions of interactions, but much more information is needed to make more accurate assessments. For nearly all interactions, we could assess only positive or negative qualitative trends, without the possibility of quantification. Further, because many of the NCPs and SDGs trade-off within and between one another, simple additive assessments cannot fully capture the range of interactions and the context for any given options needs to be considered carefully.

Assessing the literature across the global scale has also meant that many important, context-specific interactions, e.g. by location, ecosystem type, administrative unit, cannot be accounted for, and that the literature may be skewed towards some regions more than others. Importantly, all land-based options are scale dependent, and the potential adverse side effects of practices such BECCS are reflective of large-scale implementation (such as greenhouse gas removals of >3 GtCO₂e yr⁻¹). Such adverse side effects could be at least partially ameliorated if applied on a smaller share of the land, or if integrated into sustainably managed landscapes (see Smith et al. 2019).

Further, many of the positive synergies are not automatic, and are dependent on well-implemented activities requiring institutional and enabling conditions for success (IPCC 2019).

4.3 Data gaps and future research

As tables 2-7 show, there are considerable knowledge gaps. Many response options have not been investigated for their impacts on SDGs or NCPs. There are many suggestive relationships that suggest further research. These include interactions of all the response options for their impacts on gender Given that we know that women make up much of the agricultural workforce in the world, the lack of information on how various farming response options impact on gender dynamics is problematic and troubling. Further, given how important land management is for the supply of NCPs, we would expect more research to be conducted on the full range of NCPs from different land management practices, but certain NCPs have greater limitations in the literature than others (e.g. little information on pollination, or harmful pests),

4.4 Conclusions

Many land challenges can be met with existing tools and technologies, such as changing the conversion of natural ecosystems to croplands or increasing the soil carbon content using basic technologies like cover crops and minimal tillage. Use of these response options can

result in numerous co-benefits, and with minimal side effects on SDGs and NCPs and other societal goals. Portfolios of different response options are possible and are applicable at different scales, from farm to international, and the fact that there is such a wide range of adaptation and mitigation responses that have the potential to make positive contributions to sustainable development, ecosystem services and other societal goals is good news. Overall, our assessment concludes that a number of response options can both make a dent in mitigation, adaptation, land degradation or food security and at the same time contribute to eradicating poverty and eliminating hunger, promoting good health and wellbeing, clean water and sanitation, and other positive benefits. However, care must be taken to acknowledge and manage any potential trade-offs, as well as encourage synergies and cobenefits. Land management-based options that require land use change can particularly adversely affect efforts to eradicate poverty and eliminate hunger (Molotoks et al., 2018); such trade-offs were identified with afforestation, BECCS and some risk sharing instruments (particularly commercial crop insurance). Ensuring that policymakers can anticipate these adverse side-effects in advance, and potentially choose the most appropriate response options for their particular contexts and challenges, will require more assessments such as these, and increased attention to these interactions in the overall literature.

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Supplementary Online Material for "The impact of interventions in the global land and agri-food sectors on Nature's Contributions to People and the UN Sustainable Development Goals"

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Table S1 Literature on Impacts on Nature's Contributions to People of integrated response options based on land management

Integrate d response options			Pollination				Regulation of		Formation,						Medicinal		Physical and		
based on land		Habitat	and dispersal of seeds and			Regulation	freshwater quantity,	Regulation of freshwater and	protection and decontaminatio	Regulation of hazards and	Regulation of organisms			Materi als and	biochemi cal and	Learning	psycholo gical		
manage		creation and	other	Regulation of	Regulation	of ocean	flow and	coastal water	n of soils and	extreme	detrimental to		Food and	assista	genetic	and	experien	Supporting	Maintenance
ment		maintenance	propagules	air quality	of climate	acidification Increased	timing Food	quality	sediments	events	humans	Energy	feed	nce	resources	inspiration	ces	identities	of options
			Likely may reduce native pollinators if			food productivity might be achieved through	productivity increases could impact water quality if increases in	Food	Intensification										
		Higher productivity spares land (e.g. Balmford et al. 2018)	reliant on increased chemical inputs (Potts et al. 2010) but not if			pesticide or fertiliser use, which causes runoff and	chemicals used, but evidence is mixed on sustainable intensification	productivity increases could impact water flow due to demand for irrigation	through additional input of nitrogen fertiliser can result in negative impacts on		Increasing food production through agro- chemicals may		Sustainable intensification						
		especially if intensification	through sustainable			dead zones in oceans	(Rockström et al. 2009;	(Rockström et al. 2009;	climate, soil, water and air		increase pest resistance over		has potential to close yield						
	Increased food productivity	is done sustainably.	intensification	N/A	N/A	(Beusen et al. 2016).	Mueller et al. 2012).	Mueller et al. 2012).	pollution (Tilman et al. 2002).	N/A	time (Tilman et al. 2002).	N/A	gaps (Tilman et al. 2011).	N/A	N/A	N/A	N/A	N/A	N/A
	Improved	Improved cropland management can contribute to diverse agroecosystems (Tscharntke et al. 2005) and promotes soil biodiversity	Better crop management can contribute to maintaining native pollinators		See main text	Mitigation potential (see main text) will	Cropland conversion has major impacts on water quantity (Scanlon et al. 2007). Cropland management practices such as conservation tillage improve downstream water quality	Cropland conversion leads to poorer water quality due to	Improved cropland management has positive impacts on soils (see		Some forms of improved cropland management can decrease pathogens and pests		Conservation agriculture contributes to food productivity and reduces food insecurity (Rosegrant and Cline 2003; Dar & Gowda 2011;					Many cropping systems have cultural components	
	cropland	(Oehl et al.	(Gardiner et	N7/A	for mitigation	reduce ocean	(Fawcett et al.	runoff (Scanlon	main text) (Kern	NI/A	(Tscharntke et	N/ A	Godfrey &	NT/A	NT/A	NI/A	NI/A	(Tenberg et al	27/4
	Improved	Can contribute to improved habitat (Pons et al. 2003;	al. 2009).	N/A	potentials See main text	Mitigation potential (see main text) will	Likely will improve water quality	et al. 2007). Likely will improve water	Improved grassland management increases soil carbon and	N/A	al. 2016).	N.A	Improved grassland management could contribute to	N/A Grassla nd manage ment can provide other material s (e.g. biofuel material s) (Prochn ow et	N/A	N/A	N/A	Many pastoralists have close cultural connections to	N/A
Agricult ure	grazing land management	Plantureux et al 2005).	N/A	N/A	for mitigation potentials	reduce ocean acidification.	(Hibbert 1983).	flow (Hibbert 1983)	quality (Conant et al. 2001).	N/A	N/A	N/A	food security (O'Mara 2012)	al. 2009)	N/A	N/A	N/A	livestock (Ainslie 2013)	N/A
ure	management	2005).	IN/A	IN/A	potentiais	асіппсаноп.	1983).	1983)	et al. 2001).	iN/A	IN/A	IN/A	(O Mara 2012)	2009)	IN/A	iN/A	IN/A	(Ainsile 2013)	IN/A

	to h e a	Can contribute to improved habitat if more efficient animals used, leading to less				Mitigation potential (see main		Improved industrial livestock production can reduce water contamination (e.g. reduced effluents) (Hooda et al 2000). Improved livestock management can contribute to better water quality such as through manure					Improved livestock management can contribute to reduced food insecurity among smallholder	Livesto ck product ion also produce s material s for use (leather				Many pastoralists have close cultural	
Improved		feed required			See main text	text) will		management					pastoralists	, etc)				connections to	
livestock managem		(Strassburg et al. 2014)	N/A	N/A	for mitigation potentials	reduce ocean acidification.	N/A	(Herrero & Thornton 2013)	N/A	N/A	N/A	N/A	(van't Hooft et al. 2012).	(Hesse 2006)	N/A	N/A	N/A	livestock (Ainslie 2013)	N/A
Agro-fore	n d c h	Agroforestry mimics natural diversity and can improve habitat (Jose 2009).	Even intensive agroforestry can be beneficial for pollinators (Klein et al 2002).	Trees in the landscape can remove air pollutants (Sutton et al., 2007)	See main text for mitigation potentials	Mitigation potential (see main text) will reduce ocean acidification.	Planting trees on farms can increase soil water infiltration capacity (Ilsted et al. 2007). Agroforestry can be used to increase ecosystem services benefits, such as water quantity and quality (Jose 2009)	N/A	Likely to improve soil (Rao et al. 1997)	Agroforestry can reduce vulnerability to hazards like wind and drought (Thorlakson & Neufeldt 2012).	Landscape diversity generally improves opportunities for biological pest control (Gardiner et al. 2009); reduces pests/pathogens on smallholder farms (Vignola et al., 2015)	Agroforest ry can be used to produce biomass for energy (Mbow et al., 2014).	Agroforestry contributes to food productivity and reduces food insecurity (Mbow et al. 2014).	Produce s timber, firewoo d and animal fodder (Mbow et al., 2014)	Can provide medicinal and other resources (Rao et al., 2004).	N/A	N/A	Many cropping systems have cultural components (Rao et al., 2014)	Can contribute to maintaining diversity through native plantings (Rao et al., 2014).
Agricultu diversific	d ii n ti e d n n n a a fi	Crop diversification improves resilience through enhanced diversity to mimic more natural systems and provide in- field habitat for natural pest defences (Lin 2011)	Diversificatio n can enhance pollinator diversity (Altieri & Letrouneau 1982; Sardinas & Kremen 2015)	N/A	N/A	N.A	N/A	N/A	Diversification can introduce some crops that may have positive soil qualities (eg nitrogen fixation) and crop rotation with multiple crops can improve soil carbon (McDaniel et al. 2014).	N/A	Diverse agroecosystems tend to have less detrimental impacts from pests (Gardiner et al 2009; Altieri & Letourneau 1982)	N/A	Diversificatio n is associated with increased access to income and additional food sources for the farming household (Pretty et al. 2003; Ebert 2014)	ication could provide addition al material s and farm benefits (Van Huylen broeck et al. 007)	Some agricultur al diversifica tion can produce medicinal plants (Chauhan 2010).	N/A	N/A	Many cropping systems have cultural components (Rao et al., 2014)	Can contribute to maintaining diversity through native plantings (Sardiñas et al. 2015)
Avoidanc conversio grassland cropland	on of C	Can preserve natural habitat (Peeters, 2009)	N/A	N/A	See main text for mitigation potentials	Mitigation potential (see main text) will reduce ocean acidification.	Will likely improve water quality (inferred from improved soil quality in Saziozzi et al., 2001)	Will likely improve water flow (inferred from improved soil quality in Saziozzi et al., 2001)	Will improve soil quality (Saziozzi et al., 2001)	N/A	Diverse agroecosystems tend to have less detrimental impacts from pests (Gardiner et al 2009; Altieri & Letourneau 1982)	N/A	Reducing cropland conversion can reduce food production (West et al. 2010).	N/A	N/A	N/A	N/A	N/A	Retaining natural ecosystems can preserve genetic diversity (Ekins et al., 2003).

												IWM				1
												support	1			ł
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	(Nicole Bernex	Some	1333.4	favourable		trading and	Watering		reducing		resources	flow of				ł
	2016),	integrated	IWM	forests		pricing (ADB	shifting sand		evaporation		enforcement	water in	1			ł
	improving	water	practices	conditions		2016), water	dunes		losses are		(based water	watersh	1			ł
	correlation	management	exert strong	thereby		smart	(sprinkler),		significantly		resources,	eds	1			ł
	between	strategies	influence on	influencing		appliance,	water resources		contributed to		water	(Eisenb				ł
	amount of	generate	ecosystem	the storage		water smart	conservation		response		conservation	ies et	1			ł
	water resources	synergies	structure and	and flow of		landscapes	(Nejad 2013;	BVD (climate		measures,	al.				ł
	and supply	between	function, with	water in		(Dawadi and	Pereira 2002a),	IWM provide co-	change and		water	2007)	1			ł
	ecosystem	multiple	potentially	watersheds		Ahmad 2013),	enhancing	benefits such as	reduced	IWM can	allocations)	can	1			ł
	services,	ecosystem	large	(Eisenbies et		common and	rainwater	healthier soils,	impacts of	support the	(Ward et al.	restrict				ł
	combining	services, such	implications	al. 2007)		unconvention	management,	more resilient	extreme	production	2008) are	the				ł
	water resources	as pollination,	for regulating	which are		al water	reducing	and productive	weather event	of biomass	good options	access	1			ł
	management	yield and	air quality	important for		sources in use	recharge and	ecosystems	in	for energy	to response	to				ł
	and supply of	farm	(Xia et al.,	regulating		(Rengasamy	increasing water	(Grey and Sadoff	desertification	and	climate	resourc	1			ł
Integrated	ecosystem	profitability	2017;	microclimates		2006) will	use in discharge	2007; Liu et al.	areas (Dillon	firewood	change and	es (e.g.	1		1	ł
water	services (Liu et	(Hipólito et.	Hardiman et	(Pierzynski et		increase water	areas (DERM	2017; Scott et al.	and Arshad	(Mbow et	nature's	firewoo	1			ł
management	al. 2016).	al, 2018).	al, 2019).	al., 2017).	N/A	quantity.	2011).	2011)	2016b).	al., 2014).	prevention.	d).		1		ı

										т =		,							
										Forest cover			The proximity						
										can stabilise			of forest to						
										land against			cropland						
										catastrophic			constitutes a						
										movements			threat to				Forest		
		Forest								associated			livelihoods in				landscap		
		landscape								with wave			terms of crop				e		
		restoration								action and			raiding by				restoratio		
		specifically								intense run-			wild animals				n		
		aims to regain								off during			and in				specifical		
		ecological								storms and			constraints in				ly aims		
		integrity and								flood events			availability of				to		
		enhance human		Trees remove						(Locatelli et			land for				enhance		
		well-being in		air pollution						al. 2015a).			farming (Few				human		
		deforested or		by the						Reducing			et al. 2017),.				well-		
		degraded forest		interception						harvesting			The				being		
		landscape		of particulate						rates and			competition		1	1	(Maginni	1	
		(Maginnis and		matter on						prolonging			for land				s and		1
		Jackson 2007;		plant surfaces						rotation			between	Forests	1	1	Jackson	1	
		Stanturf et al.		and the						periods may			afforestation/r	provide			2007;		1
		2014). For		absorption of						induce an			eforestation	wood			Stanturf		
		example,		gaseous			Forest cover			increased			and	and			et al.		
		facilitating tree		pollutants			can stabilise			vulnerability			agricultural	fodder			2014).		
		species mixture		through the			intense run-			of stands to			production is	and			Afforesta		
		means storing		leaf stomata.			off during			external			a potentially	other			tion/refor		
		at least as		Computer			storms and			disturbances			large adverse	material			estation		
		much carbon as		simulations			flood events			and			side-effect	s			and		
		monocultures		with local			(Locatelli et			catastrophic			(Boysen et al.	(Locate			avoided		
		while		environmental			al. 2015a)	Forests tend to		events			2017a,b;	lli et al.			deforesta		
		enhancing		data reveal			.Mangroves	maintain water		(Yousefpour			Kreidenweis	2015a).			tion		
		biodiversity		that trees and			can protect	quality by		et al. 2018).			et al. 2016;	Howev			benefit		
		(Hulvey et al.		forests in the			coastal zones	reducing runoff		Forest			Smith et al.	er,			biodivers		
		2013).		conterminous			from extreme	and trapping		management			2013). An	conserv			ity and		
		Selective		United States			events	sediments and		strategies may			increase in	ation			species		
		logging		removed 17.4			(hurricanes)	nutrients (Idris		decrease			global forest	restricti			richness,		
		techniques are		million tonnes			or sea level	Medugu et al.		stand-level			area can lead	ons to	1	1	and	1	
		"middle way"		(t) of air			rise. However,	2010a; Salvati et	Forests	structural			to increases in	preserv			generally		
		between		pollution in			forests also	al. 2014).	counteract wind-	complexity	Forests can		food prices	e			improve		1
		deforestation		2010 (range:			can have	Precipitation	driven	and may	contribute to		through	ecosyst			the		1
		and total		9.0-23.2			adverse side-	filtered through	degradation of	make forest	weed and pest		increasing	em	1	1	cultural	1	
		protection,		million t),			effects for	forested	soils, and	ecosystems	control and		land	integrit			and		
		allowing to		with human			reduction of	catchments	contribute to soil	more	landscape	SFM may	competition	y can			recreatio		
		retain		health effects			water yield	delivers purified	erosion	susceptive to	diversity	increase	(Calvin et al.	restrict	1	1	nal value	Many forest	
		substantial		valued at 6.8			and water	ground and	protection and	natural	generally	availability	2014;	the		Natural	of	landscapes	Retaining
		levels of	Likely	billion U.S.		Mitigation	availability	surface water	soil fertility	disasters like	improves	of biomass	Kreidenweis	access		ecosystems	ecosyste	have cultural	natural
		biodiversity,	contributes to	dollars		potential	for human	(co-benefits)	enhancement for	wind throws,	opportunities	for energy	et al. 2016;	to	Can	often	ms (co-	ecosystems	ecosystems can
	Forest	carbon, and	native	(range: \$1.5-		(see main	consumption	(Calder 2005;	agricultural	fires, and	for biological	(Kraxner	Reilly et al.	resourc	provide	inspire	benefits)	services	preserve
	management	timber stocks	pollinators	13.0 billion)	See main text	text) will	(Bryan and	Ellison et al.	resilience	diseases	pest control	et al 2003;	2012; Smith et	es (e.g.	medicinal	learning	(Knoke	components	genetic
	and forest	(Putz et al.	(Kremen et al.	(Novak et al.,	for mitigation	reduce ocean	Crossman	2017; Neary et	(Locatelli et al.	(Seidl et al.	(Gardiner et al.	Sikkema et	al. 2013; Wise	firewoo	and other	(Turtle et	et al.	(Plieninger et	diversity (Ekins
Forests	restoration	2012),	2007)	2014)	potentials	acidification.	2013).	al. 2009).	2015a).	2014).	2009)	al 2014)	et al. 2009).	d).	resources.	al., 2015)	2014).	al. 2015)	et al., 2003).
											•		•			•			

													The proximity						
													of forest to						
													cropland						
													constitutes a						
													threat to						
													livelihoods in						
													terms of crop						
													raiding by						
													wild animals						
													(Few et al.						
								Due to					2017),. The						
								evapotranspirati					competition						
								on, trees					for land						
								recharge					between						
								atmospheric					afforestation/r						
								moisture,					eforestation						
								contributing to					and						
								rainfall locally					agricultural						
								and in distant					production is						
					1			location, and	İ	1			a potentially				1		
					1			trees' microbial	1	1			large adverse				1		
					1			flora and	1	1			side-effect				1		
					1			biogenic volatile	1	1			(Boysen et al.				1		
					1			organic	1	1			2017a,b;				1		
					1			compounds can	1	1			Kreidenweis				1		
								directly promote	Forests	Forest cover			et al. 2016;						
		Reduced						rainfall (Ameth	counteract wind-	can stabilise			Smith et al.						
		deforestation					Forests tend	et al. 2010).	driven	land against			2013) that can						
		can enhance					to maintain	Trees enhance	degradation of	catastrophic			lead to						
		connectivity					water quality	soil infiltration	soils, and	movements			increases in		Reduced		Forest		
		between forest					by reducing	and, under	contribute to soil	associated	Landscape	Reduced	food prices		deforestati		ecosyste		
		areas and					runoff and	suitable	erosion	with wave	diversity	deforestati	(Calvin et al.	Could	on can		ms often	Many forest	
		conserve					trapping	conditions,	protection and	action and	generally	on may	2014;	increase	protect	Natural	support	landscapes	Retaining
		biodiversity	Likely	Trees can		Mitigation	sediments and	improve	soil fertility	intense run-	improves	increase	Kreidenweis	availabi	forest	ecosystems	recreatio	have cultural	natural
		hotspots	contributes to	improve air		potential	nutrients	groundwater	enhancement for	off during	opportunities	availability	et al. 2016;	lity of	medicinal	often	nal	ecosystems	ecosystems can
	Reduced	(Ellison et al.	native	pollution		(see main	(Idris Medugu	recharge (Calder	agricultural	storms and	for biological	of some	Reilly et al.	biomass	plants	inspire	opportun	services	preserve
	deforestation	(Ellison et al. 2017; Locatelli	native pollinators	pollution problems	See main text	(see main text) will	(Idris Medugu et al. 2010a;	recharge (Calder 2005; Ellison et	agricultural resilience	storms and flood events	for biological pest control	of some wood for	Reilly et al. 2012; Smith et	biomass (Grisco	plants (Arnold &	inspire learning	opportun ities	services components	preserve genetic
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise	biomass (Grisco m et al.,	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a)	native pollinators	pollution problems		(see main text) will	(Idris Medugu et al. 2010a;	recharge (Calder 2005; Ellison et	agricultural resilience	storms and flood events	for biological pest control	of some wood for	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009).	biomass (Grisco m et al., 2017)	plants (Arnold &	inspire learning	opportun ities	services components	preserve genetic
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity	biomass (Grisco m et al., 2017) Forests	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to	biomass (Grisco m et al., 2017) Forests provide	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a)	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland	biomass (Grisco m et al., 2017) Forests provide wood	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a)	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a	biomass (Grisco m et al., 2017) Forests provide wood and	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to	biomass (Grisco m et al., 2017) Forests provide wood and fodder	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in	biomass (Grisco m et al., 2017) Forests provide wood and fodder and	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary et al. 2009).	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary et al. 2009).	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary et al. 2009).	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material s	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in deforested or	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary et al. 2009). Particular activities associated with	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated with wave	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals and in	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material s (Locate	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in deforested or degraded forest	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	Particular activities associated with forest landscape	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated with wave action and	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals and in constraints in	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material s (Locate lli et al.	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscape	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	recharge (Calder 2005; Ellison et al. 2017; Neary et al. 2009). Particular activities associated with forest landscape restoration, such	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated with wave action and intense run-	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals and in availability of	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material s (Locate lli et al., 2015a).	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle 1997)	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscape (Maginnis and	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	Particular activities associated with forest landscape restoration, such as mixed	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated with wave action and intense run-off during	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals and in constraints in availability of land for	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material s (Locate Ili et al., 2015a). Howey	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle 1997)	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscape (Maginnis and Jackson 2007;	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	Particular activities associated with forest landscape restoration, such as mixed planting,	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated with wave action and intense run-off during storms and	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals and in availability of land for farming (Few	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material s (Locate lli et al. 2015a). Howev er,	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle 1997) Afforesta tion/refor	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscape (Maginnis and Jackson 2007; Stanturf et al.	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvati et al.	Particular activities associated with forest landscape restoration, such as mixed planting, assisted natural	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated with wave action and intense runoff during storms and flood events	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals and in constraints in availability of land for farming (Few et al. 2017).	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material s (Locate lli et al. 2015a). Howev er, conserv	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle 1997) Afforesta tion/refor estation	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscape (Maginnis and Jackson 2007; Stanturf et al. 2014). Adverse	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvari et al. 2014).	Particular activities associated with forest landscape restoration, such as mixed planning, assisted natural regeneration,	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated with wave action and intense run-off during storms and flood events (Locatelli et clocatelli et	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals and in constraints in availability of land for farming (Few et al. 2017). The	biomass (Grisco m et al., 2017) Forests provide wood and fodder and other material s (Locate Ili et al. 2015a). Howev er, conserv ation	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle 1997) Afforesta tion/refor estation can	services components (Plieninger et	preserve genetic diversity (Ekins
	deforestation and	(Ellison et al. 2017; Locatelli et al. 2011,a 2015a) Forest landscape restoration specifically aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscape (Maginnis and Jackson 2007; Stanturf et al. 2014). Adverse side-effects	native pollinators (Kremen et al.	pollution problems (Novak et al.,	for mitigation	(see main text) will reduce ocean	(Idris Medugu et al. 2010a; Salvari et al. 2014).	Particular activities associated with forest landscape restoration, such as mixed planting, assisted natural regeneration, and reducing and reducing	agricultural resilience (Locatelli et al.	storms and flood events (Locatelli et al. 2015a) Forest cover can stabilise land against catastrophic movements associated with wave action and intense run-off during storms and flood events (Locatelli et al. 2015a)	for biological pest control (Gardiner et al.	of some wood for energy and	Reilly et al. 2012; Smith et al. 2013; Smith et al. 2013; Wise et al. 2009). The proximity of forest to cropland constitutes a threat to livelihoods in terms of crop raiding by wild animals and in constraints in availability of land for farming (Few et al. 2017). The	biomass (Grisco m et al., 2017) Forests provide wood and other material s (Locate Ili et al. 2015a). Howev er, conserv ation	plants (Arnold & Perez	inspire learning (Turtle et	opportun ities (Liddle 1997) Afforesta tion/refor estation can increase	services components (Plieninger et	preserve genetic diversity (Ekins
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		species											2017a,b;	resourc					
		(Brundu and											Kreidenweis	es (e.g.					
		Richardson											et al. 2016;	firewoo					
		2016; Ellison et											Smith et al.	d).					
		al. 2017).											2013). An						
		= 0.1.):											increase in						
													global forest						
													area can lead						
													to increases in						
													food prices						
													through						
													increasing						
													land						
													competition						
													(Calvin et al.						
													2014;						
													Kreidenweis						
													et al. 2016;						
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1					1	ĺ							2012; Smith et	l		ĺ			
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			-	 	 	 		Afforestation		-		1			 	 	1	t	
				I		1		using some				1	1	l	I	1		1	
				I		1		exotic species				1	1	l	I	1		1	
					1			can upset the					Future needs		ĺ				
								balance of					for food						
								evapotranspirati					production are						
								on regimes, with					a constraint						
		Francis																	
		Forest						negative impacts					for large-scale						
		landscape						on water					afforestation						
		restoration						availability					plans						
		specifically						particularly in					(Locatelli et						
		aims to regain						arid regions	Afforestation and				al. 2015a).						
		ecological						(Ellison et al.	reforestation				Global food						
		integrity and						2017; Locatelli	options are				crop demand						
		enhance human						et al. 2015a;	frequently used				is expected by						
		well-being in						Trabucco et al.	to counteract				50%-97%						
		deforested or						2008).	land degradation				between 2005						
		degraded forest						Afforestation in	problems				and 2050						
		landscape						arid and	(Yirdaw et al.				(Valin et al.						
		(Maginnis and						semiarid regions	2017). whereas				2014). Future						
		Jackson 2007;			1			using species	when they are				carbon prices		ĺ				
		Stanturf et al.			1			that have	established on				will facilitate		ĺ				
		2014). In the		I		1		evapotranspirati	degraded lands			1	deployment of	l	I	1		1	
		case of			1			on rates	they are				afforestation		ĺ				
		afforestation,		I		1		exceeding the	instrumental to			1	projects at	l	I	1		1	
		simply			1		Depends on	regional	preserve natural				expenses of		ĺ				
		changing the			1		where	precipitation	forests (co-				food		ĺ				
		use of land to			1		reforesting	may aggravate	benefit)				availability		ĺ				
		planted forests			1		and with what	the groundwater	(Buongiorno and				(adverse side-		ĺ				
		is not sufficient					species (Scott	decline	Zhu 2014).				effect), but		ĺ				
		to increase					et al. 2005).	(Locatelli et al.	Afforestation	Some			more		ĺ				
		abundance of		I		1	Trees enhance	2015a; Lu et al.	runs the risk of	afforestation		1	liberalised	l	I	1		1	
		indigenous		1			soil	2015a; Lu et al. 2016). Changes	decreasing soil	may make			trade in		1	1			
		species, as they					infiltration	in runoff affect	nutrients,	forest			agricultural		ĺ		Green		
		depend on type					and, under	water supply but	especially in	ecosystems		Afforestati	commodities		ĺ		spaces		
		of vegetation,		I		1	suitable	can also	intensively	more		on may	commodities could buffer	l	I	1	spaces	Afforestation/	
		scale of the					conditions,	can also contribute to				increase	food price	Could	ĺ			reforestation	
		land transition,		1					managed	susceptive to natural		availability	increases	increase	1	1	psycholo gical	can increase	
		and transition,				Mitigation	improve groundwater	changes in flood risks, and	plantations; in	disasters like		of biomass	following	availabi	ĺ		wellbein	areas available	
						potential			one study, afforestation sites	wind throws,			afforestation		ĺ			for recreation	
		required for a		I			recharge	irrigation of				for energy		lity of	I	1	g (Caldwal		
		population to			Can main to	(see main	(Calder 2005;	forest	had lower soil P	fires, and		use (Observatories	in tropical	biomass	ĺ		(Coldwel	and tourism	
		establish		1	See main text	text) will	Ellison et al.	plantations can	and N content	diseases		(Oberstein	regions	(Grisco	1	1	1 &	opportunities	
		(Barry et al.	l	37/4	for mitigation	reduce ocean	2017; Neary	increase water	(Berthrong et al	(Seidl et al.	27/4	er et al	(Kreidenweis	m et al.,			Evans,	(Knoke et al.	27/4
	Afforestation	2014).	N/a	N/A	potentials	acidification.	et al. 2009).	consumption	2009).	2014).	N/A	2006)	et al. 2016).	2017)	N/A	N/A	2018)	2014).	N/A

								(Sterling et al. 2013).											
Soils	Increased soil organic carbon content	Improving soil carbon can increase overall resilience of landscapes (Tschamtke et al. 2005)	N/A	N/A	See main text for mitigation potentials	Rivers transport dissolved organic matter to oceans (Hedges et al 1997), but unclear if improved SOM will decrease this and by how much.	Soil organic matter is known to increase water filtration and can regulate downstream flows (Keesstra et al., 2016)	Soil organic matter is known to increase water filtration and protects water quality (Lehmann & Kleber 2015)	Increasing SOM contributes to healthy soils (Lehmann & Kleber 2015)	N/A	Increased SOM decreases pathogens in soil (Lehmann & Kleber 2015)	N/A	Lal 2006 notes that "Food-grain production in developing countries can be increased by 24-39 (32+-11) million Mgy-1 through improving soil quality by increasing the SOC pool and reversing degradation processes".	In terms of raw material s, numero us product s (e.g. pharma ceutical s, clay for bricks and ceramic s, silicon from sand used in electron ics, and other mineral	In terms of raw materials, numerous products (e.g. pharmace uticals, clay for bricks and ceramics, silicon from sand used in electronic s, and other minerals; SSSA, 2015) are provided provided by soils.	N/A	N/A	N/A	N/A

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													s; SSSA, 2015) are provide d by soils.					
Reduced soil erosion	Managing soil erosion decreases need for expanded cropland into habitats (Pimental et al 1995)	N/A	Particulate matter pollution, a main pollution, a main consequence of wind erosion, imposes severe adverse impacts on materials, structures and climate which directly affect the sustainability of urban cities (Al-Thani et al. 2018)	N/A	N//A	Managing soil erosion improves water quality (Pimental et al 1995)	Managing soil erosion improves water flow (Pimental et al 1995)	Will improve soil quality (Keesstra et al., 2016)	Reducing soil erosion reduces vulnerability to hazards like wind storms in dryland areas and landslides in mountainous areas (El- Swify 1997)	N/A	N/A	Managing erosion can lead to increased food production on croplands; however, other forms of management (revegetation, zero tillage) might reduce land available for food.	N/A	N/A	N/A/	N/A	N/A	N/A
Reduced soil salinisation	Salinisation decreases soil microbial diversity (Nie et al. 2009)	N/A	N/A	N/A	N/A	N/A	Management of soil salinity improves water quality (Kotb et al. 2000; Zalidis et al 2002; Soane & Ouwerkerk 1995)	Will improve soil quality (Keesstra et al., 2016)	N/A	N/A	N/A	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw & Holden 1999).	N/A	N/A	N/A/	N/A	N/A	N/A
Reduced soil compaction	Preventing compaction can reduce need to expand croplands (Lal, 2001).	N/A	N/A	N/A	N/A	Compaction can increase water runoff (Soane & Ouwerkerk 1995). Management of soil compaction improves water quality and quantity (Soane & van Ouwerkerk 1995; Zalidist et al 2002)	Management of soil compaction improves water quality and quantity (Soane & van Ouwerkerk 1995; Zalidis et al 2002)	Will improve soil quality (Keesstra et al., 2016)	Compaction in soils increases rates of runoff and contribute to floods (Hümann et al 2011)	N/A	N/A	Compactions reduces agricultural productivity and thus contributes to food insecurity (Nawaz et al 2013)	N/A	N/A	N/A	N/A	N/A	N/A
Biochar addition to soil	N/A	N/A	N/A	See main text for mitigation potentials	Mitigation potential (see main text) will reduce ocean acidification.	Biochar improves soil water filtration and retention (Spokas et al 2011; Beck et al. 2011)	Biochar improves soil water filtration and retention (Spokas et al 2011; Beck et al. 2011)	Can improve soil quality (Sohi, 2012)	N/A	N/A	N/A	Contributes to increased food production (Smith 2016; Jefferry et al., 2017)	N/A	N/A	N/A	N/A	N/A	N/A

	Fire management	Proactive fire management can improve natural habitat (Burrows 2008).	Reducing fire risk can improve habitat for pollinators (Brown et al. 2017)	Fire management improves air quality particularly in the periurban interface (Bowman et al. 2005)	See main text for mitigation potentials	Mitigation potential (see main text) will reduce ocean acidification.	Fires affect water quality and flow due to erosion exposure (Townsend & Douglas 2000).	Fires affect water quality and flow due to crosion exposure (Townsend & Douglas 2000).	Fire cause damage to soils, therefore fire management can improve them (Certini 2005)	Will reduce risk of wildfires as a hazard (McCaffrey 2002)	Landscape diversity generally improves opportunities for biological pest control (Gardiner et al. 2009)	Will increase availability of biomass, as fuel removal is a key manageme nt strategy (Becker et al. 2009)	N/A Landslides are	N/A	N/A	N/A	Reduced wildlife risk will increase recreatio n opportun ities in landscap es (Venn & Calkin 2011).	N/A	Retaining natural ecosystems can preserve genetic diversity (Ekins et al., 2003).
	Reduced landslides and natural hazards	Can preserve natural habitat (Dolidon et al. 2009)	N/A	N/A	N/A	N/A	Likely will improve water quality (Dolidon et al. 2009)	Likely will improve water flow (Dolidon et al. 2009)	Will improve soil quality (Keesstra et al., 2016)	Will reduce risk of disasters (Dolidon et al. 2009; Kausky 2010)	N/A	N/A	Landslides are one of the natural disasters that have impacts on food security (de Haen & Hemrich 2007)	N/A	N/A	N/A	N/A	N/A	N/A
	Reduced pollution including acidification	Air pollution like acid rain has major impacts on habitats like lakes (Schindler et al 1989)	Pollution interferes with scents, which impact pollinators ability to detect resources (McFredrick et al 2008)	Will improve air quality with public health benefits (Nemet et al. 2010)	See main text for mitigation potentials	N/A	N/A	Pollution increases acidity of surface water, with likely ecological effects (Larssen et al 1999)	Soil acidification due to air pollution in a serious problem in many countries (Zhou et al. 2013)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other ecosyste ms	Management of invasive species / encroachment	Improved management of IAS can lead to improved habitat and ecosystems (Richardson & van Wilgen 2004).	Invasive species can disrupt native plant- pollinator relations (Ghazoul 2006)	N/A	N.A	N/A	Many invasives can reduce water flow (Richardson & Van Wilgen 2004).	Invasive species can reduce water quality (Burnett et al. 2007; Chamier et al. 2012)	Likely to improve soil as invasive species generally have negative effects (Ehrenfeld & Scott 2001).	N/A	Many IAS are harmful pests (Charles & Dukes 2008).	N/A	IAS can compete with crops and reduce crop yields by billions of dollars annually (Pejchar & Mooney 2009)	Many invasiv es are importa nt supplier s of material s (Pejcha r & Moone y 2009).	N/A	N/A	N/A	N/A	Reducing invasives can increase biological diversity of native organisms (Simberloff 2005)

			1	1		1			1	1			1					
						The creation												
						or restoration			The creation									
						of wetlands,			or restoration									
						tidal marshes,			of wetlands,			Mixed						
						or mangroves			tidal marshes,			evidence: can						
						provide water			or mangroves			affect						
						retention and			provide water			agriculture/fis						
						protect coastal			retention and			heries						
						cities from			protect			production						
						storm surge			coastal cities			when				Natural		
						flooding and			from storm			competition				environm		
						shoreline			surge	l		for land				ents		
						erosion during			flooding and	Landscape		occurs, or				support		
						storms. Wetlands			shoreline erosion	diversity		could increase food	Could increase		Natural	psycholo	Natural	Retaining
					Mitigation				during storms	generally		production	availabi	Wetlands		gical wellbein	environments	natural
Restoration		Will promote			potential	store freshwater	Wetlands store		(Haddad et	improves opportunities		when	lity of	can be	ecosystems often		support	ecosystems can
and avoided	Will preserve	natural			(see main	and enhance	freshwater and		al., 2015;	for biological		ecosystems	biomass	sources of	inspire	g (Coldwel	psychological	preserve
conversion of	natural habitat	pollinators		See main text	text) will	water quality	enhance water	Will improve soil	Gittman et al.	pest control		are restored	(Grisco	medicines	learning	1 &	wellbeing	genetic
coastal	(Griscom et al.,	(Seddon et		for mitigation	reduce ocean	(Bobbink et al	quality (Bobbink	quality (Griscom	2014; Kaplan	(Gardiner et al.		(Crooks et al	m et al.,	(UNEP,	(Turtle et	Evans,	(Coldwell &	diversity (Ekins
wetlands	2017)	al., 2016)	N/A	potentials	acidification.	2006)	et al 2006)	et al., 2017)	et al. 2009).	2009)	N/A	2011)	2017)	2016)	al., 2015)	2018)	Evans, 2018)	et al., 2003).
	,			1		,	,	, ,		,			Will	,	,	,	,	,
													reduce					
													supply					
													of some					
													material					
													S			Natural		
						Peatland					Will		sourced			environm		
						restoration					reduce		from			ents		
						will improve	Peatland			Landscape	supply of		peatlan			support		
						water quality	restoration will			diversity	any	May reduce	ds (e.g			psycholo		
						as they play	improve water			generally	biomass or	land available	palm	Natural	Natural	gical	Natural	Retaining
		Could			Mitigation	important	quality as they			improves	energy	for	oil,	ecosystem	ecosystems	wellbein	environments	natural
		promote			potential	roles in water	play important			opportunities	sourced	smallholders	timber)	s are often	often	g	support	ecosystems can
Restoration	Will preserve	natural		l	(see main	retention and	roles in water			for biological	from	in tropical	(Murdi	source of	inspire	(Coldwel	psychological	preserve
and avoided	natural habitat	pollinators		See main text	text) will	drainage	retention and	Will improve soil		pest control	peatlands	peatlands	yarso et	medicines	learning	1 &	wellbeing	genetic
conversion of	(Griscom et al.,	(Seddon et		for mitigation	reduce ocean	(Johnston	drainage	quality (Griscom		(Gardiner et al.	(Pin Koh	(Jewitt et al	al.	(UNEP,	(Turtle et	Evans,	(Coldwell &	diversity (Ekins
peatlands	2017)	al., 2016)	N/A	potentials	acidification.	1991).	(Johnston 1991).	et al., 2017)	N/A	2009)	2007)	2014)	2010)	2016)	al., 2015)	2018)	Evans, 2018)	et al., 2003).

			Reduced or													
			absent													
			populations of													
			seed-													
			dispersing													
			animals result													
			in poor to no													
			dispersal,espe													
			cially of													
			large-seeded													
			trees that													
			depend on													
			large animals													
			such as													
			elephants													
			(Anzures-													
			Dadda et													
			al.2011;													
1			Brodie and	Ì							1		I	1		1
			Aslan2012;										1			1
			Beaune et al.2013;						Management of				1			1
			ai.2013; Brockerhoff						wild animals and							1
1			et al. 2017).	Ì					protected habitats		1		I	1		1
			Animal						can influence soil							
			pollination,						conditions via							
			which is						changes in fire							
			fundamental						frequency (as							
			to the						grazers lower							
			reproduction						grass and							
			and						vegetation							
			persistence of						densities as							
			most						potential fuels)							
			flowering						and nutrient							
			plants, is an						cycling and						indigeno	
			important						transport (by						us	
			ecosystem						adding nutrients						peoples	
			service						to soils).						commonl	
			(Millennium						Conserving and						y link	
			Ecosystem						restoring						forest	
			Assessment						megafauna in						landscap	
			2005). As						northern regions						es and	
			biodiversity						also prevents						biodivers	1
1			contributes to	Ì					thawing of		1		I	1	ity to	1
			various						permafrost.						tribal	1
			ecosystem						Management of wild animals can				1		identities	1
			processes, functions and						influence land						, associati	1
			services, the						degradation				1		on with	1
1		Biodiversity	declining	Ì					processes by		1		I	1	place,	1
		conservation	diversity and						grazing,				1		kinship	1
		includes	abundance of				Many actions		trampling and				1		ties,	1
		measures	pollinators				taken to		compacting soil	Management					customs	1
		aiming to	(mainly				increase		surfaces, thereby	of wild					and	1
1		promote	insects and	Ì			biodiversity	Many actions	altering surface	animals can	1	Regulation of	I	1	protocols	1
1		species	birds) has	Trees in the			(eg protected	taken to increase	temperatures and	influence fire	1	wild animals	I	1	, stories,	1
		richness and	raised	landscape			areas) can	biodiversity (eg	chemical	frequency as		affects food			and	1
		natural	concerns	ensured by			also have	protected areas)	reactions	grazers lower		for hunting	1	Natural	songs	Retaining
		habitats, and to	about the	protected			incidental	can also have	affecting	grass and		and		ecosystems	(Gould et	natural
		mantain them	effects on	areas can			effects of	incidental	sediment and	vegetation		availability of		often	al. 2014;	ecosystems can
1		through	both wild and	remove air			improving	effects of	carbon retention.	densities as	1	potential feed	Source of	inspire	Lyver et	preserve
1		protected areas	crop plants	pollutants	See main text		water quantity	improving water	(Cromsigt et al.,	potential fuels	1	for livestock	medicines	learning	al.	genetic
	Biodiversity	(Cromsigt et	(Potts et al.	(Sutton et al.,	for mitigation		(Egoh et al.	quality (Egoh et	2018; Schmitz et	(Schmitz et al		(Cromsigt et	(UNEP,	(Turtle et	2017a,	diversity (Ekins
	conservation	al., 2018).	2010).	2007)	potentials	<u> </u>	2009)	al. 2009)	al., 2018)	2014).	<u> </u>	al., 2018).	2016)	al., 2015)	b).	 et al., 2003).
														•		

														Can contribute	1		1			
														to increase	1		1			
														food						
														production by						
							Addition of							replenishing						
							basic							plant available						
							minerals							silicon,						
										G 111										
							counteracts		May have	Could improve				potassium and						
							ocean		negative effects	soil quality (Rau				other plant						
		Enhanced				See main text	acidification		on water quality	& Caldiera 1999;				nutrients						
		weathering of				for mitigation	(Taylor et		(Atekwane et al.	Kantola et al				(Beerling et						
		minerals	N/A	N/A	N/A	potentials	al., 2016)	N/A	2005)	2017)	N/A	N/A	N/A	al., 2018)	N/A	N/A	N/A	N/A	N/a	N/A
								Will likely												
								require water												
								for plantations												
								of fast												
								growing trees												
								and models	Bioenergy can											
								show high	affect freshwater											
								risk of water	quality via											
								scarcity if	changes in											
								BECCS is	nitrogen runoff											
								deployed on	from fertiliser											
								widespread	application.											
								scale (Popp et	However, the											
								al 2011;	sign of the effect											
								Smith et al.	depends on what											
								2016; Hejazi	would have											
								et al., 2014)	happened absent				BECCS					BECCS		
								through both	any bioenergy				and	BECCS will				would		
								increases in	production, with				biofuels	likely lead to				drive		
				Would reduce	1	1		water	some studies				can	significant	l	l		land use		
				natural	1	1		withdrawals	indicating				contribute	trade-offs with	l	l		conversi		
			Likely will	pollinators	1	1		(Hejazi et al.,	improvements in				up to 300	food	l	l		on and	BECCS would	
			reduce natural	due to			Mitigation	2014; Bonsch	water quality	Will likely			EJ of	production	ĺ			reduce	drive land use	
			habitat with	decreased	The use of	1	potential	et al., 2015)	(Ng et al., 2010)	decrease soil			primary	(Smith et al	l	l		opportun	conversion	BECCS would
			negative effects	natural habitat	BECCS could		(see main	and changes	and others	quality if exotic			energy by	2016; Popp et	ĺ			ities for	and reduce	drive land use
C	arbon		on biodiversity	if in	reduce air	See main text	text) will	in surface	showing	fast growing			2100	al., 2017;	l	l		recreatio	culturally	conversion and
	oxide	Bioenergy and	(Hof et al.	competition	pollution	for mitigation	reduce ocean	runoff (Cibin	declines (Sinha	trees used (Stoy			(Clarke et	Fujimori et	l	l		n/tourism	significant	reduce genetic
	moval	BECCS	2018)	(Keitt 2009).	(SR1.5)	potentials	acidification.	et al., 2015)	et al., 2019)	et al. 2018)	N/A	N/A	al., 2014).	al., in review)	N/A	N/A	N/A		landscapes.	diversity.
10	movai	DECCS	2010)	(Kent 2009).	(SK1.3)	potentiais	acidification.	et al., 2013)	et al., 2019)	et al. 2016)	11/71	11/71	ai., 2014).	ai., iii ieview)	19/23	19/25	19/73		ianuscapes.	diversity.

Table S2 Literature on Impacts on Nature's Contributions to People of integrated response options based on value chain management

Integrated resp based on value management		Habitat creation and maintenance	Pollination and dispersal of seeds and other propagules	Regulation of air quality	Regulation of climate	Regulation of ocean acidification	Regulation of freshwater quantity, flow and timing	Regulation of freshwater and coastal water quality	Formation, protection and decontamination of soils and sediments	Regulation of hazards and extreme events	Regulation of organisms detrimental to humans	Energy	Food and feed	Materials and assistance	Medicinal, biochemical and genetic resources	Learning and inspiration	Physical and psychological experiences	Supporting identities	Maintenance of options
		Will lead to					Will reduce	Reduced											
		reduced					water	meat											
		expansion of					consumption	consumption											
		ag lands,					if less water-	will improve											
		which can					intensive	water					Will help						
		increase			See main		food/livestock	quality					increase						
		natural			text on		needs to be	(Stoll-					global food						
		habitat			climate		produced	Kleeman &					supplies						
Demand	Dietary	(Tilman et al.			mitigation		(Tilman et al.	O'Riordan					(Kastner et						
management	change	2001)	N/A	N/A	impacts	N/A	2001)	2015)	N/A	N/A	N/A	N/A	al. 2012)	N/A	N/A	N/A	N/A	N/A	N/A

				1						1	Reducing	1		Π			1		
	Reduced post-harvest losses	Will lead to reduced expansion of ag lands, which can increase natural habitat (Tilman et al. 2001)	N/A	N/A	See main text on climate mitigation impacts	N/A	Will reduce water consumption if less water- intensive food/livestock needs to be produced (Tilman et al. 2001)	N/A	N/A	N/A	postharvest losses will include measures to deal with pests, some of which could be biological (Wilson & Pusey 1985)	N/A	Will help increase global food supplies (Kastner et al. 2012)	N/A	N/A	N/A	N/A	N/A	N/A
	Reduced food waste (consumer or retailer)	Improved storage and distribution reduces food waste and the need for compensatory intensification of agricultural areas thereby creating cobenefits for reduced land degradation (Stathers et al. 2013).			See main text on climate mitigation impacts		Will reduce water consumption if less water- intensive food/livestock needs to be produced (Tilman et al. 2001)	Reduced food production will reduce N fertiliser use, improving water quality (Kibler et al. 2018)	N/A	N/A	N/A	N/A	Will help increase global food supplies (Kastner et al. 2012)	N/A	N/A	N/A	N/A	N/A	N/A
	Material substitution	Material substitution increases demand for wood, which can lead to loss of habitat (Sathre & Gustavsson 2006).			See main text on climate mitigation impacts	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Material substitution supplies building materials to replace concrete and other nonrewewables (Gustavsson & Sathre 2011)	N/A	N/A	N/A	N/A	N/A
	Sustainable sourcing	Forest certification and other sustainable sourcing schemes can reduce habitat fragmentation as compared to conventional supply chains (Brown et al. 2001; Rueda et al. 2015)	N/A	Forest certification improved air quality in Indonesia by 5% due to reduced incidence of fire (Miteva et al. 2015)	N/A	N/A	Forest certification has led to improved water flow due to decreased road construction for logging (Miteva et al. 2015)	Forest certificaiton has improved riparian waterways and reduced chemical inputs in some schemes (Rueda et al 2015)	N/A	N/A	N/A	Sustainable sourcing can supply energy like biomass (Sikkema et al. 2014)	Sustainable sourcing can supply food and other goods (G. Smith 2007)	Sustainable sourcing is increasingly important in timber imports (Irland 2008)	Sustainable sourcing can supply medicinals (Pierce & Laird 2003).	N/A	N/A	N/A	N/A
Supply management	Management of supply chains	N/A	N/A	Better management of supply chains may reduce energy use and air pollution in transport (Zhu et al. 2018)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Improved supply chains will help increase global food supplies (Hamprecht 2005).	Improved supply chains will help increase material supplies due to efficiency gains (Burritt & Schaltegger 2014).	N/A	N/A	N/A	N/A	N/A

						Water access	Urban					Local urban						
			** .															
			Urban			often a	agriculture					food						
			agriculture			constraint on	can					production is						
		Urban	can increase			urban	exacerbate					often more			Urban			
	Urban	beekeeping	vegetation			agriculture	urban water					accessible to			agriculture			
	gardening can	has been	cover and			and can	pollution					local			can be used		Urban	
	improve	important in	improve air			increase	problems					populations			for		agriculture	
	habitat and	keeping	quality in			demands (De	(pesticide					and can			teaching		can	Urban food
	biodiversity	pollinators	urban areas	See main		Bon et al	runoff, etc)					increase food			and		promote	can
	in cities	alive	(Cameron et	text on		2010; Badami	(Pothukuchi					security			learning		cultural	contribute to
Enhanced	(Orsini et al.	(Gunnarsson	al. 2012;	climate		&	&					(Eigenbrod			(Travaline		identities	preserving
urban food	2014; Lin et	& Federsel	Lin et al.	mitigation		Ramankutty	Kaufmann					& Gruda			& Hunold		(Baker	local genetic
systems	al. 2015)	2014)	2015).	impacts	N/A	2015).	1999)	N/A	N/A	N/A	N/A	2015)	N/A	N/A	2010).	N/A	2004)	diversity
-	ai. 2013)	2014)	2013).	impacts	1071	2013).	1777)	1071	10/1	10/1	14/14	2013)	1071	10/71	2010).	1071	2004)	diversity
Improved																		
food																		
processing																		
and retail	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
				See main														
Improved				text on														
energy use				climate														
in food				mitigation														
systems	N/A	N/A	N/A	impacts	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table S3 Literature on Impacts on Nature's Contributions to People of integrated response options based on risk management

			Pollination and				Regulation of		Formation,	Regulation									
Integr	se options	Habitat	dispersal of seeds	Regulation		Regulation	freshwater quantity,	Regulation of freshwater and	protection and decontamination	of hazards and	Regulation of organisms				Medicinal, biochemical	Learning	Physical and		
based		creation and	and other	of air	Regulation	of ocean	flow and	coastal water	of soils and	extreme	detrimental to		Food and	Materials and	and genetic	and	psychological	Supporting	Maintenance
manas	ement	maintenance	propagules	quality	of climate	acidification	timing	quality	sediments	events	humans	Energy	feed	assistance	resources	inspiration	experiences	identities	of options
o	Ianagement Furban orawi	Reducing urban sprawl can help preserve natural habitat in periurban areas (Pataki et al 2011)	Reducing urban sprawl will help reduce loss of natural pollinators from habitat conversion (Cane 2005)	Urban sprawl is a major contributor to air pollution (Frumkin 2002)	See main text on climate mitigation impacts		Managing urban sprawl can increase water availability (ratki et al 2011)	Urban sprawl is associated with higher levels of water pollution due to loss of filtering vegetation and increasing impervious surfaces (Romero & Ordenes 2004; Tu et al 2007; Pataki et al 2011)	Likely to be beneficial for soils as soil sealing is major problem in urban areas (Scalenghe & Marsan 2009)	N/A	N/A		Urban sprawl often competes with land for food production and can reduce overall yields (Chen 2007, Barbero-Sierra et al., 2013)	N/A	N/A	N/A	N/A	N/A	N/A
	ivelihood	N/A	MIA	MA	N/A	N/A	N/A	MA	N/A	N/A	MA	MA	Diversification is associated with increased access to income and additional food sources for the household (Pretty et al.	Diversification can increase access to materials (Smith et al.	N/A	MA	N/A	MA	NA
d	iversification	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2003)	2017)	N/A	N/A	N/A	N/A	N/A

												Local seeds can lead to more diverse					
Use of local seeds	Use of commercial seeds can contribute to habitat loss (Upreti & Upreti 2002)	Use of open pollinated seeds is beneficial for pollinators and creates political will to conserve them (Helicke 2015)	N/A	N/A	N/A	Local seeds often have lower water demands, as well as less use of pesticides that can contaminate water (Adhikari 2014)	Likely to contribute to less pollution as local seeds are usually grown organically (Adhikari 2014)	Likely to contribute to better soils as local seeds are usually grown organically (Adhikari 2014)	N/A	Local seeds often need less pesticides thereby reducing pest resistance (Adhikari 2014)	N/A	and healthy food in areas with strong food sovereignty networks (Coomes et al. 2015; Bisht et al. 2018). However local seeds often are less productive than improved varieties.	Many local seeds can have multiple functions, including medicinals (Hammer & Teklu 2008)	Passing on seed information is important cultural learning process (Coomes et al. 2015)		Seeds associated with specific cultural identities for many (Coomes et al. 2015)	Food sovereignty movements have promoted saving of genetic diversity of crops through on-farm maintenance (Isakson 2009)
<u>Disaster risk</u> management	N/A Commercial	N/A	N/A	N/A	N/A	N/A	N/A	N/A	DRM helps people avoid extreme events and adapt to climate change (Mechler et al. 2014)	N/A	N/A	Famine early warning systems have been successful in Sahelian Africa to alert authorities to impending food shortages so that food acquisition and transportation from outside the region can begin, potentially helping millions of people (Genesio et al. 2011; Hillbruner and Moloney 2012)	N/A	N/A	N/A	N/A	N/A
Risk sharing instruments	Commercial crop insurance often encourages habitat conversion; Wright and Wimberly (2013) found a 531,000 ha decline in grasslands in the Upper Midwest of the US 2006-2010 due to crop conversion driven by higher prices and access to insurance.	Crop insurance is likely to impact natural pollinators due to incentives for production (Horowitz & Lichtenberg 1993)	N/A	N/A	N/A	N/A	Likely to have negative effect as crop insurance encourages more pesticide use (Horowitz & Lichtenberg 1993).	One study found a 1% increase in farm receipts generated from subsidised farm programs (including crop insurance and others) increased soil erosion by 0.135 tons per acre (Godwin and Smith 2003).	N/A	Crop insurance increasess nitrogen use and leads to treating more acreage with both herbicides and insecticides (Horowitz & Lichtenberg 1993)	N/A	Crop insurance has generally lead to (modest) expansions in cultivated land area and increased food production (Claassen et al. 2011; Goodwin et al. 2004)	Insurance encourages monocropping leading to loss of genetic diversity for future (Glauber 2004)	N/A	N/A	N/A	Insurance encourages monocropping leading to loss of genetic diversity for future (Glauber 2004)

Table S4 Literature on Impacts on the UN SDG of integrated response options based on land management

Integra ted respon se options based on land manag ement		GOAL 1: No Poverty	GOAL 2: Zero Hunger	GOAL 3: Good Health and Well-being	GOAL 4: Quality Education	GOAL 5: Gender Equality	GOAL 6: Clean Water and Sanitation	GOAL 7: Affordable and Clean Energy	GOAL 8: Decent Work and Economi c Growth	GOAL 9: Industry, Innovation and Infrastruct ure	GOAL 10: Reduced Inequality	GOAL 11: Sustainable Cities and Communities	GOAL 12: Respon sible Consu mption and Product ion	GOAL 13: Climate Action	GOAL 14: Life Below Water	GOAL 15: Life on Land	GOAL 16: Peace and Justice Strong Institutions	GOAL 17: Partnerships to achieve the Goal
		Increasing farm yields for smallholders contributes to poverty reduction (Irz et al 2001;	Increasing farm yields for smallholders reduces food insecurity (Irz et al 2001;	Increased food productivity leads to better health status (Rosegrant & Cline 2003; Dar		Increased productivity can benefit fermale farmers, who make up 50% of agricultural labor in sub- Saharan	Food productivit y increases could impact water quality if increases in chemicals used, but evidence is mixed on sustainable intensificat ion (Rockstro" m et al 2009;	~	Increased agricultur al productio n generally (Lal 2006) contribute s to increased		Increased agricultura 1 production can contribute to reducing inequality among smallholde rs (Datt &	Increased food production can increase urban food security (Ellis &		See main text on climate mitigate on and	Increased food productivity might be achieved through increased pesticide or fertiliser use, which causes runoff and dead zones in oceans	See main text on desertificati		Improved agricultural productivity generally correlates with increases in trade in agricultural
	Increased food productivity	Improved cropland management increases yields for smallholders and contributes to poverty reduction (Irz	Pretty et al 2003). Conservation agriculture contributes to food productivity and reduces food insecurity (Rosegrant & Cline 2003; Dar & Gowda 2011; Godfray & Garnett 2014). Land consolidation has played an active role in China to in increase cultivated land area promotin a gargicultural	& Gowda 2011) Conservatio n agriculture contributes to improved health through several pathways, including reduced fertiliser/pes ticide use which cause health impacts	N/A	Africa (Ross et al 2015)	Mueller et al 2012). Cropland manageme nt practices such as conservati on tillage improve downstrea m and groundwat er water quality (Fawcett et al 1994, Foster 2018). Good manageme nt practices can substantiall y decrease	N/A	economic growth. Increased agricultur al productio n generally (Lal 2006) contribute s to increased economic growth, mainly in smallhold er	N/A	Increased agricultura 1 production can contribute to reducing inequality among smallholde rs (Datt &	Sumberg 1998).	Improve d conserv ation agricult ure contribu tes to sustaina	adaptati on	(Beusen et al 2016)	on and degradation	N/A	goods (Fader et al. 2013) Improved agricultural productivity generally correlates
Agricu lture	Improved cropland management	et al 2001; Pretty et al 2003; Schneider & Gugerty 2011).	production scale, improving rural production conditions and	(Erisman et al 2011) as well as improved food security.	N/A	N/A	P losses from existing land use, to achieve	N/A	agricultur e (Abrahan and Pingali 2017).	N/A	Ravallion 1998, Abrahan and Pingali 2017)).	N/A	ble producti on goals (Hobbs et al. 2008).	text on climate mitigati on and adaptati on	N/A	See main text on desertificati on and degradation	N/A	with increases in trade in agricultural goods (Fader et al. 2013)

		living				'good'											
		environment,				water											
		alle-viating				quality in											
		ecological risk				catchment											
		and				in New											
		supporting for				Zealand,											
		rural				United											
		development				Kingdom											
		(Zhou et al.				and United											
		2019).				States (
			Improved														
			livestock														
			and grazing														
			managemen					Improved		Improved							
			t could					land		pastoral		Improve					
			contribute					managem		manageme		d					
			to better			Grassland		ent for		nt		grasslan				Grazing land	
			health			manageme		livestock		strategies		d				management	
			among			nt practices		can		can		manage				requires	
	Increases		smallholder			can		increase		contribute		ment				collective	
	vields for		pastoralists					economic		to		contribu	See			action and	
	smallholders	T				improve											
		Improved	(van't Hooft		ĺ	downstrea		productivi		reducing		tes to	main	1	ĺ	therefore can	
	and	grassland	et al. 2012)		ĺ	m and		ty,		inequality		sustaina	text on	1	l	increase	
	contributes to	management	but	1	1	groundwat	1	especially		but are	Ī	ble	climate	1	See main	social capital	
	poverty	could	pathways			er water		in global		context		producti	mitigati		text on	and build	
Improved	reduction	contribute to	are not			quality		South		specific		on goals	on and		desertificati	institutions	
grazing land	(Boval &	food security	entirely			(Foster		(Pender et		(Lesorogol		(O'Mara	adaptati		on and	(Mearns	
management	Dixon 2012)	(O'Mara 2012)	clear.	N/A	N/A	2018).	N/A	al 2006)	N/A	2003)	N/A	2012).	on	N/A	degradation	1996)	N/A
	Improved livestock management (e.g. better breeding) can contribute to poverty reduction for	Improved livestock management can contribute to reduced food insecurity among				can reduce water contaminat ion (e.g. reduced effluents) (Hooda et al 2000). Improved livestock manageme nt can contribute to better water quality such as through manageme manageme		Improved livestock managem ent can increase economic productivi ty and employm ent opportuni ties in				Sustaina ble livestoc k manage ment contribu tes to sustaina ble producti	See main text on climate		See main		Improved livestock productiv would lik correlate with
1	smallholder	smallholder	1			nt (Herrero		global		1		on goals	mitigati	1	text on		increases
Improved	pastoralists	pastoralists	1		1	&		South		1		(de Wit	on and	1	desertificati	1	trade
livestock	(van't Hooft	(van't Hooft et	1		1	Thornton		(Mack		1		et al	adaptati	1	on and	1	(Herrero
management	et al. 2012)	al. 2012).	N/A	N/A	N/A	2013)	N/A	1990)	N/A	N/A	N/A	1995).	on	N/A	degradation	N/A	al. 2009)
					Increased	Agroforest		Agrofores		Agroforest		Agrofor					
			Agroforestr	1	use of	ry can be	1	try and		ry	Ī	estry		1	1	I	
							i	other		promotion		contribu		1	1		1
		Agroforestry			agroforestry	used to				-	1		i				
	Agroforestry	Agroforestry contributes to	y positively		agroforestry can benefit	used to		forms of				tes to	See				
	Agroforestry	contributes to	y positively contributes		can benefit	increase		forms of		can		tes to	See				
	can be	contributes to food	y positively contributes to food		can benefit female	increase ecosystem		employm		contribute		sustaina	main				
	can be usefully used	contributes to food productivity	y positively contributes to food productivity		can benefit female farmers as it	increase ecosystem services	Acustomate	employm ent in		contribute to		sustaina ble	main text on		Saa main		
	can be usefully used for poverty	contributes to food productivity and reduces	y positively contributes to food productivity and		can benefit female farmers as it requires low	increase ecosystem services benefits,	Agroforestry	employm ent in forest		contribute to reducing		sustaina ble producti	main text on climate		See main		
	can be usefully used for poverty reduction	contributes to food productivity and reduces food	y positively contributes to food productivity and nutritious		can benefit female farmers as it requires low overhead,	increase ecosystem services benefits, such as	could increase	employm ent in forest managem		contribute to reducing inequality		sustaina ble producti on goals	main text on climate mitigati		text on		
	can be usefully used for poverty reduction (Leakey&	contributes to food productivity and reduces food insecurity	y positively contributes to food productivity and nutritious diets		can benefit female farmers as it requires low overhead, but land	increase ecosystem services benefits, such as water	could increase biomass for	employm ent in forest managem ent make		contribute to reducing inequality among		sustaina ble producti on goals (Mbow	main text on climate mitigati on and		text on desertificati		
Agro-forestry	can be usefully used for poverty reduction	contributes to food productivity and reduces food	y positively contributes to food productivity and nutritious	N/A	can benefit female farmers as it requires low overhead,	increase ecosystem services benefits, such as	could increase	employm ent in forest managem	N/A	contribute to reducing inequality	N/A	sustaina ble producti on goals	main text on climate mitigati	N/A	text on	N/A	N/A

						attention to	(Jose		ons to		(Leßmeist							
						(Kiptot &	2009)		global		er et al							
						Franzel			GDP		2018).							
						2012).			(Pimental									
									et al									
									1997).									
l –									Agricultu									
									ral									
									diversific									
									ation can									
									lead to									
									economic									
									growth									
									(Rahman									
									2009;									
									Pingali &									
									Rosegrant									
									1995). It									
									allows									
									farmers to									
									choose a		Increased							
									strategy		agricultura							
					1	1	1		that both		1							
									increases		diversifica							
									resilience		tion can							
									and		contribute							
									provides		to							
									economic		reducing							
									benefits,		inequality							
									including		among							
									functional		smallholde							
			Diversificatio						biodiversi		rs (Makate							
			n is associated						ty at		et al							
		Agricultural	with increased						multiple		2016),							
		diversificatio	access to	More					spatial		although							
		n is	income and	diversified					and/or		there is							
		associated	additional	agriculture					temporal		mixed							
		with	food sources	leads to					scales,		evidence							
		increased	for the	diversified					through		of							
		welfare and	farming	diets which					practices		inequality							
		incomes and	household	have better					developed		also							
		decreased	(Pretty et al.	health					via		increasing							
		levels of	2003; Ebert	outcomes					traditional		in							
		poverty in	2014).Diversif	(Block &					and/or		commerci							
		several	ication can	Webb 2001;					agroecolo		alised							
		country	also reduce	Ebert 2014;					gical		systems							
		studies	the risk of	Kadiyala et					scientific		(Pingali &							
		(Arslan et al.	crop	al 2014)					knowledg		Rosegrant							
		2018; Asfaw	pathogens	particularly					e (Lin		1995;					See main		
		et al. 2018;	spreading	for women	1	1	1		2011;	1	Weinberge				1	text on	1	
		Weinberger	across	and children	1	1	1		Kremen	1	r &				1	desertificati	1	
	Agricultural	& Lumpkin	landscapes	(Pretty et al.	1	1	1		et al.		Lumpkin					on and		
	diversification	2007).	(Lin 2011).	2003)	N/A	N/A	N/A	N/A	2012).	N/A	2007)	N/A	N/A		N/A	degradation	N/A	N/A
	a.c.sincation	May reduce	(EIII 2011).	2003)	. 1//1	. 4/1%	. 1//1	4 1/ F1	2012).	.4/23	2007)	11/21	1971	1	1071	acgradation	14/11	14/11
		land			1		1		1									
		available for			1	1	1		ĺ									
					1	1	Retaining		ĺ									
		cropping or]	1	1			I	1]				1		1	
		livestock for]	1	1	grasslands contributes		Reduced	1]				1		1	
		poorer			1	1								C				
		farmers;	G		1	1	to better		cropland					See				
		some	Can affect		1	1	water		expansion					main				
		grassland	food security		1		retention		may					text on				
		restoration	when]	1	1	and		decrease	1]			climate	1	See main	1	
	Avoidance of	programs in	competition]	1	1	improved		GDP	1]			mitigati	1	text on	1	
	conversion of	China have	for land]	1	1	quality		(Lewandr	1]			on and	1	desertificati	1	
	grassland to	been	occurs		1		(Scanlon et	1	owski et					adaptati		on and		
	cropland	detrimental	(O'Mara 2012)	N/A	N/A	N/A	al 2007).	N/A	al 1999)	N/A	N/A	N/A	N/A	on	N/A	degradation	N/A	N/A

		to poor																
		pastoralists																
		(Foggin																
		2008)																
		2000)					Water											
							resource											
							manageme											
							nt is											
							intended to											
							solve											
							watershed											
							problems											
							on a											
							sustainable											
							basis, and											
				Water is a			these											
				finite and			problems											
				irreplaceabl			can be											
				e resource			categorised											
				that is			into lack of											
		1		fundamental			water		l		1				1	1		
		1		to human			(quantity),		l			1			1	1	l	
		1		well-being.			deteriorati		l			1			1	1	l	
		1		It is only			on in water		l		1				1	1		
		1		renewable if					Water is		1				1	1		
		1		well			quality, ecological		at the		1				1	1		
				managed.			effects,		core of									
				Integrated			poor public		sustainabl									
				water			participatio		e									
				managemen			n, and low		developm									
				t is vital			output		ent and is									
		Green water		option for			economic		critical									
		harvesting		reducing the			value for		for socio-									
		contributes to		global			investment		economic									
		alleviate		burden of			in		developm									
		poverty in		disease and			watershed-		ent,									
		Sub-Saharan		improving			related		healthy									
													D					
		Africa		the health,			activities		ecosyste				Poor					
		(Rockström		welfare and			(Lee et al.		ms and				sectoral					
		and		productivity			2018).		for human				coordin					
		Falkenmark		of			Integrated		survival				ation					
		2015),		populations.			water		itself.				and					
		Improving		Today,			manageme		Integrated				instituti				Integrated	
		water		more than			nt, increase		water			1	onal		1	1	water	
		irrigation		1.7 billion			water-use		managme			1	fragmen		1	1	management,	
1		(Rengasamy	1	people live			efficiency	1	nt can		1		tation		1	1	increase]
		2006),		in river			across all		play a key			1	have		1	1	water-use	
		improving		basins			sectors and		enabling			1	triggere		1	1	efficiency	
									-			1			1	1	-	
1		rainfed	1	where			ensure	1	role in		1		d an		1	1	across all]
		agriculture		depletion			sustainable		strengthe			1	unsustai		1	1	sectors and	
1		(integrating	1	through use			withdrawal	1	ning the		1		nable		1	1	ensure]
		soil and	l	exceeds			s and		resilience			1	use of		1	1	sustainable	
1		water	Integrated,	natural			supply of	1	of social,		1		resource		1	1	withdrawals]
		management,	efficient,	recharge, a		Involving	freshwater		economic			1	s and		1	1	and supply	
		rainfall	equitable and	trend that		both women	to address		and			1	threaten		1	1	of freshwater	
1		infiltration	sustainable	will see		and men in	water	1	environm		1		ed the		1	1	to address]
		and water	water resource	two-thirds		integrated	scarcity,		ental		1		long-		IWM on	1	water	
		harvesting,	management	of the		water	and		systems		IWM can	1	term		land is	1	scarcity, and	
		provides a	(as water for	world's		resources	substantiall		in the		increase	Water is a	sustaina		likely to	1	substantially	
		large co-	agroecosyste	population		initiatives	y reduce		light of		access of	limiting factor	bility of	See	improve	1	reduce the	
1		benefit to	m) plays	living in		can increase	the number	1	rapid and		industry to	in urban	food,	main	water	1	number of]
1								1								1]
		delivery of	importance for	water-		project	of people		unpredict		water for	growth and	water,	text on	quality	C	people	
1		food security	food	stressed		effectiveness	suffering	1	able		economic	IWM can help	and	climate	runoff into	See main	suffering]
		and poverty	production	countries by		and	from water		changes		growth	improve access	energy	mitigati	oceans	text on	from water	
1		reduction	and benefits to	2025		efficiency	scarcity	1	(UN		(Rahman	to urban water	security	on and	(Agboola &	desertificati	scarcity (UN]
1	Integrated water	(UNCTAD	people (Lloyd	(UNWater		(Green &	(UNWater	1	Water,		& Varis	supplies (Bao	(Rassul	adaptati	Braimoh	on and	Water,]
	management	2011)	et al. 2013).	2015)	N/A	Baden 1995)	2015).	N/A	2015).	N/A	2005)	&Fang 2012)	2016).	on	2009)	degradation	2015).	

							Forests											
							tend to											
							maintain											
							water											
							quality by											
							reducing											
							runoff and											
							trapping											
							sediments											
							and											
							nutrients											
							(Idris											
							Medugu et											
							al. 2010c;											
							Salvati et											
							al. 2014a).											
							Due to											
							evapotrans											
							piration,											
							trees											
							recharge											
							atmospheri											
							c moisture,											
							contributin											
							g to											
							rainfall											
							locally and											
							in distant											
							location,											
							and trees'											
							microbial											
							flora and											
							biogenic											
							volatile											
							organic											
							compound											
							s can											
							directly											
							promote											
							rainfall											
			Forest				(Arneth et											
			expansion can				al. 2010).											
			affect crop				Trees											
			production				enhance											
			when				soil											
1			competition				infiltration			ĺ	ĺ					1		
1			for land			1	and, under	I		1	I		1			1	1	
1		May	occurs				suitable			ĺ	ĺ					1		
1		contribute to	(Angelsen			1	conditions,	I		1	I		Improve			1	1	
1		poverty	2010). An		1	1	improve	1	1	1	1	1	d forest			1	1	
1		reduction if	increase in				groundwat			ĺ	ĺ		manage			1		
1		conditions	global forest				er recharge			ĺ	ĺ		ment			1		
1		are right	area can lead			1	(Calder	I		1	I		contribu			1	1	
1		(Blomley &	to increases in				2005;			ĺ	ĺ		tes to			1		
1		Ramadhani	food prices			1	Ellison et	I		1	I		sustaina			1	1	
1		2006;			1	1	al. 2017a;	1	1	1	1	1				1	1	Custainable
1			through		1			1	F	1	1	1	ble			1	1	Sustainable
1		Donovan et	increasing			Women face	Neary et		Forest	ĺ	ĺ		producti			1		forest
1		al 2006), but	land		1	challenges	al. 2009b).	1	managem	1	1	1	on			1	l	management
1		conflicting	competition			in	Particular		ent often	ĺ	ĺ		goals,			1	Sustainable	can
1		data, as it	(Calvin et al.		1	sustainable	activities	SFM may	require	1	1	1	e.g. thru			1	forest	contribute to
1		may also	2014b;		1	forest	associated	increase	employm	Forestry	1	Community	certifica	See		1	management	increases in
1		favor large	Kreidenweis			management	with forest	availability of	ent for	supplies	ĺ	forest	tion of	main		1	often	demand for
1		landowners	et al. 2016c;			(Mwangi et	landscape	biomass for	active	wood for	I	management	timber	text on		1	requires	wood
1		who are less	Reilly et al.			al 2011), but	restoration,	energy	replanting	industrial	ĺ	can contribute	(Ramets	climate		See main	collective	products (e.g.
1	Forest	poor	2012b; Smith			N/A how	such as	(Kraxner et al.	, etc.	use	ĺ	to stronger	teiner	mitigati		text on	action	certification)
1	management	(Rametsteine	et al. 2013a;			SFM affects	mixed	2013;	(Ros-	(Gustavsso	ĺ	communities	and	on and		desertificati	institutions	(McDonald
Forestr	and forest	r and Simula	Wise et al.			gender	planting,	Sikkema et al.	Tonen et	n & Sathre	I	(Padgee et al	Simula	adaptati		on and	(Ros-Tonen	& Lane
у	restoration	2003).	2009b)	N/A	N/A	equity.	assisted	2013)	al 2008)	2011)	N/A	2006)	2003).	on	N/A	degradation	et al 2008).	2004)
	•			•			•			•					•			

natural	
regeneratio	
n, and	
reducing	
impact of	
disturbanc	
es (e.g.	
prescribed	
burning)	
have	
positive	
implication	
s for fresh	
water	
supply	
(Ciccarese	
et al. 2012;	
Suding et	
al. 2015).	
Forests	
tend to	
maintain maintain	
water	
quality by	
reducing	
runoff and	
trapping	
sediments	
and	
nutrients	
[(Idris	
Medugu et	
al. 2010c;	
Salvati et	
al. 2014b).	
Due to	
evapotrans	
May piration,	
contribute to trees	
poverty	
reduction but atmospheri conflicting c moisture,	
conflicting c moisture, data.	
Although poverty is a Reduced rainfall	
poverty is a Reduced Infinial focus of deforestatio locally and	
many n can indistant	
niany n can in usuant REDD+ enhance location,	
projects human well- and trees'	
(Arthin 2014), being by Unclear how microbial REDD+	
evidence is microclimat avoided flora and has been	
thin that ic regulation deforestation biogenic shown to	
poverty for might volatile Reduced have no	
reduction has protecting enhance organic forest impact on	Likely to
actually people from gender compound exploitati inequality	contribute to
happened heat stresses equity, but s can on may (Shresta et	decline in
(Corbera et (Locatelli et REDD+ directly decrease al 2017) or	trade in
al. 2017; Avoided al. 2015c) projects promote Avoiding GDP and to increase	forest
Porkorny et deforestation and need to pay rainfall deforestation thus inequality	products, but
al 2013; can affect crop generally attention to (Armeth et can take needs to in some See	increases in
Scheba 2018) production improve the gender al. 2010). biofuel land be project main	partnerships
and in some when cultural and issues to be Trees out of compensa areas text on	between
cases benefits competition recreational successful enhance production as ted for (Andersso climate	See main donors and
have been for land value of (Westholm soil they both tend (e.g. n et al mitigati	
Reduced captured by occurs ecosystems & Arora- infiltration to compete for REDD+) 2018; on and	text on countries
	desertificati with REDD+
deforestation wealthier (Angelsen (Knoke et Jonsson and, under land (Dixon et Motel et Pelletier et adaptati and degradation participants 2010). al. 2014). N/A 2015) suitable al. 2016) al 2009) N/A al 2018) N/A N/A on N/A	

						conditions,											
						improve											
						groundwat											
						er recharge											
						(Calder											
						2005;											
						Ellison et											
						al. 2017a;											
						Neary et											
						al. 2009b).											
			Reforestatio			ai. 20090).				-			 				
			n can														
			enhance														
			human well-														
			being by														
		_	microclimat														
		Forest	ic regulation			Particular											
		expansion can	for			activities											
		affect crop	protecting			associated											
		production	people from			with forest											
İ	May	when	heat stresses	1	1	landscape]						1	1	1	1
1	contribute to	competition	(Locatelli et			restoration,		l							1		
	poverty	for land	al. 2015c)			such as											
İ	reduction but	occurs	and	1	1	mixed]						1	1	1	1
	conflicting	(Angelsen	generally			planting,											
	data	2010). An	improve the			assisted											
	(Tschakert	increase in	cultural and			natural											
	2007). Many	global forest	recreational			regeneratio											
	projects for	area can lead	value of			n, and											
	reforestation	to increases in	ecosystems			reducing											
	may have	food prices	(Knoke et			impact of											
	some small	through	al. 2014).			disturbanc											
	impacts on	increasing	Trends of			es (e.g.											
	poor	land	forest			prescribed											
	households,	competition	resources of			burning)											
	while others	(Calvin et al.	nations are			have		Reforestat									
	actually	2014b;	found to			positive		ion often									
	increased	Kreidenweis	positively			implication		require					See				
	poverty due	et al. 2016c;	correlate			s for fresh	Reforestation	employm					main				
	to land losses	Reilly et al.	with UNDP			water	can increase	ent for					text on				
	or lack of	2012b; Smith	Human			supply	availability of	active					climate		See main		
	economic	et al. 2013a;	Developme			(Ciccarese	biomass for						mitigati		text on		
	impacts	Wise et al.	nt Index			et al. 2012;		replanting , etc.					on and		desertificati		
	(Jindal et al	2009b)					energy	(Jindal et							on and		
Reforestation	2008).	20096)	(Kauppi et al. 2018).	NI/A	N/A	Suding et al. 2015).	(Swischer 1994).	al 2008)	NI/A	N/A	N/A	N/A	adaptati	N/A		NI/A	N/A
Reforestation	2008).			N/A	N/A		1994).	ai 2008)	N/A	N/A	N/A	N/A	on	N/A	degradation	N/A	N/A
		Future needs	Afforestatio			Afforestati											
	Although	for food	n can			on using											
	some have	production are	enhance			some											
	argued that	a constraint	human well-			exotic											
1	afforestation	for large-scale	being by			species can		l							1		
1	can be a tool	afforestation	microclimat	1		upset the		l									
1	for poverty	plans	ic regulation			balance of		l							1		
1	reduction	(Locatelli et	for			evapotrans		l							1		
1	(Holden et al	al. 2015c).	protecting			piration		l							1		
1	2003),	Global food	people from			regimes,		l							1		
İ	afforestation	crop demand	heat stresses	1	1	with]						1	1	1	1
1	can compete	is expected by	(Locatelli et			negative		Afforestat							1		
İ	with land	50%-97%	al. 2015c)	1	1	impacts on		ion often]	1	1	1
1	available for	between 2005	and			water		requires							1		
1	cropping and	and 2050	generally	1		availability		employm					See				
1	poor farmers	(Valin et al.	improve the			particularl	Afforestation	ent for					main		1		
1	often do not	2014). Future	cultural and			y in arid	may increase	active					text on		1		
1	benefit from	carbon prices	recreational			regions	availability of	replanting					climate		See main		
1	afforestation	will facilitate	value of			(Ellison et	biomass for	, etc.					mitigati		text on		
1	projects	deployment of	ecosystems	1		al. 2017a;	energy use	(Mather					on and		desertificati		
1	(McElwee	afforestation	(Knoke et	1		Locatelli et	(Obersteiner	& Murray					adaptati		on and		
					1				l	1	1					1	1
Afforestation	2009)	projects at	al. 2014).	N/A	N/A	al. 2015c;	et al 2006)	1987).	N/A	N/A	N/A	N/A	on	N/A	degradation	N/A	N/A

			expenses of	Trends of			Trabucco											
			food	forest			et al.											
			availability	resources of			2008).											
			(adverse side-	nations are			Afforestati											
			effect), but	found to			on in arid											
			more	positively			and											
			liberalised	correlate with UNDP			semiarid											
			trade in				regions											
			agricultural	Human			using											
			commodities	Developme			species											
			could buffer	nt Index			that have											
			food price	(Kauppi et al. 2018)			evapotrans											
			increases following	al. 2018)			piration											
							rates											
			afforestation				exceeding the											
			in tropical regions				regional											
			(Kreidenweis				precipitatio											
			et al. 2016c)				n may											
			ct al. 2010c)				-											
1							aggravate the				l	1						
							groundwat				1	1						
							er decline				1	1						
							(Locatelli				1	1						
							et al.				1	1						
							2015a; Lu				1	1						
							et al.											
							2016).											
							Changes in											
							runoff											
							affect											
							water											
							supply but											
							can also											
							contribute											
							to changes											
							in flood											
							risks, and											
							irrigation											
							of forest											
							plantations											
							can											
							increase											
							water											
							consumpti											
							on											
							(Sterling et				1	1						
<u> </u>		G		771			al. 2013)					1						
		Can increase yields for	Lal (2006b)	There is evidence							l	İ						
1		smallholders,	notes that	that							l	1						
1]	which can	"Food-grain	increasing							l	1						
		contribute to	production in	soil organic							1	1	Improve					
		poverty	developing	carbon			Soil				Increased	1	d		Rivers			
		reduction,	countries can	could be			organic		Increased		agricultura	1	conserv		transport			
		but because	be increased	effective in		Gender	matter is		agricultur		1	1	ation		dissolved			
1]	adoption	by 24–39	reducing the		impacts use	known to		al		production	1	agricult		organic			
		often	(32+-11)	prevalence		of soil	increase		productio		can	1	ure		matter to			
1]	depends on	million Mgy-1	of disease-		organic	water		n		contribute	1	contribu		oceans			
		exogenous	through	causing		matter	filtration		generally		to	1	tes to	See	(Hedges et			
		factors these	improving soil	helminths		practices	and		(Lal		reducing	1	sustaina	main	al 1997),			
		need to be	quality by	(Lal 2016;		(Quansah et	protects		2006c)		inequality	1	ble	text on	but unclear			
1]	taken into	increasing the	Wall et al.		al 2001) but	water		contribute		among	1	producti	climate	if improved	See main		
		consideration	SOC pool and	2015). Also		N/A how the	quality		s to		smallholde	1	on goals	mitigati	SOM will	text on		
Soil	Increased soil	(Wollni et al	reversing	indirectly		relationship	(Lehmann		increased		rs (Datt &	1	(Hobbs	on and	decrease	desertificati		
manag	organic carbon	2010; Kassie	degradation	contributes		works in	& Kleber		economic		Ravallion	1	et al.	adaptati	this and by	on and		
ement	content	et al 2013).	processes".	to food	N/A	reverse.	2015)	N/A	growth.	N/A	1998).	N/A	2008).	on	how much.	degradation	N/A	N/A

			productivity														
			which may														
			have impact														
			on diets.														
						Various researchers											
						showed a											
						relationshi											
						p between											
						impact of											
						soil											
						erosion											
						and											
						degradatio											
						n on water quality											
						indicating											
						the source											
						of											
						pollutant					Particulate						
						as					matter						
						anthropoge					pollution, a						
						nic and industrial					main consequence of						
						activities.					wind erosion,						
			Contributes			in China					imposes severe						
			to food			(Issaka &					adverse						
		Contributes to	productivity			Asheraf					impacts on						
	Can increases	agricultural	and			2017).					materials,						
	yields for	productivity	improves			Managing					structures and		See				
	smallholders and	and reduces food	farmer health			soil erosion					climate which directly affect		main text on				
	contributes to	insecurity	(Pimentel et			improves					the		climate		See main		
	poverty	(Pimentel et	al. 1995;			water					sustainability		mitigati		text on		
	reduction	al. 1995;	Shiferaw &			quality					of urban cities		on and		desertificati		
Reduced soil	(Ananda &	Shiferaw &	Holden			(Pimentel					(Al-Thani et al.		adaptati		on and		
erosion	Herath 2003)	Holden 1999).	1999).	N/A	N/A	et al 1995)	N/A	N/A	N/A	N/A	2018)	N/A	on	N/A	degradation	N/A	N/A
			Salinisation														
			is known to have human														
	Salinisation		health														
	can		impacts:														
	impoverish		wind-borne														
	farmers		dust and														
	(Duraiappah	Reversing	respiratory														
	1998)	degradation	health;			Manageme											
	therefore	contributes to	altered			nt of soil	1				1			1		1	
	preventing or reversing can	food productivity	ecology of mosquito-			salinity improves	1				1		See	1		1	
	increases	and reduces	borne			water	I				I		main	I	1	I	
	yields for	food	diseases;			quality and	1				1		text on	1		1	
	smallholders	insecurity	and mental			quantity	I				I		climate	I	See main	I	
	and	(Pimiental et	health			(Kotb et al.	I				I		mitigati	I	text on	I	
	contributes to	al. 1995;	consequenc			2000;	1				1		on and	1	desertificati	1	
Reduced soil	poverty	Shiferaw &	es (Jardine	NI/A	27/4	Zalidis et	N. (4	N7/A	27/4	NT/A	N/4	N/A	adaptati	27/4	on and	N/4	27/4
salinisation	reduction. Soil	Holden 1999).	et al 2007) Soil	N/A	N/A	al 2002) Managama	N/A	N/A	N/A	N/A	N/A	N/A	on	N/A	degradation	N/A	N/A
	compaction	Compactions	compaction			Manageme nt of soil	1				1			1		1	
	and other	reduces	has human			compactio	1				1			1		1	
	forms of	agricultural	health			n improves	I				I		See	I	1	I	
	degradation	productivity	consequenc			water	1				1		main	1		1	
	can	and thus	es as it			quality and	1				1		text on	1		1	
	impoverish	contributes to	contributes			quantity	I				I		climate	I	See main	I	
	farmers	food	to runoff of			(Soane and	1				1		mitigati	1	text on	1	
Reduced soil	(Scherr	(Navoz et al.	water and pollutants			van Ouwerkerk	I				I		on and	I	desertificati on and	I	
Reduced soil compaction	2000); prevention of	(Nawaz et al 2013)	pollutants into surface	N/A	N/A	Ouwerkerk 1994;	N/A	N/A	N/A	N/A	N/A	N/A	adaptati on	N/A	on and degradation	N/A	N/A
сопраснов	prevention of	2013)	imo surrace	IN/A	IN/A	1994;	IN/A	IN/A	IN/A	IN/A	IN/A	IN/A	OH	IN/A	degradation	1N/ /A	IN/A

			1				7 11 11	1	1		1	1				1	1	
		compaction thus		and groundwate			Zalidis et al 2002)						1					
		contributes to		rs (Soane			ai 2002)											
		poverty		and van														
		reduction.		Ouwerkerk														
		-caacaon.		1994)														
		Land to		,														
		produce																
		biochar may																
		reduce land																
		available for																
		smallholders,																
		and it tends																
		to be unaffordable																
		for poor																
		farmers; as of																
		yet, few																
		biochar	Could				Biochar							See				
		projects have	potentially				improves							main				
		shown	affect crop				soil water							text on				
		poverty	production if				filtration							climate		See main		
		reduction	competition				and .							mitigati		text on		
	B. 1 111.1	benefits	for land				retention							on and		desertificati		
	Biochar addition to soil	(Leach et al 2012)	occurs (Ennis et al 2012)	N/A	N/A	N/A	(Spokas et al 2011)	N/A	N/A	N/A	N/A	N/A	N/A	adaptati on	N/A	on and degradation	N/A	N/A
	50H	2012)	5t at 2012)	14/21	17/21	1973	ai 2011)	1973	17/21	. 1/ / 1	11/21	Wildfires can	1971	OII	17/73	acgradation	1971	1971
												threaten						
												property and						
												human health						
												in urban areas,						
				Fire			Fires affect					with unique						
				managemen			water					vulnerabilities		See				
				t reduces health risks			quality and flow due to					(Gill & Stevens 2009; Winter		main text on				
				from			erosion					& Fried 2010),		climate		See main		
				particulates			exposure					therefore		mitigati		text on		
				(Bowman &			(Townsend					management		on and		desertificati		
	Fire			Johnston			& Douglas					will reduce risk		adaptati		on and		
	management	N/A	N/A	2005).	N/A	N/A	2000).	N/A	N/A	N/A	N/A	to urban areas.	N/A	on	N/A	degradation	N/A	N/A
		Landslides																
		can increase	Landslides are															
		vulnerability	one of the											g.,				
		to poverty (Msilimba	natural disasters that											See main				
		(Misilimba 2010),	have impacts	Managing								Landslide	1	main text on				
		therefore	on food	landslides								hazards are a		climate		See main		
		management	security (de	reduces								major risk to		mitigati		text on		
	Reduced	will reduce	Haen &	health risks								urban areas		on and		desertificati		
	landslides and	risks to the	Hemrich	(Haines et								(Smyth &		adaptati		on and		
	natural hazards	poor	2007)	al 2006)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Royle 2000).	N/A	on	N/A	degradation	N/A	N/A
				Reducing acid														
				deposition														
				reduces														
				health risks,														
				including			Pollution			Manageme								
				respiratory			increases			nt of					Reduction			
				illnesses			acidity of			pollution				See	in pollution			
				and			surface			can		Management of		main	can improve			
Other				increased morbidity			water, with likely			increase demand for		pollution can reduce	1	text on climate	water	See main		
ecosyst	Reduced			(Lübkert-			ecological			new		exposure to		mitigati	quality running to	see main text on		
em	pollution			Alcamo &			effects			technologie		health risks in		on and	oceans	desertificati		
manag	including			Krzyzanows			(Larssen et			s (Popp		urban areas		adaptati	(Doney et al	on and		
	acidification	N/A	N/A	ki 1995;	N/A	N/A	al 1999)	N/A	N/A	2006).	N/A	(Bartone 1991)	N/A	on	2007).	degradation	N/A	N/A

			Larssen et al 1999)														
			ai 1999)					IAS									
						IAS like		removal									
						the golden		policies									
	Invasive	IAS can				apple		can									
	species	compete with	IAS have			snail/zebra		increased									
	removal	crops and	strong			mussel		employm					See				
	policies have	reduce crop yields by	negative			have		ent due to					main				
	been beneficial to	billions of	effects on human well-			damaged aquatic		need for labor (van					text on climate		See main		
	the poor (van	dollars	being			ecosystems		Wilgen &					mitigati		text on		
Management of	Wilgen &	annually	(Pejchar &			(Pejchar &		Wannenb					on and		desertificati		
invasive species /	Wannenburg	(Pejchar &	Mooney			Mooney		urgh					adaptati		on and		
encroachment	h 2016)	Mooney 2009)	2009)	N/A	N/A	2009)	N/A	2016)	N/A	N/A	N/A	N/A	on	N/A	degradation	N/A	N/A
	Impacts on																
	poverty are mixed																
	(Kumar et al																
	2011). May																
	reduce land																
	available for	Mixed															
	cropping, and	evidence: can															
	poor design	affect	Wetlands														
	can impoverish	agriculture/fis heries	contribute to local														
	people	production	well-being											Restoration			
	(Ingram et al	when	(Crooks et					Restoratio						of coastal			
	2006;	competition	al 2011),					n projects	Protecting					wetlands			
	Mangora	for land	and					often	coastal					can play a			
	2011). Can	occurs, or	restoration			Wetlands		require	wetlands				_	large role in			
	also decrease vulnerability	could increase	generally			store		employm	may reduce				See	providing			
	to coastal	food production	improve the cultural and			freshwater and		ent for active	infrastructu re projects				main text on	habitat for marine fish			
	storms,	when	recreational			enhance		replanting	in coastal				climate	species	See main		
Restoration and	however	ecosystems	value of			water		, etc.	areas (e.g.				mitigati	(Bobbink et	text on		
avoided	(Jones et al.	are restored	ecosystems			quality		(Crooks	sea dikes,				on and	al 2006;	desertificati		
conversion of	2012; Feagin	(Crooks et al	(Knoke et			(Bobbink		et al.	etc.) (Jones				adaptati	Hale et al	on and		
coastal wetlands	et al 2010)	2011)	al. 2014).	N/A	N/A	et al 2006)	N/A	2011).	et al. 2012)	N/A	N/A	N/A	on	2009)	degradation	N/A	N/A
		Can affect crop				Peatland restoration											
		production				will											
		when				improve											
		competition				water	Peatlands in										
		for land				quality as	tropics are	Reduced									
	M	occurs,				they play	often used for	peatland			1		G	1	1		
	May reduce land	although much use of				important roles in	biofuels and palm oil, so	exploitati on may			1		See main	1	1		
	available for	peatlands in	1		1	water	may reduce	decrease			I		text on	I	I]	
	smallholders	tropics is for	1		1	retention	the	GDP in			I		climate	I	See main]	
Restoration and	in tropical	palm oil, not				and	availability of	Southeast			1		mitigati	1	text on		
avoided	peatlands	food				drainage	these	Asia (Koh			1		on and	1	desertificati		
conversion of peatlands	(Jewitt et al 2014)	(Sellamuttu et al 2011)	N/A	N/A	N/A	(Johnston 1991).	(Danielsen et al 2008).	et al 2011)	N/A	N/A	N/A	N/A	adaptati on	N/A	on and degradation	N/A	N/A
peananus	2014)	Biodiversity,	Biodiversity	14/17	14/71	33 out of	ai 2000).	2011)	14/71	14/11	11/13	IV/A	JII	14/74	acgrauation	Indigenous	14/71
		and its	, and its			105 of the								1	Indigenous	peoples	
		management,	managemen		1	largest					[Biodiversity	peoples'	commonly	
		is crucial for	t, is crucial		1	urban areas								conservatio	roles in	link forest	
	There is	improving	for .		1	worldwide	Some							n measures	biodiversity	landscapes	
	mixed evidence on	sustainable and	improving sustainable		1	rely on biodiversit	biodiversity conservation							like protected	conservatio n can	and biodiversity	
	the impacts	diversified	and			v	measures							areas can	n can increase	to tribal	
	of	diets (Global	diversified			conservati	might increase							increase	institutions	identities,	
1	biodiversity	Panel on	diets			on	access to							ocean	and conflict	association	
	conservation	Agriculture	(Global		1	measures	biomass							biodiversity	resolution	with place,	
Biodiversity	measures on	and Food	Panel on			such as	supplies (Erb							(Selig et al	(Garnett et	kinship ties,	
conservation	poverty	Systems for	Agriculture	N/A	N/A	protected	et al. 2012)	1	l				1	2014)	al. 2018)	customs and	l

			Nutrition	and Food			areas for										protocols,	
			2016).	Systems for	1		some, or	'									stories, and	
			Indirectly, the	Nutrition	1		all, of their	!									songs	
			loss of	2016).	1		drinking	!									(Gould	
			pollinators	2010).	1		water	·									2014; Lyver	
				'	1			!										
			(due to	'	1		(Secretaria	!									et al. 2017a,	
			combined	'	1		t of the	!									b).	
			causes,	'	1		Conventio	!										
			including the	'	1		n on	!										
			loss of		1		Biological	·										
			habitats and	'	1		Diversity	!										
			flowering		1		2008)	·										
				'	1		2008)	!										
			species)		1			·										
			would	'	1			!										
			contribute to		1			·										
			1.42 million	'	1			!										
			additional	'	1			!										
			deaths per		1			·										
			year from	'	1			!										
					1			·										
			non-	1 '	1 '	l		1 '			1						1 !	
]		1	communicable	1 '	1 '	1		1 '			1			1			1	
			and	1 '	1 '	l		1 '			1						1 !	
		1	malnutrition-	1 '	1 '	1		1 '			1			1			1	1
			related		1			·										
]		1	diseases, and	1 '	1 '	1		1 '			1			1			1	1
			27.0 million	'	1			!										
			lost disability-	'	1			!										
				'	1			!										
			adjusted life-	'	1			!										
			years		1			·										
			(DALYs) per	'	1			!										
			year (Smith et	'	1			!										
			al. 2015).	'	1			!										
			However, at		1			·										
			the same time,	'	1			!										
				'	1			!										
			some options	'	1			!										
			to preserve	'	1			!										
			biodiversity,		1			·										
			like protected	'	1			!										
			areas, may	'	1			!										
			potentially		1			·										
			conflict with	'	1			!										
					1			·										
			food	'	1			!										
			production by	'	1			!										
			local		1			·										
			communities	'	1			!										
			(Molotoks et	'	1			!										
			al. 2017)	1 '	1 '	l		1 '			1						1 !	
			2017)				Mineral				·	†		-	1		$\vdash \vdash \vdash$	
		1	1	1 '	1 '	1		1 '		Will			1	1			1	1
		1	1	1 '	1 '	1	weathering	1 '		Will			1	1			1	1
				1 '	1 '	l	can affect	1 '		require			1				1 !	
				1 '	1 '	l	the	1 '		developme			1	See			1 !	
		1	1	1 '	1 '	1	chemical	1 '		nt of new			1	main			1	1
				1 '	1 '	l	compositio	1 '		technologie			1	text on			1 !	
]		1	1	1 '	1 '	1	n of soil	1 '		s			1	climate		See main	1	1
				1 '	1 '	l	and surface	1 '		(Schuiling			1	mitigati		text on	1 '	
]	Enhanced	1	1	1 '	1 '	1	waters	1 '		and			1	on and		desertificati	1	
]		1	1	1 '	1 '	1		1 '					1				1	
]	weathering of	l	l	1 !	1 '		(Katz	1 '		Krijgsman				adaptati		on and	1 !	
	minerals	N/A	N/A	N/A	N/A	N/A	1989)	N/A	N/A	2006)	N/A	N/A	N/A	on	N/A	degradation	N/A	N/A
		Bioenergy	Biofuel	BECCS	1	l	Will likely	BECCS and	Access to				Switchi				1	
		production	plantations	could have	1 '	l	require	biofuels can	clean,				ng to	See	Reductions		1 '	
]		could create	may lead to	positive	1 '	1	water for	contribute up	affordable	BECCS			bioener	main	in carbon		1	1
		jobs in	decreased	effects	1 '	1	plantations	to 300 EJ of	energy	will require			gy	text on	emissions		1	1
					1 '	l										Soo main	1 '	
		agriculture,	food security	through	1 '		of fast	primary	will help	developme			reduces	climate	will reduce	See main	1	
		but could	through	improveme	No direct	No direct	growing	energy by	economic	nt of new	No direct		depletio	mitigati	ocean	text on	No direct	
		also compete	competition	nts in air	interaction	interaction	trees and	2100 (cross-	growth	technologie	interaction	No direct	n of	on and	acidification	desertificati	interaction	No direct
	Bioenergy and					interaction (IPCC	trees and models	2100 (cross- chapter box 7	growth (IPCC	technologie s (Smith et	interaction (IPCC	No direct interaction	n of natural	on and adaptati	acidification . See main	desertificati on and	interaction (IPCC	No direct interaction
CDR	Bioenergy and BECCS	also compete	competition	nts in air	interaction													

	uses.	al. 2015c).	(IPCC		risk of	bioenergy can			s (IPCC	climate		
	Therefore,	BECCS will	2018), but		water	provide clean,			2018).	mitigation.		
	bioenergy	likely lead to	BECCS		scarcity if	affordable						
	could have	significant	could have		BECCS is	energy (IPCC						
	positive or	trade-offs with	negative		deployed	2018).						
	negative	food	effects on		on							
	effects on	production	health and		widespread							
	poverty rates	(Popp et al.	wellbeing		scale							
	among	2011c; Smith	through		(IPCC							
	smallholders,	et al. 2016b).	impacts on		2018).							
	among other		food									
	social effects		systems									
	(IPCC 2018).		(Burns and									
			Nicholson									
			2017).									
			Additionall									
			y, there is a									
			non-									
			negligible									
			risk of									
			leakage of									
			sequestered									
			CO2 (IPCC									
			2018).									

Table S5 Literature on Impacts on the UN SDG of integrated response options based on value chain interventions

Internated				l														
Integrated									GOAL 8:				GOAL 12:	GOAL			GOAL 16:	
response				GOAL 3:			GOAL 6:		Decent Work	GOAL 9:		GOAL 11:		13:				GOAL 17:
options			0017.0		0017.4	0017.5		0017.5			0017.40		Responsible		0017.44		Peace and	
based on		0017.4.31	GOAL 2:	Good Health	GOAL 4:	GOAL 5:	Clean Water	GOAL 7:	and	Industry,	GOAL 10:	Sustainable	Consumption	Climat	GOAL 14:	0017.45	Justice	Partnerships
value chain		GOAL 1: No	Zero	and Well-	Quality	Gender	and	Affordable and	Economic	Innovation and	Reduced	Cities and	and	е	Life Below	GOAL 15:	Strong	to achieve
management		Poverty	Hunger	being	Education	Equality	Sanitation	Clean Energy	Growth	Infrastructure	Inequality	Communities	Production	Action	Water	Life on Land	Institutions	the Goal
				Overnutrition			Reduced											
,				contributes to			meat											
,				worse health			consumption											
,				outcomes,			will reduce											
				including			water											
,				diabetes and			consumption.											
,				obesity			(Muller et al.											
,				(Tilman and			2017b) found											
				Clark 2014a;			that lower											
,				McMichael et			impact											
,				al. 2007).			agriculture								Dietary			
		Reduced meat	High-meat	Dietary			could be				There are				change			
		consumption can	diets in	change away			practiced if				currently large				away from			
,		free up land for	developed	from meat			dietary				discrepancies in				meat might			
		other activities to	countries	consumption			change and				diets between				put			
		reduce poverty	may limit	has major			waste				developed and				increased			
,		(Röös et al. 2017;	improvement	health			reduction				developing		A dietary shift		pressure on			
		Stoll-Kleemann	in food	benefits,			were				nations (Sans &		away from		fish stocks			
1		and O'Riordan	security in	including			implemented,				Combris 2015).	Dietary	meat can		(Vranken et			
		2015). However,	developing	reduced heart			leading to				Dietary change	change is	contribute to		al. 2014;			
1		reduced demand	countries	disease and			lower GHG				will reduce food	most needed	sustainable		Mathijs			
1		for livestock will	(Rosegrant	mortality			emissions,				inequality by	in urbanised,	consumption		2015).			
1		have negative	et al. 1999);	(Popkin 2008;			lower rates				reducing meat	industrialised	by reducing		Overall			
		effect on	dietary	Friel et al.			of				overconsumption	countries and	greenhouse gas		reduced			
,		pastoralists and	change can	2008). Dietary			deforestation,				in Western	can help	emissions and	See	emissions			
1		could suppress	contribute to	change could			and	Dietary shifts away	Health costs		countries and	contribute to	reducing	main	would			
[demand for other	food security	contribute to			decreases in	from meat to	of meat-heavy		free up some	demand for	cropland and	text on	decrease			
1		inputs (grains) that	goals	5.1 million			use of	fish/fruits/vegetables	diets add to		cereals for	locally grown	pasture	climate	rate of	See main text		
1		would affect poor	(Godfray et	avoided deaths	No direct		fertiliser	increases energy use	health care		consumption in	fruits and	requirements	mitigati	ocean	on		
·		farmers (Garnett	al. 2010a;	per year	interaction	No direct	(nitrogen and	in the US by over	costs and		poorer diets	vegetables	(Stehfest et al.	on and	acidification	desertification		1
Demand	Dietary	2011; IPCC	Bajželj et al.	(Springmann	(IPCC	interaction	phosphorus),	30% (Tom et al.	reduce GDP		(Rosegrant et al.	(Tom et al.	2009; Bajželj	adaptati	(Doney et	and		
management	change	SR1.5)	2014)	et al. 2016)	2018)	(IPCC 2018)	pesticides,	2016)	(Popkin 2008)	N/A	1999)	2016)	et al. 2014).	on	al. 2009)	degradation	N/A	N/A

						water and											
						energy.											
						However,											
						Tom et al.											
						(2016) found											
						water											
						footprints of											
						fruit/veg											
						dietary shift											
						in the US to											
						increase by											
						16%											
			Improved														
			storage														
			enhances food														
			quality and														
			can reduce														
			mycotoxin														
			intake														
			(Bradford et			Kummu et al.											
			al. 2018;			(2012a)											
			Temba et al.			reported that		In East and									
		1	2016; Stathers	1		24% of		Southern					l	1			
			et al. 2013;					Africa,									
1			et al. 2013; Tirado et al.			global freshwater		postharvest						1			
			2010)		Postharvest	use and 23%		loss for six									
		D. L. C.															
	p	Reducing	especially in		losses do have	of global		major cereals									
	Reducing food	food losses	humid		a gender	fertiliser use		was US\$1.6									
	losses from	increases	climates		dimension	is attributed		billion or 15%									
	storage and	food	(Bradford et		(Kaminski	to food		of total		Poorer							
	distribution	availability,	al. 2018). The		and	losses.		production		households tend							
	operation can	nutrition,	perishability		Christiaensen	Reduced post	Reduced losses	value;		to experience							
	increase economic	and lower	and safety of	Reduced	2014), but	harvest	would reduce energy	reducing		more PHL, and							Post harvest
	well-being without	prices	fresh foods are	losses can	unclear if	losses can	demands in	losses would	Reducing PHL	thus reducing			See				losses
	additional	(Sheahan	highly	increase	reducing	decrease	production; 2030 +-	thus boost	can involve	PHL can			main				contribute to
	investment in	and Barrett	susceptible to	income	losses will	need for	160 trillion BTU of	GDP	improving	contribute to		Reducing PHL	text on				higher food
	production	2017b;	temperature	that could	contribute to	additional	energy were	substantially	infrastructure	reducing		contributes to	climate		See main text		prices and
	activities	Abass et al.	increase	be spent on	gender	agricultural	embedded in wasted	in developing	for farmers and	inequality		sustainable	mitigati		on		constraints
Reduced	(Bradford et al.	2014;	(Bisbis et al.	education,	equality	production	food in 2007 in the	countries with	marketers	among farmers		production	on and		desertification		on trade
post-harvest	2018; Temba et al.	Affognon et	2018; Ingram	Acres and Area	(Rugumamu	and	US (Cuéllar and	PHL (Hodges	(Parfitt et al.	(Hodges et al.							on nauc
lesses	2016)	Amognon ct	2018; Ingram	but no data	(reagamenta				(1 ai iiti ci ai.	(Houges et al.		goals (Parfitt et	adaptati		and		(Tefera
losses	2010)	al. 2015)	et al. 2016a).	available	2009)	irrigation.	Webber 2010)	et al. 2011)	2010)	2011).	N/A	goals (Parfitt et al. 2010)	adaptati on	N/A		N/A	
iosses	2010)	al. 2015) People who				irrigation. Kummu et al.								N/A	and	N/A	(Tefera
iosses	2010)	al. 2015)				irrigation.		et al. 2011)			N/A There have			N/A	and	N/A	(Tefera
iosses	2010)	al. 2015) People who				irrigation. Kummu et al.		et al. 2011) Waste						N/A	and	N/A	(Tefera
iosses	2010)	al. 2015) People who are already	et al. 2016a).			irrigation. Kummu et al. (2012a)		et al. 2011) Waste generation			There have			N/A	and	N/A	(Tefera
iosses	2010)	al. 2015) People who are already food	et al. 2016a). Food waste			irrigation. Kummu et al. (2012a) reported that		et al. 2011) Waste generation has grown			There have been large			N/A	and	N/A	(Tefera
IUSSES	Food waste tends	al. 2015) People who are already food insecure tend	et al. 2016a). Food waste can increase			irrigation. Kummu et al. (2012a) reported that 24% of		et al. 2011) Waste generation has grown faster than GDP in recent years			There have been large increases in			N/A	and	N/A	(Tefera
iosses		al. 2015) People who are already food insecure tend not to waste	et al. 2016a). Food waste can increase with healthier		2009)	irrigation. Kummu et al. (2012a) reported that 24% of global		et al. 2011) Waste generation has grown faster than GDP in recent years			There have been large increases in the			N/A	and	N/A	(Tefera
IUSSES	Food waste tends	al. 2015) People who are already food insecure tend not to waste food	Food waste can increase with healthier diets (Parizeau		2009) Reducing	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater		et al. 2011) Waste generation has grown faster than GDP in recent			There have been large increases in the throughput of			N/A	and	N/A	(Tefera
iosses	Food waste tends to rise as incomes	al. 2015) People who are already food insecure tend not to waste food (Nahman et	Food waste can increase with healthier diets (Parizeau et al. 2015).		2009) Reducing food waste	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of		et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson			There have been large increases in the throughput of materials			N/A	and	N/A	(Tefera
IUSSES	Food waste tends to rise as incomes rise (Parfitt et al.	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012).	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and		2009) Reducing food waste within	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global		et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996).			There have been large increases in the throughput of materials such as the	al. 2010)		N/A Reducing	and	N/A	(Tefera
IOSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can		Reducing food waste within households	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the		et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw			There have been large increases in the throughput of materials such as the food-waste stream,	al. 2010) Post-consumer food waste in		Reducing	and	N/A	(Tefera
IUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some		Reducing food waste within households often falls to women	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of		et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out US\$745			There have been large increases in the throughput of materials such as the food-waste stream, import and	Post-consumer food waste in industrialised		Reducing food waste	and	N/A	(Tefera
IUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to		Reducing food waste within households often falls to women (Stefan et al.	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses,	Webber 2010)	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out US\$745 of food and			There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste	Post-consumer food waste in industrialised countries (222		Reducing food waste may be	and	N/A	(Tefera
JUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food		Reducing food waste within households often falls to women (Stefan et al. 2013) and can	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction	Webber 2010) Reduced losses	et al. 2011) Waste generation has grown faster than Gly for in recent years (Thogerson 1996). Households in the UK throw out US\$745 of food and drink each			There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is		Reducing food waste may be related to	and	N/A	(Tefera
AUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2013; so it is not clear what the relationship to poverty is. Could be potentially	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO)	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste	Webber 2010) Reduced losses would reduce energy	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out US\$74\$ of food and drink each year as food	2010)		There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is almost as high		Reducing food waste may be related to food	and	N/A	(Tefera
AUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al.		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could	Webber 2010) Reduced losses would reduce energy demands in	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out USS745 of food and drink each year as food waste; South	2010) Food waste		There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al.	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net		Reducing food waste may be related to food packaging,	and	N/A	(Tefera
JUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014).		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide	Reduced losses would reduce energy demands in production; 2030 +-	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out US\$745 of food and drink each year as food waste; South Africans	2010) Food waste could be an	2011).	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008).	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food		Reducing food waste may be related to food packaging, which is a	and	N/A	(Tefera
IUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload (Hebrok and	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide significant	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out USS745 of food and drink each year as food waste; South Africans throw out	Food waste could be an important	2011). Wealthier	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008).	Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food		Reducing food waste may be related to food packaging, which is a major	and	N/A	(Tefera 2012)
IUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on other activities	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if this would	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in packaging to		Reducing food waste within households often falls to women (Stefan et al. 2013) and can labor workload (Hebrok and Boks 2017).	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide significant co-benefits	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of energy were	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK strow out UK St745 of food and drink each year as food waste; South Africans throw out S7billion US	Food waste could be an important source of	Wealthier households tend	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008). Reducing compostable	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food production in sub-Saharan	on	Reducing food waste may be related to food packaging, which is a major	and	N/A	(Tefera 2012)
IUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013; so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on other activities (Dorward 2012).	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if this would benefit those	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in packaging to reduce waste		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload (Hebrok and Boks 2017). Women also	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide significant co-benefits for	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of energy were embedded in wasted	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out US\$745 of food and drink each year as food waste; South Africans throw out \$75billion US worth of food	Food waste could be an important source of needed	Wealthier households tend to waste more	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008). Reducing compostable food waste	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food production in sub-Saharan Africa (230	See	Reducing food waste may be related to food packaging, which is a major source of ocean	and	N/A	(Tefera 2012) Food waste can
IUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on other activities (Dorward 2012). Redistribution of	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if this would benefit those who are food who are already for the area of	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in packaging to reduce waste might have		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload (Hebrok and Boks 2017). Women also generate more	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide significant co-benefits for freshwater	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of energy were embedded in wasted food in 2007 in the	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out US5745 of food and drink each year as food waste; South Africans throw out S7billion US worth of food per year	Food waste could be an important source of needed chemicals for	Wealthier households tend to waste more food (Parfitt et	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008). Reducing compostable food waste reduces need	Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food much sharran Africa (230 million ton).	See main	Reducing food waste may be related to food packaging, which is a major source of ocean	and	N/A	(Tefera 2012) Food waste can contribute to
IUSSES	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on other activities (Dorward 2012), Redistribution of food surplus to the	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if this would benefit those who are food insecure in	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in packaging to reduce waste might have negative		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload (Hebrok and Boks 2017). Women also generate more food waste	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide significant co-benefits for freshwater provision and	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of energy were embedded in wasted food in 2007 in the US (Cuellar and	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out USS745 of food and drink each year as food waste; South Africans throw out S7billion US worth of food per year	Food waste could be an important source of needed chemicals for industrial	Wealthier households tend to waste more food (Parfitt et al. 2010), but	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008). Reducing compostable food waste reduces need for landfills	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food production in sub-Saharan Africa (230 million ton). (FAO 2011).	See main text on	Reducing food waste may be related to food packaging, which is a major source of ocean pollution, but	and degradation	N/A	(Tefera 2012) Food waste can contribute to higher food
	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013; so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on other activities (Dorward 2012). Redistribution of food surplus to the poor could also	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if this would benefit those who are food insecure in developing	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in packaging to reduce waste might have negative health impacts		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload (Hebrok and Boks 2017). Women also generate more food waste and could be a	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide significant co-benefits for freshwater provision and on nutrient	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of energy were embedded in wasted food in 2007 in the US (Cuéllar and Webber 2010). Food	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out US\$745 of food and drink each year as food waste; South Africans throw out \$75tillion US worth of food per year (Nahman and de Lange	Food waste could be an important source of needed chemicals for industrial development in	Wealthier households tend to waste more food (Parfitt et al. 2010), but unclear how	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008). Reducing compostable food waste reduces need for landfills (Smit and	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food production in sub-Saharan Africa (230 million ton), (FAO 2011), thereby	See main text on climate	Reducing food waste may be related to food packaging, which is a major source of ocean pollution, but relationship	and degradation	N/A	Food waste can contribute to higher food prices and
Reduced	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on other activities (Dorward 2012). Redistribution of food surplus to the poor could also have impacts on	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if this would benefit those who are food insecure in developing countries	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in packaging to reduce waste might have negative health impacts (e.g. increased		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload (Hebrok and Boks 2017). Women also generate more food waste and could be a site for	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide significant co-benefits for freshwater provision and on nutrient cycling	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of energy were embedded in wasted food in 2007 in the US (Cuéllar and Webber 2010). Food waste can be a	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out USS745 of food and drink each year as food waste: South Africans throw out S7billion US worth of food per year (Nahman and de Lange 2013).	Food waste could be an important source of needed chemicals for industrial development in resource	Wealthier households tend to waste more food (Parfitt et al. 2010), but unclear how reducing waste	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008). Reducing compostable food waste reduces need for landfills (Smit and Nasr 1992;	Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food production in sub-Saharan Africa (230 million ton). (FAO 2011), thereby reducing waste	See main text on climate mitigati	Reducing food waste may be related to food packaging, which is a major source of ocean pollution, but relationship is not	and degradation	N/A	Food waste can contribute to higher food prices and constraints
Reduced food waste	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on other activities (Dorward 2012). Redistribution of food surplus to the poor could also have impacts on poverty	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if this would benefit those who are food insecure in developing countries (Hertel and	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in packaging to reduce waste might have negative health impacts (e.g. increased contamination)		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload (Hebrok and Boks 2017). Women also generate more food waste and could be a site for intervention	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global feriliser is used in the production of food losses, so reduction in food waste could provide significant co-benefits for freshwater provision and on nutrient cycling (Kummu et	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of energy were embedded in wasted food in 2007 in the US (Cuellar and Webber 2010). Food waste can be a sustainable source of	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out US\$745 of food and drink each year as food waste; South Africans throw out \$7billion US worth of food per year (Nahman and de Lange 2013). Reductions of	Food waste could be an important source of needed chemicals for industrial development in resource constrained	Wealthier households tend to waste more food (Parfitt et al. 2010), but unclear how reducing waste may contribute	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008). Reducing compostable food waste reduces need for landfills (Smit and Nasr 1992; Zaman and	al. 2010) Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food production in sub- Saharan Africa (230 million ton). (FAO 2011), thereby reducing waste contributes to	See main text on climate mitigati on and	Reducing food waste may be related to food packaging, which is a major source of ocean pollution, but relationship is not known	and degradation See main text on descriptication	N/A	Food waste can contribute to higher food prices and constraints on trade
Reduced	Food waste tends to rise as incomes rise (Parfitt et al. 2010; Liu et al. 2013), so it is not clear what the relationship to poverty is. Could be potentially beneficial as it would free up money to spend on other activities (Dorward 2012). Redistribution of food surplus to the poor could also have impacts on	al. 2015) People who are already food insecure tend not to waste food (Nahman et al. 2012). Reduced food waste would increase the supply of food (FAO 2011; Smith 2013), but it is unclear if this would benefit those who are food insecure in developing countries	et al. 2016a). Food waste can increase with healthier diets (Parizeau et al. 2015). Health and safety standards can restrict some approaches to reducing food waste (Halloran et al. 2014). Changes in packaging to reduce waste might have negative health impacts (e.g. increased		Reducing food waste within households often falls to women (Stefan et al. 2013) and can increase their labor workload (Hebrok and Boks 2017). Women also generate more food waste and could be a site for	irrigation. Kummu et al. (2012a) reported that 24% of global freshwater and 23% of global fertiliser is used in the production of food losses, so reduction in food waste could provide significant co-benefits for freshwater provision and on nutrient cycling	Reduced losses would reduce energy demands in production; 2030 +- 160 trillion BTU of energy were embedded in wasted food in 2007 in the US (Cuéllar and Webber 2010). Food waste can be a	et al. 2011) Waste generation has grown faster than GDP in recent years (Thogerson 1996). Households in the UK throw out USS745 of food and drink each year as food waste: South Africans throw out S7billion US worth of food per year (Nahman and de Lange 2013).	Food waste could be an important source of needed chemicals for industrial development in resource	Wealthier households tend to waste more food (Parfitt et al. 2010), but unclear how reducing waste	There have been large increases in the throughput of materials such as the food-waste stream, import and solid-waste accumulation in urban areas (Grimm et al. 2008). Reducing compostable food waste reduces need for landfills (Smit and Nasr 1992;	Post-consumer food waste in industrialised countries (222 million ton) is almost as high as the total net food production in sub-Saharan Africa (230 million ton). (FAO 2011), thereby reducing waste	See main text on climate mitigati	Reducing food waste may be related to food packaging, which is a major source of ocean pollution, but relationship is not	and degradation	N/A	Food waste can contribute to higher food prices and constraints

		1											1		1	1		
							(2017b)		increase									
							found that		household									
							lower impact		income									
							agriculture		(Hodges et al.									
							could be		2011)									
							practiced if											
							dietary											
							change and											
							waste											
							reduction											
							were											
							implemented,											
							leading to											
							lower GHG emissions,											
							lower rates											
							of											
							deforestation,											
							and											
							decreases in											
							use of											
							fertiliser											
							(nitrogen and											
							phosphorus),											
							pesticides,											
							water and											
							energy.											
								Concrete frames					Material					
							If water is	require 60-80%					substitution is					
							used	more energy than				Changing	a form of					
			Could				efficiently in	wood (Börjesson	The			materials for	sustainable		Overall			
			increase				production of	and Gustavsson	relationship	Material		urban	production/con		reduced			
			demand for				wood, likely	2000). Material	between	substitution		construction	sumption	See	emissions			
			wood and				to be positive	substitution can	material	may reduce		can reduce	which replaces	main	would			
			compete				impact over	reduce embodied	substitution	need for		cities'	cement and	text on	decrease			
			with land for				cement	energy of buildings	and GDP	industrial		ecological	other energy-	climate	rate of	See main text		
			agriculture,				production	construction by up	growth is	production of		footprint	intensive	mitigati	ocean	on		
			but no				(Gustavsson	to 20% (Thormark	unclear	cement etc.		(Zaman and	materials with	on and	acidification	desertification		
	Material		evidence of				and Sathre	2006; Upton et al.	(Moore et al.	(Petersen and		Lehmann	wood (Fiksel	adaptati	(Doney et	and		
	substitution	N/A	this yet.	N/A	N/A	N/A	2011)	2008)	1996)	Solberg 2005)	N/A	2013)	2006)	on	al. 2009)	degradation	N/A	N/A
			Poor farmers															
		Value adding has	can benefit								Value-adding							
		been promoted as	from value-								can be an							
		a successful	adding and			***					important	1						
		poverty reduction	new markets			Women are					component of	I			Ì	Ì		
		strategy in many	(Bamman			highly					additional	I			Ì	Ì		
		countries (Lundy et al. 2002;	2007) and may help to			employed in value-added					employment for poorer areas, and	1						
		Whitfield 2012;	improve			agriculture in					can contribute to	1						
		Swanson 2006).	food security			many					reductions in	1						
		Volatility of food	by			many developing				Value adding	overall	I			Ì	Ì		
		supply and food	increasing its			countries, but				can create	inequality.	1						
		price spikes in	economic			do not always				incentives to	However, data	I			Ì	Ì		
		2007 increased the	performance			gain				improve	shows high-	Value-adding						
		number of people	and revenues			substantive			Value-adding	infrastructure in	value agriculture	can increase			Ì	Ì		
		under the poverty	to local			benefits			and export	processing	is not always a	incentives to	Value-adding					
		line by between	farmers			(Dolan and			diversification	(Delgado 2010).	pathway toward	keep peri-	in agriculture					
		100 million people	(Reidsma et			Sorby 2003).	Value-added		generates	Expanding	enhanced	urban	(.e.g. fair trade,					Value-adding
		(Ivanic and Martin	al. 2010).	Value-chains	Value-	Value-chains	products		additional	value chains can	welfare (Dolan	agriculture,	organic) can be					has a strong
		2008) to 450	However,	can help	adding can	that target	might require		employment	incorporate new	and Sorby 2003),	but faces	an important	See	Ì	Ì		relationship
		million people	much value-	increase the	increase	women could	additional		and expands	sources of food	and much value-	threats from	source of	main				to expanding
		(Brinkman et al.	adding is	nutritional	income	increase	water use		GDP in	producers into	adding is	rising land	sustainable	text on				trade in
		2009), and caused	captured	status of food	that could	gender equity,	(Guan and		developing	industrial	captured not by	prices in	consumption	climate		See main text		developing
		welfare losses of	upstream,	reaching	be spent on	but data is	Hubacek		countries in	systems of	smallholders but	urban areas	and production	mitigati		on		countries in
		3% or more for	not by poor	consumers	education,	scare	2007), but		particular	distribution	higher up the	(Midmore	(de Haen and	on and	Ì	desertification		particular
Supply	Sustainable	poor households	producers	(Fan et al.	but no data	(Gengenbach	depends on		(Newfarmer	(Bloom and	chain (Neilson	and Jansen	Réquillart	adaptati		and		(Newfarmer
management	sourcing	in many countries	(McMichael	2012)	available	et al. 2018)	context.	N/A	et al. 2009)	Hinrichs 2011)	2007)	2003)	2014)	on	N/A	degradation	N/A	et al. 2009)
	-																	

											1							
		(Zezza et al.	and															
		2009).	Schneider															
			2011b).															
			Food prices															
			strongly															
			affect food															
			security															
			(Lewis and															
			Witham															
			2012; Regmi															
			and Meade															
			2013;															
			Fujimori et															
			al. 2018a),															
			and policies															
			to decrease															
			volatility															
			will likely															
			have strong															
			impacts on				1					1					l	
			food security				1					1					l	
1			(Timmer	1			1		1			1	1			1	1	
			2009;				1					1					l	
							1					1					l	
1			Torlesse et	1			1		1			1	1			1	1	
			al. 2003b;				1					1					l	
			Raleigh et al.															
			2015b).															
										Excessive								
										disruptions in								
										food supply can								
		Reducing food								place strains on								
										infrastructure								
		transport costs																
		generally helps	Improving							(e.g. needing								
		poor farmers	storage							additional								
		(Altman et al.	efficiency							storage								
		2009). More than	can reduce							facilities) (Yang	Food volatility							
		\$200 million is	food waste							and Zehnder	makes it more							
		generated in fresh	and health							2002).	challenging to							
		fruit and veg trade	risks							Improved food	supply food to							
		between Kenya	associated							transport can	vulnerable							
		and the UK; much	with poor							create demands	regions, and							
		has contributed to	storage							for improved	likely increases	Improved						_
		poverty reduction	management		Reduction					infrastructure	inequality	food						Better
		and better	practices		in staple		1			(Akkerman et	(Baldos and	distribution					l	transport
		transport could	(James and		food price		1		Food supply	al. 2010;	Hertel 2015;	can contribute					l	improves
		increase the	James		costs to		1		instability is	Shively and	Frank et al.	to better food					l	chances for
1		amount generated	2010a;	1	consumers		1		often driven	Thapa 2016).	2017; Porter et	access and	1			1	1	expanding
		(MacGregor and	Bradford et	Access to	in		1		by price	For example,	al. 2014;	stronger					l	trade in
		Vorley 2006;	al. 2018;	quality food is	Bangladesh		1		volatility,	weatherproofing	Wheeler and von	urban					l	developing
1		Muriithi and Matz	Temba et al.	a major	from food		Food imports		which can be	transport	Braun 2013).	communities	1			1	1	countries
1		2015). Volatility	2016;	contributor to	stability		-		driven by	-	Improved food	(Kantor 2001;	Improved			1	1	(Newfarmer
							can			systems and			Improved				l	
		of food supply and	Stathers et	whether a diet	policies		contributed		rapid .	improving the	distribution	Hendrickson	storage and				l	et al. 2009),
		food price spikes	al. 2013;	is healthy or	saved rural		to water		economic	efficiency of	could reduce	et al. 2006).	distribution are				l	Well-planned
		in 2007 increased	Tirado et al.	not (Neff et al.	households		scarcity		growth and	food trade	inequality in	Food price	likely to				l	trade systems
		the number of	2010). There	2009).	\$887		through		which can	(Ingram et al.	access to high	spikes often	contribute to				l	may act as a
		people under the	is some	Increased	million		"embodied"	Food supply chains	contribute to	2016a; Stathers	quality nutritious	hit urban	sustainable				l	buffer to
1		poverty line by	limited	distribution	total	Women and	or "virtual"	and flows have	consumer	et al. 2013)	foods. Food	consumers	production by		1	1	1	supply food
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		million people	improved	packaged	et al.	the most	accounting	to reliance on non-	and higher	countries with	consumers	food	biomass of				l	regions
		(Ivanic and Martin		foods however	2003b), but	effected ones		renewable energy			benefit from			See			l	(Baldos and
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		2008) to 450	farm	can decrease	N/A if this	in households	Zehnder	(Kurian 2017; Scott	as a	infrastructure	better access and	countries, and	aluminum and	main			l	Hertel 2015;
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	of supply	3% or more for	countries	Monteiro et al.	in	Hadley et al.	2010; Jiang	al. 2010; Chakauya	(Gilbert and	al. 2012a), can	Coveney and	(Cohen and	(Ingram et al.	adaptati		and	l	von Braun
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Enhanced urban food (Ellis and systems Sumberg 1998) et al. 2014b). Improved processing and food food systems of food specification food growing and processing and food growing and processing and food growing and systems of food systems of the food growing and systems of the food growing and food growing and growing	and																	1
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Systems Sumberg 1998 et al. 2014b . et al. 2003 2013 (Smith 1998 1999 Coley et al. 2009 1999 Kaufman 1999 2010 2015 Allen 2010 on al. 2009 degradation	(Cohen &																	
Improved Food Phytosanitary barriers Efficiency in distribution and currently food &storage packaging prevent much processing systems can activities food export	Garrett																	
processing and processing barriers Efficiency in distribution and currently food &storage packaging prevent much processing systems can activities food export	2010). N/A	2010).	degradation	al. 2009)	on	Allen 2010)	2015)	2010)	Kaufman 1999)	,	Coley et al. 2009)	,	(Smith 1998)	2013)		et al. 2014b).	Sumberg 1998)	systems
Efficiency in distribution and currently food &storage packaging prevent much processing systems can activities food export						1		1		Phytosanitary		Food			Improved			
Efficiency in distribution and currently food &storage processing systems can activities food export			1 '		, !	, ,	₁ 1	1					1 '	, ,				İ
food &storage packaging prevent much processing systems can activities food export	l		1 '		, ,	, ,	₁ 1	1					1 '	, ,		Efficiency in		İ
processing systems can activities food export			1 '		, ,	, ,	ı l	1				packaging	1 '	, ,				1
	l		1 '		, ,	, ,	į l	1					1 '	, ,				1
			1 '		, ,	, ,	₁ 1	1		from		such as	Improved	. !	provide safer	and supply		I
chains can and healthier food washing, developing	l		1 '		, ,	, ,	₁ 1	1						, ,				İ
cranic can and nearliner 1000 washing, ueveroping contribute to food to processing heating, countries, and			1 '		, ,	, ,	ı l	1						, ,				1
	Improved		1 '	Overell	, ,	, ,	Improved	1	Improvements		Food processing and			, ,				1
	Improved		1 '		, ,	, ,		1						, ,			Egod processing	İ
	processing		1 '		e	, ,		1						, ,				İ
has been a useful consumers al. 2012a) and and informal dependent on such as heating and would refrigeration, can reduce See emissions	increases		1 '			!		1				•		, ,				İ
strategy for and reduce food food sellers, freshwater so cooling are heavily increase and cities Improved food main would	chances for		1 '					1						, ,				İ
poverty reduction improved waste and who are improved dependent on energy exports and transportation ecological processing and text on decrease	expanding		1 '					1						, ,				İ
in some countries nutrition health risks predominantly postharvest so improved GDP (Henson will require footprints and agro-retailing climate rate of See main text	trade in						•	1	•		•			, ,				1 _
Improved (Weinberger and (Vermeulen associated women storage and efficiency could and Loader investments in reduce overall contributes to mitigati ocean on	developing							1						, ,				
food Lumpkin 2007; et al. 2012a; with poor (Smith 1998; distribution reduce energy 2001; improved emissions sustainable on and acidification description			desertification					1						, ,	-			
processing Haggblade et al. Keding et al. storage Dixon et al. could reduce demand (Garcia and Jongwanich infrastructure (Du et al. production adaptati (Doney et and	countries										1					17 . 15 1	Haggblada at al	processing
and retailing 2010) 2013) management N/A 2007) water You 2016). 2009). (Ingram 2011) N/A 2006) (Ingram 2011) on al. 2009) degradation	countries (Newfarmer N/A et al. 2009)				adaptati							could reduce		'	storage			

			practices			demand via											
			(James and			more											
			James 2010a),			efficiently											
			although			performing											
			overpackaged			systems											
			prepared foods			(Garcia and											
			that are less			You 2016).											
			healthy are														
			also on rise														
			(Monteiro														
			2009;														
			Monteiro et al.														
			2011).														
								There is no									
								clear									
								association									
								between									
								higher energy									
		Utilising	Organic					use in									
		energy-	agriculture is			Increased		agriculture									
		saving	associated			energy		and economic									
		strategies	with increased			efficiency		growth; these									
		can support	energy			(e.g. in		have become									
		reduced food	efficiency,			irrigation)		decoupled in									
		waste	which have			can lead to		many						Overall			
		(Ingram et	can have co-		Increased	more		countries						reduced			
		al. 2016a)	benefits by		efficiency	efficient	Increased energy	(Bonny				Reducing	See	emissions			
		and	reduced		might reduce	water use	efficiency will	1993). Data is				energy use in	main	would			
		increased	exposure to		women's labor	(Rothausen	reduce demands for	unclear				agriculture	text on	decrease			
	Might possibly	production	agrochemicals		workloads on	and Conway	energy but can have	though on				contributes to	climate	rate of	See main text		
Improved	have impact on	efficiencies	by farm		farms	2011;	rebound effect in	economic				sustainable	mitigati	ocean	on		
energy use	poverty by	(Smith and	workers		(Rahman	Ringler and	expanded acreage	impacts of				production	on and	acidification	desertification		
in food	reducing farmer	Gregory	(Gomiero et		2010) but data	Lawford	(Swanton et al.	potential cost				goals (Ingram	adaptati	(Doney et	and		
systems	costs, but no data.	2013).	al. 2008)	N/A	is scarce.	2013)	1996)	savings.	N/A	N/A	N/A	et al. 2016a).	on	al. 2009).	degradation	N/A	N/A

Table S6 Literature on Impacts on the UN SDG of integrated response options based on risk management

Integrated response options based on risk		GOAL 1: No	GOAL 2: Zero Hunger	GOAL 3: Good Health and	GOAL 4: Quality	GOAL 5: Gender	GOAL 6: Clean Water and	GOAL 7: Affordable and Clean	GOAL 8: Decent Work and Economic	GOAL 9: Industry, Innovation and	GOAL 10: Reduced	GOAL 11: Sustainable Cities and Communities	GOAL 12: Responsible Consumption	GOAL 13: Climate Action	GOAL 14: Life Below Water	GOAL 15: Life	GOAL 16: Peace and Justice Strong Institutions	GOAL 17: Partnershi ps to achieve the
management		Poverty	Zero Hunger	Well-being	Education	Equality	Sanitation	Energy	Growth	Infrastructure	Inequality	and Communities	and Production	Action	water	on Land	institutions	Goal
i l									Sprawl is									
i l			There are						associated			Urban sprawl is						
i l			likely to be						with rapid			associated with						
i l			some benefits						economic			unsustainability,						
i l			for food	Strong					growth in			including						
i l			security since	association					some areas			increased transport						
			it is often	between					(Brueckner			and CO ₂						
i l			agricultural	urban					2000).	Urban sprawl		emissions, lack of						
			land that is	sprawl and					Reducing	often increases		access to services,					There are	
			sealed by the	poorer					urban sprawl	public		and loss of civic					debates over	
			urban	health				Sprawling or	is part of	infrastructure		life (Kombe 2005;	Reducing urban				the role of	
			expansion	outcomes			Urban sprawl is	informal	many	costs (Brueckner		Andersson 2006).	sprawl and				urban sprawl	
ı		Inner city	(Barbero-	(air			associated with	settlements	managed	2000), and		Sustainable cities	promoting				in reducing	
ı		poverty closely	Sierra et al.	pollution,			higher levels of	often do not	"smart	densification		include	community				social capital	
i l		associated with	2013a). Some	obesity,			water pollution	have access to	growth" plans,	and		compactness,	gardens and				and	
i l		urban sprawl in	evidence for	traffic			due to loss of	electricity or	which may	redevelopment	Urban	sustainable	periurban	See main			weakening	
i l		US context	sprawl	accidents)			filtering vegetation	other services,	reduce overall	can improve	sprawl is	transport, density,	agriculture can	text on		See main	participatory	
i l		(Frumkin 2002;	reducing food	(Frumkin			and increasing	increasing	economic	equality of	associated	mixed land uses,	contribute to	climate		text on	governance in	
ı		Powell 1999;	production,	2002; Lopez			impervious	chances HH	growth in	access to	with	diversity, passive	more sustainable	mitigation		desertific	cities	
ı l	Management	Jargowsky	particularly in	2004;			surfaces (Romero	rely on dirty	return for	infrastructure	inequality	solar design, and	production in	and		ation and	(Frumkin	1
i l	of urban	2002; Deng and	China (Chen	Freudenberg			and Ordenes 2004;	fuels (Dhingra	sustainability	(Jenks and	(Jargowsky	greening (Chen et	cities (Turner	adaptatio		degradati	2002; Nguyen	1
i l	sprawl	Huang 2004)	2007b)	et al. 2005)	N/A	N/A	Tu et al. 2007)	et al. 2008)	benefits	Burgess 2000).	2002)	al. 2008; Jabareen	2011)	n	N/A	on	2010)	N/A

	,							•	1				1	•	•		•	,
ļ									(Godschalk			2006; Andersson						
ļ									2003)			2006)						
ļ					More													
Į.					diversified													
ļ			Diversification		households						The							
ļ			is associated		tend to be	Women are					relationship							
ļ			with increased		more affluent,	participants					between							
ļ.			access to	More	& have more	in and					livelihood							
ļ			income and	diversified		benefit from					diversificati	0	Livelihood					
ļ					disposal							One part of urban						
ŀ			additional	livelihoods	income for	livelihood					on and	livelihoods in	diversification					
Į.			food sources	have	education	diversificatio					inequality is	developing	does not always					
ŀ			for the	diversified	(Ellis 1998;	n, such as					inconclusiv	countries are	lead to					
ļ		Diversification	household	diets which	Estudillo and	having					e (Ellis	linkages between	sustainable					
ļ		is associated	(Pretty 2003);	have better	Otsuka 1999;	increased					1998). In	rural and urban	production and					
ļ		with increased	likely some	health	Steward	control over		Access to	Livelihood		some cases	areas through	consumption					
ļ													•					
,		welfare and	food security	outcomes	2007), but	sources of		clean energy	diversification		diversificati	migration and	choices, but it		ĺ			
Į.		incomes and	benefits but	(Block and	diversification	HH income		can provide	by definition		on reduced	remittances	can strengthen		ĺ			
Į.		decreased	diversification	Webb 2001;	through	(Smith		additional	contributes to		inequality	(Rakodi 1999;	autonomy		ĺ			
,		levels of	can also lead	Kadiyala et	migration	2015),		opportunities	employment		(Adams	Rakodi & Lloyd	potentially	See main	ĺ			
ļ		poverty in	to more	al. 2014)	may reduce	although it	Lack of access to	for livelihood	by providing		1994) while	2002); this	leading to better	text on	1	See main		
,		several country	purchased	particularly	educational	can increase	affordable water	diversification	additional		in others	livelihood	choices	climate	ĺ	text on		
ļ		studies (Arslan	(unhealthy)	for women	outcomes for	their labor	may inhibit	(Brew-	work		cases it	diversification can	(Elmqvist and	mitigation		desertific		
Į.		et al. 2018b;	foods (Niehof	and children	children	requirements	livelihood	Hammond			increases it	strengthen urban	Olsson 2007;	and		ation and		
ļ									opportunities									
ļ.	Livelihood	Asfaw et al.	2004; Barrett	(Pretty	(Gioli et al.	(Angeles and	diversification	2010; Suckall	(Ellis 1998;		(Reardon et	income (Ricci	Schneider and	adaptatio		degradati		
	diversification	2018).	et al. 2001)	2003)	2014)	Hill 2009)	(Calow et al. 2010)	et al. 2015)	Niehof 2004)	N/A	al 2000)	2012)	Niederle 2010)	n	N/A	on	N/A	N/A
Į.				Local seed														
ļ				use is														
ŀ				associated														
Į.				with fewer														
ļ				pesticides														
ļ																		
J				(Altieri et														
ļ			Local seeds	al. 2012b);														
ļ			revive and	loss of local														
ļ			strengthen	seeds and														
J			local food	substitution														
J			systems	by														
ļ			(McMichael	commercial									Locally					
J			and Schneider			***************************************							developed seeds					
,				seeds is		Women play			l						ĺ		01	G 1
ļ			2011b) and	perceived		important							can both help		1		Seed	Seed
ļ			lead to more	by farmers		roles in							protect local		1		sovereignty is	sovereignty
,		Many hundreds	diverse and	to increase		preserving			l		Seed		agrobiodiversity		ĺ		positively	could be
ļ		of millions of	healthy food	health risks		and using			Food		sovereignty		and can often be		1		associated	seen as
,		smallholders	in areas with	(Mazzeo		local seeds			sovereignty		advocates		more climate		ĺ		with strong	threat to
ļ		still rely on	strong food	and Brenton		(Ngcoya and			supporters		believe it		resilient than		1		local food	free trade
ļ		local seeds;	sovereignty	2013),		Kumarakulas			believe		will	Seed sovereignty	generic		1		movements,	and imports
ľ		without them	networks								contribute				ĺ		which	of
ļ				although		ingam 2017;			protecting			can help	commercial		1			
ľ		they would	(Coomes et al.	overall		Bezner Kerr			smallholder		to reduced	sustainable urban	varieties, leading		ĺ		contribute to	genetically
ļ		have to find	2015a; Bisht	literature on		2013) and			agriculture		inequality	gardening	to more		1		social capital	modified
Į.		money to buy	et al. 2018).	links		sovereignty	Local seeds often		provides more		(Wittman	(Demailly and	sustainable	See main	ĺ		(McMichael	seeds
Į.		commercial	However local	between		movements	have lower water		employment		2011; Park	Darly 2017) which	production	text on	ĺ	See main	and Schneider	(Kloppenbe
ļ		seeds (Altieri et	seeds often are	food		paying more	demands, as well		than		et al. 2015)	can be part of a	(Coomes et al.	climate	1	text on	2011b;	rg 2010;
ļ		al. 2012b;	less	sovereignty		attention to	as less use of		commercial		but there is	sustainable city by	2015a; van	mitigation	1	desertific	Coomes et al.	Howard
ļ		ai. 20120,	1035															2015;
		McGuiro and	productivo	and boolth :-		gondor poods												
i		McGuire and	productive	and health is		gender needs	pesticides that can		agriculture		inconclusiv	providing fresh,	Niekerk and	and		ation and	2015a; Grey	
ŀ	Use of local seeds	McGuire and Sperling 2016; Howard 2015)	productive than improved varieties.	and health is weak (Jones et al. 2015)	N/A	gender needs (Park et al. 2015)	pesticides that can contaminate water (Adhikari 2014)	N/A	agriculture (Kloppenberg 2010)	N/A	e empirical evidence.	local food (Leitgeb et al. 2016).	Wynberg 2017a).	and adaptatio n	N/A	ation and degradati on	and Patel 2015).	Kloppenbur g 2014)

Diesetor risk	DRM can help prevent impoverishment as disasters are a major factor in poverty (Basher 2006; Estherrill and	Famine early warning systems have been successful to prevent impending food shortages (Genesio et al. 2011; Hillbruner and Molones:	EWS very important for public health to ensure people can get shelter and medical care during disasters (Greenough et al. 2001; Ebi and Schmier		Women often disproportion ately affected by disasters; gender-sensitive EWS can reduce their vulnerability (Enarson and Meyreles 2004; Mustefe et	Many EWS include water monitoring components that contribute to access to clean water (Wilhite 2005; Iglesias et al. 2007). Some urban areas use water EWS successfully to monitor levels of contaminants (Hazan et al. 2009)		DRM can help minimise damage from disasters, which impacts economic	DRM can help protect infrastructures from damage during disaster (Rongers and	EWS can ensure inequality is taken into account when making predictions of impacts	EWS can be very effective in urban settings such as heat wave EWS and flooding EWS to minimise vulnerability (Parnell et al. 2007; Bambrick et al. 2011; Disorlieus for al.	DRM can make sustainable production more possible by providing farmers with advance notice of environmental needs (Stigter et	See main text on climate mitigation and	EWS can play important role in marine managemen t, e.g. warnings of red tide, tsunami warnings for coastal communitie s (Lee et al. 2005;	See main text on desertific ation and	DRM can reduce risk of conflict (Meier et al. 2007), increase resilience of communities (Mathbor 2007) and strengthen trust in institutions (Altierie et al.	
Disaster risk management	Fothergill and Peek 2004)	Moloney 2012)	Schmier 2005)	N/A	Mustafa et al. 2015)	(Hasan et al. 2009; Hou et al. 2013)	N/A	growth (Basher 2006)	(Rogers and Tsirkunov 2011)	(Khan et al. 1992)	Djordjević et al. 2011)	al. 2000; Parr et al. 2003)	adaptatio n	Lauterjung et al. 2010)	degradati on	(Altieri et al. 2012b)	N/A
	100 100 10	Availability of			Women	Crop insurance can be indexed to weather and water access and thereby increase adapation		(Marie 2000)				Crop insurance has been implicated as a		There is mixed evidence that crop insurance may encourage excess fertiliser use (Kramer et al. 1983; Wu 1999; Smith and Goodwin 1996), which contributes to ocean pollution; however, some government			
	Crop insurance	Availability of crop insurance	General		farmers vulnerable to	increase adapation to water stress		Subsidised				implicated as a driver of		government s re			
	reduces risks	has generally	forms of	Households	crop shocks,	(Hoff and Bouwer		crop insurance				unsustainable		requiring			
	which can	lead to	social	lacking	but tend to	2003). Subsidised		contributes to				production and		reductions			
	improve	(modest)	protection	insurance	be more risk-	insurance can also		economic				disincentive to		in nonpoint			Subsidised
	poverty outcomes by	expansions in cultivated land	lead to better health	may withdraw children from	averse and skeptical of	be linked to reductions in		growth in the US (Atwood				diversification (Bowman and		source pollution		Community risk sharing	crop insurance
	avoiding	area and	outcomes;	school after	commercial	pesticide use to		et al. 1996)				Zilberman	See main	from farms		instruments	can be seen
	catastrophic	increased food	unclear how	crop shocks	insurance	reduce non-point		but at		1		2013), although	text on	otherwise	See main	can help	as a subsidy
	losses, but is	production	much crop	(Jacoby and	(Akter et al.	source pollution,		considerable		1		community risk	climate	farmers lose	text on	strenthen	and barrier
	often not used	(Claassen et	insurance	Skoufias	2016;	which has shown		cost to the		1		sharing might	mitigation	crop	desertific	resilience and	to trade
District order	by poorest	al. 2011;	contributes	1997;	Fletschner	success in the US		governance		1		increase	and	insurance	ation and	institutions	(Young and
Risk sharing	people (Platteau	Goodwin et al. 2004)	(Tirivayi et al. 2016)	Bandara et al. 2015)	and Kenney 2014)	and China (Luo et al. 2014)	NI/A	(Glauber 2004).	N/A	N/A	N/A	diversification	adaptatio	(Iho et al. 2015)	degradati	(Agrawal 2001)	Westcott 2000)
 instruments	et al. 2017)	2004)	ai. 2010)	2013)	2014)	ат. 2014)	N/A	2004).	IV/A	IN/A	IV/A	and production	n	2015)	on	2001)	2000)