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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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1 Abstract

2

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
- 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
- 12 a relatively small number of interventions show significant positive synergies with both SDGs
- 13 and NCPs, including increasing soil organic matter, improved cropland, grazing land and
- 14 livestock production, sustainable sourcing, reducing postharvest waste and losses, and disaster
- 15 risk management. Several interventions show strong negative impacts on either SDGs, NCPs or
- 16 in some cases, both, including bioenergy, afforestation, and some risk sharing measures, like
- 17 commercial crop insurance. Our results demonstrate that better understanding of benefits and
- 18 trade-offs of comparative policy approaches can help decisionmakers choose the most effective,
- 19 or at the very minimum, the less negative interventions for implementation in specific contexts.
- 20 21

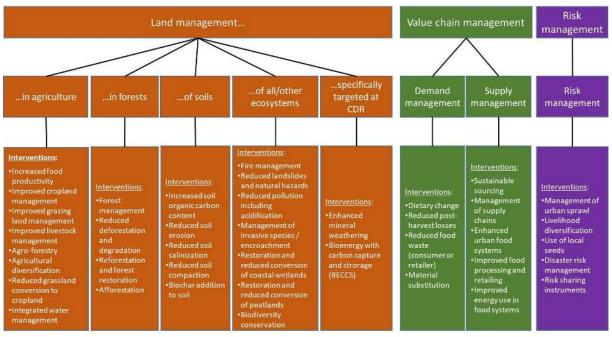
1. Introduction

22 The world currently faces a series of interrelated problems: climate change, biodiversity and 23 ecosystems loss, land degradation, and poverty, among others, highlighting the need for 24 transformative solutions that cut across these challenges. This has highlighted hopes that changes 25 in how we use land might be able to co-deliver multiple benefits, such as reduced greenhouse gas 26 emissions, increased adaptive capacity to current and future climate changes, improved land 27 health and quality, and improved access to and productivity of agriculture to reduce food 28 insecurity and poverty. However, a major dilemma is how to access these multiple benefits 29 without undue adverse side effects on other social development goals or on natural ecosystems. 30

31 Numerous potential options have been suggested to address these land challenges, and this study 32 assesses 40 of the response options examined in the most recent IPCC report (on climate change 33 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 34 35 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 36 37 biodiversity and water, and against their impacts on people, such as poverty reduction efforts or 38 gender equality measures. We do so by assessing the 40 practices against 18 identified Nature's 39 Contributions to People (NCP), a new term for ecosystem services used by the

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

- 1 2019), and the 17 UN Sustainable Development Goals (SDGs), in order to identify those that 2 result in least trade-offs and most co-benefits.
- 3
- 4 The 40 practices considered in this study were categorized into those that rely on a) land
- 5 management, b) value chain management and c) risk management (Figure 1). The land
- 6 management practices can be grouped according to those that are applied in agriculture, in
- 7 forests, on soils, in other/all ecosystems and those that are applied specifically for carbon dioxide
- 8 removal (CDR). The value chain management practices can be categorised as those based
- 9 demand management and supply management. The risk management options are grouped
- 10 together. Smith et al. (2019) provides further details on each of the response options and how
- 11 they were evaluated.
- 12



- 13
- Figure 1. Broad categorisation of practices categorised into three main classes and eight sub-classes.
- 16

17 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
- increase or decrease the supply of ecosystem services/NCP can be a useful shorthand for a morecomprehensive environmental impact. Such evaluations are important as response options may
- 21 lead to unexpected trade-offs (adverse side effects) or potential co-benefits with social goals and
- 22 important environmental indicators like water or biodiversity. These synergies and co-benefits
- 23 associated with some response options may increase their cost-effectiveness or attractiveness.
- 24 Because many of these synergies are not automatic and are dependent on well-implemented and
- 25 coordinated activities in appropriate environmental contexts, often requiring institutional and

1 enabling conditions for success and participation of multiple stakeholders, it is important to

- 2 identify these interactions early on in decision-making processes (IPCC 2019).
- 3

4 In defining co-benefits and adverse side effects, we use the IPCC AR5 WGIII definitions: co-

5 benefits are "positive effects that a policy or measure aimed at one objective might have on other

6 objectives, thereby increasing the total benefits for society or the environment" while adverse

7 side-effects are "negative effects that a policy or measure aimed at one objective might have on

8 other objectives, without yet evaluating the net effect on overall social welfare." Both co-benefits

9 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).

12

13 Assessing policy options against their co-benefits and adverse side effects needs to account for 14 impacts on both natural and human systems. The importance of assessing a range of climate 15 change response options and policies against the SDGs in particular was emphasized in the IPCC 16 1.5 report, especially Figure SPM4 (IPCC 2018). In this approach, mitigation options were 17 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 18 19 noted for SDG 1 and 2 (zero poverty and no hunger) and SDG 6 and 15 (clear water and 20 sanitation and life on land), while positive effects were noted on SDG 3 (good health) and SDG 7 21 (affordable and clean energy). However, as many commentators have pointed out, it is 22 insufficient to judge progress against SDGs alone, as many of the planetary support systems that 23 make sustainable development possible might be degraded through economic development, 24 hence there is a need for indicators of ecosystem change and health as well beyond some of the 25 SDGs specifically focused on ecosystems (SDG 14 and 15) (Griggs et al. 2013). 26 27 We chose to examine NCP as indicators of ecosystem benefits and services. Ecosystem services 28 have become a useful concept to describe the benefits that humans obtain from ecosystems, 29 while NCP is a newer approach championed by IPBES, defined as "all the contributions, both 30 positive and negative, of living nature (i.e., diversity of organisms, ecosystems and their 31 associated ecological and evolutionary processes) to the quality of life of people" (Díaz et al.

32 2018). However, IPBES has stressed NCP are a particular *way to think* of ecosystem services,

33 rather than a replacement for the concept (Pascual et al. 2017; Díaz et al. 2018). Many mitigation

34 actions may have positive impacts on adaptation or food production (Carpenter et al. 2009) but

35 may also come with a decline in ecosystem provisioning, or adversely impact biodiversity (Foley

36 et al. 2005), which is why it is important to specifically assess them. Global climate models are

37 increasingly incorporating some ecosystem services/NCP indicators to understand vulnerability

to change or loss in future climate scenarios (Schröter et al. 2005).

- 39
- 40

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	

2 3

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

11 they were useful for one or both. On the other hand, the NCP "regulation of climate" does not

1 include an adaptation component, and refers to specifically to "positive or negative effects on

2 emissions of greenhouse gases and positive or negative effects on biophysical feedbacks from

3 vegetation cover to atmosphere, such as those involving albedo, surface roughness, long-wave

4 radiation, evapotranspiration (including moisture-recycling) and cloud formation or direct and

- 5 indirect processes involving biogenic volatile organic compounds (BVOC), and regulation of
- 6 aerosols and aerosol precursors by terrestrial plants and phytoplankton" (Díaz et al. 2018).
- 7

8 For the evaluation process for NCP, we considered that NCP are about ecosystems, therefore

9 options which may have overall positive effects, but which are *not* ecosystem-based are not

10 included; for example, improved food transport and distribution could reduce ground-level ozone

11 and thus improve air quality, but this is not an ecosystem-based NCP. Similarly, energy

12 efficiency measures would increase energy availability, but the 'energy' NCP refers specifically

13 to biomass-based fuel provisioning. This necessarily means that the land management options

14 have more direct NCP effects than the value chain or governance options, which are less

15 ecosystem-focused.

16

17 In evaluating NCP, we have also tried to avoid 'indirect' effects – that is a response option might

18 increase household income which then could be invested in habitat-saving actions, or dietary

19 change would lead to conservation of natural areas, which would then led to increased water

20 quality. These can all be considered *indirect* impacts on NCP, which were not evaluated².

21 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

23 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

26 one another (Rodriguez et al 2006), so supply of one might lead to less availability of another –

27 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

29 interactions between NCPs are not mapped directly in our assessment.

30

31 For our assessment of SDGs, the literature was particularly uneven. Because many land

32 management options only produce indirect or unclear effects on SDG, we did not include these

33 where there was no literature. Therefore, the value chain and risk management options appear to

34 offer more direct benefits for SDGs. Further, it is noted that some SDG are internally difficult to

35 assess because they contain many targets, not all of which could be evaluated (e.g., SDG 17 is

36 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).
- 9

10 **3. Results**

11 In the sections below, we provide the primary interactions arising from the extensive literature

- 12 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:
- 14 positive (blue) or negative (brown), and the scale of the impact (dark colours for large impact
- 15 and/or strong evidence to light colours for small impact and/or less certain evidence).
- 16 Supplementary tables show the values and references used to define the colour coding used in all
- 17 tables. In cases where there is no evidence of an interaction or at least no literature on such
- 18 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
- 22 specific caveats that may apply.
- 23 24

3.1 Interactions of the options on NCP supply

- 25 Tables 2-4 summarise the impacts of the response options on NCP supply. Examples of
- 26 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).
- 32
- 33 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*.
- 37
- 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).

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 -					
Improved forest management and forest restoration									+ or -				+ or -					

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

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

Bioenergy and	BECCS ³							
		Medium positive	Small		Medium negative			
LEGEND:	Large positive impacts, strong evidence	impacts, some evidence	positive impacts, low evidence	Low negative impacts, low evidence	impacts, medium evidence	Large negative impacts, high evidence		

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 sourcing													
Management of supply													
chains													
Enhanced urban food													
systems													
Improved food													
processing and retail													
Improved energy use in													
food systems													
Large po impacts,		Medium positive impacts, some	-	all itive acts, lo	w negati pacts, lo	ive	Medium negative impacts, medium	rge ne pacts,	-	e			
LEGEND: evidence	-	evidence	-	lence	idence		evidence	idence	-				

Integrated resp based on risk n Management o 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																			
Disaster risk m	anagement																		
Risk sharing in																			
LEGEND:	Large posit impacts, str evidence	ive ong	Medium positive impacts, some evidence		Small positiv impact eviden	ts, low	Low n impact eviden		Med nega impa med evid	ative acts, ium	Large impact eviden	s, hig							

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

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 45 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 46 47 over multiple SDG with potentially significant adverse consequences.

T-11. 5 T 44 41.	INCOC . C		
1 able 5. Impacts on the	e UN SDG of integrated res	ponse options based on land	management

<u>Integrated response options</u> <u>based on land management</u> Increased food productivity	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
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											
											<u> </u>
Increased soil organic carbon content											
Reduced soil erosion											
Reduced soil salinisation											
Reduced soil compaction											
Biochar addition to soil											
											11
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 -									
		I		. <u> </u>			I				I]
Enhanced weathering of minerals											

Bioenergy and	BECCS ⁴	+ or -		+ or -														
LEGEND:	Large positive impacts, strong evidence	Mediu positiv impac some evider	ve ts, nce	imp evi	itive bacts, dence		impact eviden	ce	Medin negati impac mediu evider	ive ets, im nce	impa evide							
	Т	able 6.	Impa	cts on th	e UN	SDC	d of integ	grated re	sponse o	ptions h	ased	on value	chain ir	iterve	entior	ıs		
on value chain	onse options based 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
Dietary change																		
Reduced post-h																		
Reduced food w retailer)	vaste (consumer or																	
Material substit	ution																	
Sustainable sou	rcing																	

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 energy	y use in food													
systems														
LEGEND:	Large positive impacts, strong evidence	Medi positi impac some evide	ve ets,	imp	all iitive pacts, dence		Small impact	Mediu negati impac mediu evider	ive ets, 1m	-	e negativ cts, high ence			

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 -					

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

62 **3.3 Interactions between SDGs and NCPS**

63 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 64

65 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-66
- 67 harvest losses, sustainable sourcing, improved energy use in food systems, livelihood
- 68 diversification and disaster risk management. Only three options (afforestation, bioenergy

69 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 70 shading).

- 71
- 72

	Positive Co-	Positive Co-	Adverse	Adverse		
	benefits for	benefits for	Side Effects	Side Effects		
	<u>NCPs</u>	<u>SDGs</u>	for NCPs	for SDGs		
Increased food productivity	2	<u>3D03</u> 12	4	101 00 05		
	-		-			
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				

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

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 &		11		1
retail				
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

74 Notes: Columns are sums of categories of co-benefits and side effects from Tables 2-7 and do not

75 indicate magnitude of effect (e.g. large, medium or small benefits). ~ indicates a mixed effect.

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

77 Brown indicates presence of significant adverse side effects

78

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

80 options stand out as being particularly good across a range of SDGs, but few NCPs: increased

81 food productivity, dietary change, reduced food loss and waste, management of supply

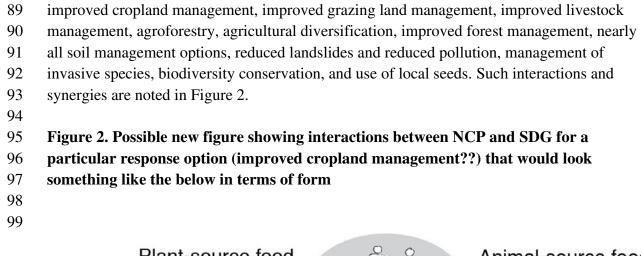
82 chains, enhanced urban food systems, improved food processing and retail, and improved

83 energy use in food systems, livelihood diversification, disaster risk reduction and risk sharing

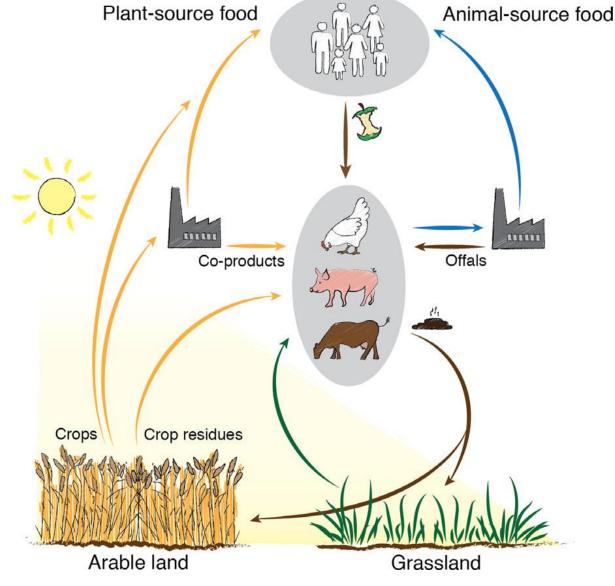
84 instruments. Conversely, some options deliver co-benefits for many NCPs but few SDGs:

85 avoidance of grassland conversion, reduced deforestation and degradation, reforestation and

86 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:



102 **4. Discussion**

103 Decisionmakers are increasingly asking for policy options that will help them meet agreed-

104 upon global goals like the Paris Agreement or the SDGs. Our assessment across an extended

105 literature review has been as comprehensive as possible (forty options times 18 NCPs and 17

106 SDGs) and robust (literature in the thousands of documents) to provide some direction to

107 such policymaking. Below we discuss the primary findings, limitations of the study, and

108 some future research directions.

109 Our findings of co-benefits and adverse side effects should be combined with attention to

- 110 how the response options deliver across objectives such as mitigation, adaptation, land
- 111 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
- 114 grazing land management, improved livestock management, agroforestry, improved forest
- 115 management, increased soil organic carbon content, fire management and reduced post-
- harvest losses. For mitigation only, five options have large potential (> 3 $GtCO_2e yr^{-1}$)
- 117 without adverse impacts on the other land challenges: increased food productivity, reduced
- 118 deforestation and degradation, increased soil organic carbon content, fire management and
- reduced post-harvest losses. Sixteen practices have large adaptation potential (>25 million
- 120 people benefit), without adverse side-effects on other land challenges: increased food
- 121 productivity, improved cropland management, agroforestry, agricultural diversification,
- improved forest management, increased soil organic carbon content, reduced landslides and
- 123 natural hazards, restoration and reduced conversion of coastal wetlands, reduced post-harvest
- 124 losses, sustainable sourcing, management of supply chains, improved food processing and
- 125 retailing, improved energy use in food systems, livelihood diversification, use of local seeds,
- 126 and disaster risk management.
- 127

128 **4.1 Co-benefits for people and nature**

129 There are a range of potential synergies and co-benefits provided by the assessed response

130 options. For example, there are positive co-benefits between response options and important

131 SDGs including positive poverty reduction impacts from activities like increased food

- 132 productivity and livelihood diversification. Table 9 indicates the strongest positive
- 133 relationships between options and specific SDGs, providing a possible template for what the
- 134 better response options for each SDG might be.
- 135

136 **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

	dimension and and a site of a state of the
	diversification, reduced soil erosion and
	salinisation, reduced post-harvest losses,
	enhanced urban food systems, management
	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
SDG 0. Decent work and economic growth	food systems
SDG9: Industry, innovation and	Sustainable sourcing
infrastructure	Sustainable sourcing
SDG10: Reduced inequality	Dietary change, reduced losses,
SD010. Reduced mequanty	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
	conservation, bioenergy &BECCS
SDG 15: Life on land	Increased food productivity, improved
	cropland, grazing and livestock
	management, agroforestry, avoided
	management, agrororestry, avolueu

	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	

138 Examples of positive co-benefits between response options and NCPs include positive

139 ecosystem impacts on habitat maintenance from activities like reduced land conversion

140 (across forests, grasslands, wetlands and peatlands) fire management. Table 10 indicates the

141 strongest positive relationships between options and specific NCPs, providing a possible

142 template for what the better response options for each NCP might be.

143

144 **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,

NCD 7. Deculation of functions of 1	Interneted water management and the 1
NCP 7: Regulation of freshwater and coastal	Integrated water management, reduced
water quality	deforestation, increased soil carbon,
	reduced soil erosion, salinisation and
	compaction, reduced pollution, restoration
	and avoided conversion of wetlands and
	peatlands,
NCP 8: Formation, protection and	Improved cropland and grazing land
decontamination of soils and sediments	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
	~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~

146 The strong synergies between positive co-benefits with both NCPs and SDGs on a number of

147 response options is an important finding that indicates there are potentially win-wins that do

148 not require the degradation of natural capital and ecosystems to achieve poverty and

- 149 development objectives (Miteva 2019). However, all too often such options are not
- 150 implemented in an integrated manner, and the synergies are not managed for explicitly,
- 151 which can result in lost opportunities (IPCC 2019).
- 152

153 **4.2 Study limitations**

154 The literature assessed points to general directions of interactions, but much more 155 information is needed to make more accurate assessments. For nearly all interactions, we

- 156 could assess only positive or negative qualitative trends, without the possibility of
- 157 quantification. Further, because many of the NCPs and SDGs trade-off within and between

158 one another, simple additive assessments cannot fully capture the range of interactions and

- 159 the context for any given options needs to be considered carefully.
- 160

161 Assessing the literature across the global scale has also meant that many important, context-

162 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.

164 Importantly, all land-based options are scale dependent, and the potential adverse side effects

165 of practices such BECCS are reflective of large-scale implementation (such as greenhouse

166 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 sustainablymanaged landscapes (see Smith et al. 2019).

169

170 Further, many of the positive synergies are not automatic, and are dependent on well-

implemented activities requiring institutional and enabling conditions for success (IPCC2019).

173

174 **4.3 Data gaps and future research**

175 As tables 2-7 show, there are considerable knowledge gaps. Many response options have not

176 been investigated for their impacts on SDGs or NCPs. There are many suggestive

177 relationships that suggest further research. These include interactions of all the response

178 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

180 options impact on gender dynamics is problematic and troubling. Further, given how

- 181 important land management is for the supply of NCPs, we would expect more research to be
- 182 conducted on the full range of NCPs from different land management practices, but certain
- 183 NCPs have greater limitations in the literature than others (e.g. little information on184 pollination, or harmful pests),
- 185

4.4 Conclusions

187 Many land challenges can be met with existing tools and technologies, such as changing the

188 conversion of natural ecosystems to croplands or increasing the soil carbon content using

189 basic technologies like cover crops and minimal tillage. Use of these response options can

190	result in numerous co-benefits, and with minimal side effects on SDGs and NCPs and other
191	societal goals. Portfolios of different response options are possible and are applicable at
192	different scales, from farm to international, and the fact that there is such a wide range of
193	adaptation and mitigation responses that have the potential to make positive contributions to
194	sustainable development, ecosystem services and other societal goals is good news. Overall,
195	our assessment concludes that a number of response options can both make a dent in
196	mitigation, adaptation, land degradation or food security and at the same time contribute to
197	eradicating poverty and eliminating hunger, promoting good health and wellbeing, clean
198	water and sanitation, and other positive benefits. However, care must be taken to
199	acknowledge and manage any potential trade-offs, as well as encourage synergies and co-
200	benefits. Land management-based options that require land use change can particularly
201	adversely affect efforts to eradicate poverty and eliminate hunger (Molotoks et al., 2018);
202	such trade-offs were identified with afforestation, BECCS and some risk sharing instruments
203	(particularly commercial crop insurance). Ensuring that policymakers can anticipate these
204	adverse side-effects in advance, and potentially choose the most appropriate response options
205	for their particular contexts and challenges, will require more assessments such as these, and
206	increased attention to these interactions in the overall literature.
207	
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209	
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- 235 Supplementary Online Material for "The impact of interventions in the global land and agri-food sectors on Nature's Contributions to
- 236 **People and the UN Sustainable Development Goals**"
- 237 Table S1 Literature on Impacts on Nature's Contributions to People of integrated response options based on land management

Integrate	1											r		1		1			
												1							
<u>d</u>															Medicinal		Physical		
response															Medicinal				
options			Pollination				Regulation of		Formation,						· · · ·		and		
based on			and dispersal				freshwater	Regulation of	protection and	Regulation of	Regulation of			Materi	biochemi		psycholo		
land		Habitat	of seeds and			Regulation	quantity,	freshwater and	decontaminatio	hazards and	organisms			als and	cal and	Learning	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	timing	quality	sediments	events	humans	Energy	feed	nce	resources	inspiration	ces	identities	of options
						Increased	Food												
						food	productivity												
						productivity	increases												
			Likely may			might be	could impact												
			reduce native			achieved	water quality												
			pollinators if				if increases in	Food	Intensification										
			•			through													
			reliant on			increased	chemicals	productivity	through										
		Higher	increased			pesticide or	used, but	increases could	additional input										
		productivity	chemical			fertiliser use,	evidence is	impact water	of nitrogen		Increasing food								
		spares land	inputs (Potts			which	mixed on	flow due to	fertiliser can		production								
		(e.g. Balmford	et al. 2010)			causes	sustainable	demand for	result in negative		through agro-		Sustainable						
		et al. 2018)	but not if			runoff and	intensification	irrigation	impacts on		chemicals may		intensification						
		especially if	through			dead zones	(Rockström et	(Rockström et	climate, soil,		increase pest		has potential						
		intensification	sustainable			in oceans	al. 2009;	al. 2009;	water and air		resistance over		to close yield						
	Increased food	is done	intensification			(Beusen et	Mueller et al.	Mueller et al.	pollution (Tilman		time (Tilman et		gaps (Tilman						
	productivity	sustainably.		N/A	N/A	al. 2016).	2012).	2012).	et al. 2002).	N/A	al. 2002).	N/A	et al. 2011).	N/A	N/A	N/A	N/A	N/A	N/A
							Cropland												
							conversion												
							has major												
							impacts on												
							water quantity						Conservation						
							(Scanlon et al.						agriculture						
		1																	
		Improved					2007).						contributes to						
		cropland					Cropland						food						
		management					management						productivity						
		can contribute	Better crop				practices such				Some forms of		and reduces						
		to diverse	management				as				improved		food						
		agroecosystems	can contribute				conservation		Improved		cropland		insecurity					Many	
		(Tscharntke et	to			Mitigation	tillage	Cropland	cropland		management		(Rosegrant					cropping	
		al. 2005) and	maintaining			potential	improve	conversion leads	management has		can decrease		and Cline					systems have	
		promotes soil	native			(see main	downstream	to poorer water	positive impacts		pathogens and		2003 ; Dar &					cultural	
	Improved	biodiversity	pollinators		See main text	text) will	water quality	quality due to	on soils (see		pests		Gowda 2011;					components	
	cropland	(Oehl et al.	(Gardiner et		for mitigation	reduce ocean	(Fawcett et al.	runoff (Scanlon	main text) (Kern		(Tscharntke et		Godfrey &					(Tenberg et al	
	management	2017)	al. 2009).	N/A	potentials	acidification.	1994).	et al. 2007).	et al. 2003).	N/A	al. 2016).	N.A	Garnett 2014)	N/A	N/A	N/A	N/A	2012).	N/A
														Grassla					
														nd					
														manage					
														ment					
														can					
														provide					
														other					
														material					
									T				T	s (e.g.					
									Improved				Improved	biofuel				Many	
		Can contribute				Mitigation			grassland				grassland	material				pastoralists	
		to improved				potential	Likely will		management				management	s)				have close	
		habitat (Pons et				(see main	improve water	Likely will	increases soil				could	(Prochn				cultural	
	Improved	al. 2003;			See main text	text) will	quality	improve water	carbon and				contribute to	ow et				connections to	
Agricult	grazing land	Plantureux et al			for mitigation	reduce ocean	(Hibbert	flow (Hibbert	quality (Conant				food security	al.				livestock	
ure	management	2005).	N/A	N/A	potentials	acidification.	1983).	1983)	et al. 2001).	N/A	N/A	N/A	(O'Mara 2012)	2009)	N/A	N/A	N/A	(Ainslie 2013)	N/A
-																			

							Improved industrial											
Improved	Can contribute to improved habitat if more efficient animals used, leading to less feed required			See main text	Mitigation potential (see main text) will		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 management					Improved livestock management can contribute to reduced food insecurity among smallholder pastoralists	Livesto ck product ion also produce s material s for use (leather , etc)				Many pastoralists have close cultural connections to	
livestock management	(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
o Agro-forestry	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 (Ilstedt 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, firewo d and animal fodder (Mbow et al., 2014) Diversif	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).
Agricultural diversification	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)
Avoidance of conversion of grassland to cropland	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				
														support				
										Change in				s				
										water				favoura				
										availability				ble				
		Ecosystem								through				forests				
		health and								-				conditio				
										improving co-								
		services can be								managing				ns				
		enhanced by								floods and				thereby				
		improving								groundwater				providi				
		water								depletion at				ng				
		management								the river basin				wood				
		(Boelee E and								such as				and				
		E 2011).								Managed				fodder				
		Securing								Aquifer			Increasing	and				
		ecosystem								Recharge			demand for	other				
		(Lloyd et al.								(MAR),			food, fiber	material				
		2013),						Improving		Underground			and feed will	s				
		integrated						regulation to		Taming of			put great	(Locate				
		0						0		Floods for				lli et al.				
		ecosystem-						prevent aquifer					strains on					
		based						and surface		Irrigation			land, water,	2015a).				
		management						water depletion,		(UTFI),			energy and	Howev				
		into water						controlling over		restore over-			other	er,				
		resources						water extraction,		allocated or			resources	conserv				
		planning and						improvement of		brackish			(WBCSD,	ation				
		management,						water		aquifers,			2014). Water	restricti				
		linking						management and		groundwater			conservation	ons on				
		ecosystem					Improving	management of		dependent			and balance in	the				
		services and			IWM		regulations for	landslides and		ecosystems			the use of	storage				
		water security			supports		water sharing,	natural hazards.		protection,			natural	and				
		(Nicole Bernex	Some		favourable		trading and	Watering		reducing			resources	flow of				
		2016),	integrated	IWM	forests		pricing (ADB	shifting sand		evaporation			enforcement	water in				
		improving	water	practices	conditions		2016), water	dunes		losses are			(based water	watersh				
		correlation	management	exert strong	thereby		smart	(sprinkler),		significantly			resources,	eds				
		between	strategies	influence on	influencing		appliance,	water resources		contributed to			water	(Eisenb				
			0		0		••	conservation										
		amount of	generate	ecosystem	the storage		water smart			response			conservation	ies et				
		water resources	synergies	structure and	and flow of		landscapes	(Nejad 2013;		climate			measures,	al.				
		and supply	between	function, with	water in		(Dawadi and	Pereira 2002a),	IWM provide co-	change and			water	2007)				
		ecosystem	multiple	potentially	watersheds		Ahmad 2013),	enhancing	benefits such as	reduced		IWM can	allocations)	can				
		services,	ecosystem	large	(Eisenbies et		common and	rainwater	healthier soils,	impacts of		support the	(Ward et al.	restrict				
		combining	services, such	implications	al. 2007)		unconvention	management,	more resilient	extreme		production	2008) are	the				1
		water resources	as pollination,	for regulating	which are		al water	reducing	and productive	weather event		of biomass	good options	access				1
1		management	yield and	air quality	important for	1	sources in use	recharge and	ecosystems	in		for energy	to response	to				1
		and supply of	farm	(Xia et al.,	regulating		(Rengasamy	increasing water	(Grey and Sadoff	desertification		and	climate	resourc				1
1	Integrated	ecosystem	profitability	2017;	microclimates	1	2006) will	use in discharge	2007; Liu et al.	areas (Dillon		firewood	change and	es (e.g.				1
	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
	management	al. 2016).	al, 2018).	al, 2019).	al., 2017).	N/A	quantity.	2011).	2011)	2016b).		al., 2014).	prevention.	d).				1
L	g-incit		,0).	,)).	,).		<i>j</i> .	/-):	I	,	r		l	I	I	1

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										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		1	competition	1	1		(Maginni		
1		(Maginnis and		matter on						prolonging		1	for land	1	1		s and		
		Jackson 2007;		plant surfaces						rotation			between	Forests			Jackson		
		Stanturf et al.		and the						periods may			afforestation/r	provide			2007;		
		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			and		
		"middle way"		(t) of air			rise. However,	2010a; Salvati et	Forests	structural			to increases in	preserv			generally		
1		between		pollution in			forests also	al. 2014).	counteract wind-	complexity	Forests can	1	food prices	e	1		improve		
		deforestation		2010 (range:			can have	Precipitation	driven	and may	contribute to		through	ecosyst			the		
		and total		9.0-23.2			adverse side-	filtered through	degradation of	make forest	weed and pest		increasing	em			cultural		
		protection,		million t),			effects for	forested	soils, and	ecosystems	control and		land	integrit			and		
1		allowing to		with human			reduction of	catchments	contribute to soil	more	landscape	SFM may	competition	y can	1		recreatio		
		retain		health effects			water yield	delivers purified	erosion	susceptive to	diversity	increase	(Calvin et al.	restrict			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	1	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).
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т г				l.	1		1				1	The second states		1				
												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						
1							and in distant					production is						
							location, and					a potentially						
i I							trees' microbial				1				1			
i I											1	large adverse			1			
							flora and					side-effect						
i I							biogenic volatile				1	(Boysen et al.			1			
							organic					2017a,b;						
							compounds can					Kreidenweis						
				1	1		directly promote	Forests	Forest cover			et al. 2016;						
	Reduced						rainfall (Arneth	counteract wind-	can stabilise			Smith et al.						
1	deforestation					Forests tend	et al. 2010).	driven	land against			2013) that can						
1	can enhance					to maintain	Trees enhance	degradation of	catastrophic		1	lead to			1			
1 1	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	2017; Locatelli	pollinators	problems	See main text	text) will	et al. 2010a;	2005; Ellison et	resilience	flood events	pest control	wood for	2012; Smith et	(Grisco	(Arnold &	learning	ities	components	genetic
and	et al. 2011,a	(Kremen et al.	(Novak et al.,	for mitigation	reduce ocean	Salvati et al.	al. 2017; Neary	(Locatelli et al.	(Locatelli et	(Gardiner et al.	energy and	al. 2013; Wise	m et al.,	Perez	(Turtle et	(Liddle	(Plieninger et	diversity (Ekins
	2015a)	2007)	2014)	potentials	acidification.	2014).	et al. 2009).	2015a).	al. 2015a)	2009)	industry	et al. 2009).	2017)	2001)	al., 2015)	(Endane 1997)	al. 2015)	et al., 2003).
	Forest	2007)	201.17	Potentiais	acianteation.	201.17.		_01.047.	a. 2013a)	2007)	maasuy	The proximity	Forests	2001)	, 2013)	•///)		5. un, 200 <i>5)</i> .
	landscape										1	of forest to			1			
											1		provide		1			
	restoration			1	1				Ferret			cropland	wood					
	specifically								Forest cover		1	constitutes a	and		1			
	aims to regain								can stabilise			threat to	fodder					
	ecological								land against		1	livelihoods in	and		1			
	integrity and								catastrophic			terms of crop	other					
i I	enhance human						Particular		movements		1	raiding by	material		1			
	well-being in						activities		associated		1	wild animals	s		1			
	deforested or						associated with		with wave		1	and in	(Locate		1			
	degraded forest						forest landscape		action and			constraints in	lli et al.					
i I	landscape						restoration, such		intense run-		1	availability of	2015a).		1			
		1					as mixed		off during		1	land for	Howev		1	Afforesta		
	(Maginnis and				1	1	planting,		storms and			farming (Few	er,			tion/refor		
	(Maginnis and Jackson 2007;							1		I	1	et al. 2017),.	conserv		1	estation		
							assisted natural		flood events									
	Jackson 2007;								(Locatelli et			The	ation			can		
	Jackson 2007; Stanturf et al. 2014). Adverse					Forests tend	regeneration,		(Locatelli et							can		
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects					Forests tend	regeneration, and reducing		(Locatelli et al. 2015a)			competition	restricti			can increase		
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially					to maintain	regeneration, and reducing impact of		(Locatelli et al. 2015a) Some forest			competition for land	restricti ons to			can increase areas		
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to					to maintain water quality	regeneration, and reducing impact of disturbances		(Locatelli et al. 2015a) Some forest ecosystems			competition for land between	restricti			can increase areas available		
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to forests include	Likaly				to maintain water quality by reducing	regeneration, and reducing impact of disturbances (e.g. prescribed	Foracte	(Locatelli et al. 2015a) Some forest ecosystems can be		Poforeteti	competition for land between afforestation/r	restricti ons to preserv e			can increase areas available for	Many freed	
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to forests include establishment	Likely				to maintain water quality by reducing runoff and	regeneration, and reducing impact of disturbances (e.g. prescribed burning) have	Forests	(Locatelli et al. 2015a) Some forest ecosystems can be susceptive to		Reforestati	competition for land between afforestation/r eforestation	restricti ons to preserv e ecosyst		Notors	can increase areas available for recreatio	Many forest	
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to forests include establishment of non-native	contributes to	T			to maintain water quality by reducing runoff and trapping	regeneration, and reducing impact of disturbances (e.g. prescribed burning) have positive	contribute to soil	(Locatelli et al. 2015a) Some forest ecosystems can be susceptive to natural		on can	competition for land between afforestation/r eforestation and	restricti ons to preserv e ecosyst em		Natural	can increase areas available for recreatio n and	landscapes	
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to forests include establishment of non-native species,	contributes to native	Trees can		Mitigation	to maintain water quality by reducing runoff and trapping sediments and	regeneration, and reducing impact of disturbances (e.g. prescribed burning) have positive implications for	contribute to soil erosion	(Locatelli et al. 2015a) Some forest ecosystems can be susceptive to natural disasters like		on can increase	competition for land between afforestation/r eforestation and agricultural	restricti ons to preserv e ecosyst em integrit		ecosystems	can increase areas available for recreatio n and tourism	landscapes have cultural	
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to forests include establishment of non-native species, especially with	contributes to native pollinators if	improve air		potential	to maintain water quality by reducing runoff and trapping sediments and nutrients	regeneration, and reducing impact of disturbances (e.g. prescribed burning) have positive implications for fresh water	contribute to soil erosion protection and	(Locatelli et al. 2015a) Some forest ecosystems can be susceptive to natural disasters like wind throws,		on can increase availability	competition for land between afforestation/r eforestation and agricultural production is	restricti ons to preserv e ecosyst em integrit y can		ecosystems often	can increase areas available for recreatio n and tourism opportun	landscapes have cultural ecosystems	
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to forests include establishment of non-native species, especially with the risks related	contributes to native pollinators if native forest	improve air pollution		potential (see main	to maintain water quality by reducing runoff and trapping sediments and nutrients (Idris Medugu	regeneration, and reducing impact of disturbances (e.g. prescribed burning) have positive implications for fresh water supply	contribute to soil erosion protection and soil fertility	(Locatelli et al. 2015a) Some forest ecosystems can be susceptive to natural disasters like wind throws, fires, and		on can increase availability of biomass	competition for land between afforestation/r eforestation and agricultural production is a potentially	restricti ons to preserv e ecosyst em integrit y can restrict	Source of	ecosystems often inspire	can increase areas available for recreatio n and tourism opportun ities	landscapes have cultural ecosystems services	
	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to forests include establishment of non-native species, especially with the risks related to the spread of	contributes to native pollinators if native forest species used	improve air pollution problems	See main text	potential (see main text) will	to maintain water quality by reducing runoff and trapping sediments and nutrients (Idris Medugu et al. 2010a;	regeneration, and reducing impact of disturbances (e.g. prescribed burning) have positive implications for fresh water supply (Ciccarese et al.	contribute to soil erosion protection and soil fertility enhancement	(Locatelli et al. 2015a) Some forest ecosystems can be susceptive to natural disasters like wind throws, firres, and diseases		on can increase availability of biomass for energy	competition for land between afforestation/r eforestation and agricultural production is a potentially large adverse	restricti ons to preserv e ecosyst em integrit y can restrict the	medicines	ecosystems often inspire learning	can increase areas available for recreatio n and tourism opportun ities (Knoke	landscapes have cultural ecosystems services components	
Reforestation	Jackson 2007; Stanturf et al. 2014). Adverse side-effects potentially associated to forests include establishment of non-native species, especially with the risks related	contributes to native pollinators if native forest	improve air pollution	See main text for mifgation potentials	potential (see main	to maintain water quality by reducing runoff and trapping sediments and nutrients (Idris Medugu	regeneration, and reducing impact of disturbances (e.g. prescribed burning) have positive implications for fresh water supply	contribute to soil erosion protection and soil fertility	(Locatelli et al. 2015a) Some forest ecosystems can be susceptive to natural disasters like wind throws, fires, and	N/A	on can increase availability of biomass	competition for land between afforestation/r eforestation and agricultural production is a potentially	restricti ons to preserv e ecosyst em integrit y can restrict		ecosystems often inspire	can increase areas available for recreatio n and tourism opportun ities	landscapes have cultural ecosystems services	

	species											2017a,b;	resourc					
	(Brundu and											Kreidenweis	es (e.g.					
	Richardson											et al. 2016;	firewoo					
	2016; Ellison et											Smith et al.	d).					
													u).					
	al. 2017).											2013). An						
												increase in						
												global forest						
												area can lead						
												to increases in						
												food prices						
												through						
												increasing						
												land						
												competition						
												(Calvin et al.						
												2014;						
												Kreidenweis						
												et al. 2016;						
												Reilly et al.						
												2012; Smith et						
												al. 2013; Wise						
												et al. 2009).						
							Afforestation					,						
							using some											
							exotic species											
							can upset the					Future needs						
							balance of					for food						
							evapotranspirati					production are						
							on regimes, with					a constraint						
	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						
							Trabucco et al.					50%-97%						
	well-being in							to counteract										
	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;						using species	when they are				carbon prices						
	Stanturf et al.						that have	established on				will facilitate						
	2014). In the						evapotranspirati	degraded lands				deployment of						
	case of						on rates	they are				afforestation						
	afforestation,	1	1	1			exceeding the	instrumental to	1	1		projects at	1	1	1	1	1	1
	simply			1		Depends on	regional	preserve natural				expenses of		1	1	1		
	changing the			1		where	precipitation	forests (co-				food		1	1	1		
	use of land to			1		reforesting	may aggravate	benefit)				availability		1	1	1		
	planted forests					and with what	the groundwater	(Buongiorno and				(adverse side-		I	1	I		
	is not sufficient			1		species (Scott	decline	Zhu 2014).				effect), but		1	1	1		
						et al. 2005).	(Locatelli et al.	Afforestation	Some									
	to increase											more		I	1	I		
	abundance of			1		Trees enhance	2015a; Lu et al.	runs the risk of	afforestation			liberalised		1	1	1		
	indigenous					soil	2016). Changes	decreasing soil	may make			trade in		I	1	I		
	species, as they					infiltration	in runoff affect	nutrients,	forest			agricultural		I	1	Green		
	depend on type					and, under	water supply but	especially in	ecosystems		Afforestati	commodities		I	1	spaces		
	of vegetation,	1	1	1		suitable	can also	intensively	more	1	on may	could buffer	1	1	1	support	Afforestation/	1
	scale of the					conditions,	contribute to	managed	susceptive to		increase	food price	Could	I	1	psycholo	reforestation	
	land transition,					improve	changes in flood	plantations; in	natural		availability	increases	increase	I	1	gical	can increase	
				1	Million									1	1			
	and time			1	Mitigation	groundwater	risks, and	one study,	disasters like		of biomass	following	availabi	1	1	wellbein	areas available	
	required for a				potential	recharge	irrigation of	afforestation sites	wind throws,		for energy	afforestation	lity of	I	1	g	for recreation	
	population to	1	1	1	(see main	(Calder 2005;	forest	had lower soil P	fires, and	1	use	in tropical	biomass	1	1	(Coldwel	and tourism	1
	establish			See main text	text) will	Ellison et al.	plantations can	and N content	diseases		(Oberstein	regions	(Grisco	1	1	1 &	opportunities	
	(Barry et al.			for mitigation	reduce ocean	2017; Neary	increase water	(Berthrong et al	(Seidl et al.		er et al	(Kreidenweis	m et al.,	1	1	Evans,	(Knoke et al.	
Afforestati		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
Anorestati	2014).	iva	17/71	Potentiais	aciumcauoli.	ci al. 2007).	consumption	2007).	2014).	11/1	2000)	ci al. 2010).	2017)	11/11	11/11	2010)	2014).	11/A

No. N	-		1								1	1								
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organic carbon (Tscharntke et for mitigation and by how (Keesstra et (Lehmann & (Lehmann & soil (Lehmann) degradation other provided	1	Increased soil				See main text	decrease this	flows					1		ics, and	2015) are				
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	Soils			N/A	N/A						N/A		N/A				N/A	N/A	N/A	N/A
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l													s; SSSA, 2015) are provide d by					
Reduced soil erosion	Managing soil erosion decreases need for expanded cropland into habitats (Pimental et al 1995)	N/A	Particulate matter pollution, a main consequence of wind erosion, imposes severe adverse impacts on materials, structures and climate which directly affect the sustainability of urban cities (AI-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 (EI- 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.	soils.	N/A	N/A/	N/A	N/A	N/A
Reduced soil salinisation	Salinisation decreases soil microbial diversity (Nie et al. 2009)	N/A	al. 2018)	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	NA	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	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; Zalidis 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 can contribute to floods (Hümann et al 2011)	N/A N/A	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 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

	opportun r ities in e	Retaining natural ecosystems can
	es (Venn g & Calkin d	preserve genetic diversity (Ekins
N/A N/A		et al., 2003). N/A
N/A N/A	N/A N/A N/A N/A M	N/A
		Reducing invasives can increase biological diversity of native organisms (Simberloff

		1	1			The creation			T									
		1	1			or restoration			The creation									
		1	1			of wetlands, tidal marshes.			or restoration of wetlands.			Mixed						
		1	1			or mangroves			tidal marshes.			evidence: can						
		1	1			provide water			or mangroves			affect						
		1	1			retention and			provide water			agriculture/fis						
		1	1			protect coastal			retention and			heries						
		1	1			cities from			protect			production						
		1	1			storm surge			coastal cities			when				Natural		
		1	1			flooding and			from storm			competition				environm		
		i -	1			shoreline			surge			for land				ents		
		1	1			erosion during			flooding and	Landscape		occurs, or				support		
		1	1			storms.			shoreline	diversity		could increase	Could			psycholo		
		1	1			Wetlands			erosion	generally		food	increase		Natural	gical	Natural	Retaining
		1	1		Mitigation	store			during storms	improves		production	availabi	Wetlands	ecosystems	wellbein	environments	natural
Restoration		Will promote	1		potential	freshwater	Wetlands store		(Haddad et	opportunities		when	lity of	can be	often	g	support	ecosystems can
and avoided	Will preserve	natural	1		(see main	and enhance	freshwater and		al., 2015;	for biological		ecosystems	biomass	sources of	inspire	(Coldwel	psychological	preserve
conversion of	natural habitat	pollinators	1	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	l	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	1										Will					
		1	1										reduce					
		1	1										supply of some					
		1	1										material					
		1	1										materiai			Natural		
		1	1			Peatland					Will		sourced			environm		
		1	1			restoration					reduce		from			ents		
		1	1			will improve	Peatland			Landscape	supply of		peatlan			support		
		1	1			water quality	restoration will			diversity	any	May reduce	ds (e.g			psycholo		
		1	1			as they play	improve water			generally	biomass or	land available	palm	Natural	Natural	gical	Natural	Retaining
		Could	1		Mitigation	important	quality as they			improves	energy	for	oil,	ecosystem	ecosystems	wellbein	environments	natural
		promote	1		potential	roles in water	play important			opportunities	sourced	smallholders	timber)	s are often	often	g	support	ecosystems can
Restoration	Will preserve	natural	1		(see main	retention and	roles in water			for biological	from	in tropical	(Murdi	source of	inspire	(Coldwel	psychological	preserve
and avoided	natural habitat	pollinators	1	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	1	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		
populations of seed-		1
seed-	1	
dispersing		
animals result		
in poor to no		
dispersal,espe		
cially of the second seco		
large-seeded		
trees that		
depend on		
large animals		
such as		
elephants		
(Anzures-		
Dadda et		
al.2011;		
Brodie and		1
Aslan2012;		
Beame et		
al.2013; Management of		
Brockerhoff wild animals and		
et al. 2017). protected habitats		
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 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	
contributes to thawing of	ity to	
various permafrost.	tribal	1
ecosystem Management of	identities	
processes, wild animals can	,	
functions and influence land	associati	
services, the degradation	on with	
Biodiversity declining processes by	place,	1
conservation diversity and grazing	kinship	
includes abundance of Many actions trampling and	ties,	
measures pollinators taken to compacting soil Management	customs	
aiming to (mainly increase surfaces, thereby of wild provide the surfaces are surfaces, thereby and the surface of the surface	and	
promote insects and biodiversity Many actions altering surface animals can Regulation of	protocols	
species birds) has Trees in the (eg protected taken to increase temperatures and influence fire wild animals	, stories,	
richness and raised landscape areas) can biodiversity (eg chemical frequency as affects food	and	Destriction
natural concerns ensured by also have protected areas) reactions grazers lower for hunting Natural	songs	Retaining
habitats, and to about the protected incidental can also have affecting grass and ecosystems	(Gould et	natural
manain them effects on areas can effects of incidental sediment and vegetation availability of often	al. 2014;	ecosystems can
through both wild and remove air improving effects of carbon retention. densities as potential feed Source of inspire	Lyver et	preserve
protected areas crop plants pollutants See main text water quantity improving water (Cromsign et al., potential fuels for livestock medicines learning.	al.	genetic dimension (Elvino
Biodiversity (Cromsigt et (Potts et al. (Sutton et al., for mitigation (Ego h et al. quality (Ego h et al. 2018; Schmitz et (Schmitz et al. (Cromsigt et (UNEP, (Turtle et al., conservation al., 2018). 2010). 2007) potentials 2009) al. 2009) al., 2018) 2014). al., 2018). 2016) al., 2015)	2017a, b).	diversity (Ekins
conservation al, 2018. 2010. 2007. potentials 2009. al. 2009. al, 2018. 2014. al. 2018. al, 2018. 2016. al. 2019. al. 2014. al. 2018. al. 2019.	U).	et al., 2003).

												1				1			
													Can contribute						
													to increase						
													food						
													production by						
						Addition of							replenishing						
						basic							plant available						
						minerals							silicon,						
						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.											
								However, the											
							scale (Popp et 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				water	some studies				can	significant				land use		
			natural				withdrawals	indicating				contribute	trade-offs with		1		conversi		
		Likely will	pollinators				(Hejazi et al.,	improvements in				up to 300	food		1		on and	BECCS would	
		reduce natural	due to			Mitigation	2014; Bonsch	water quality	Will likely			EJ of	production				reduce	drive land use	
		habitat with	decreased	The use of		potential	et al., 2015)	(Ng et al., 2010)	decrease soil			primary	(Smith et al				opportun	conversion	BECCS would
		negative effects	natural habitat	BECCS could		(see main	and changes	and others	quality if exotic			energy by	2016; Popp et		1		ities for	and reduce	drive land use
Carbon		on biodiversity	if in	reduce air	See main text	text) will	in surface	showing	fast growing			2100	al., 2017;				recreatio	culturally	conversion and
dioxide	Bioenergy and	(Hof et al.	competition	pollution	for mitigation	reduce ocean	runoff (Cibin	declines (Sinha	trees used (Stoy			(Clarke et	Fujimori et				n/tourism	significant	reduce genetic
removal	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.
. c.mo.r.d		-310)	((rotentino						4 *	, 201 .).	,				•	aocupeo.	

9 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

		Will lead to					Will reduce				Reducing postharvest losses will								
		reduced expansion of ag lands, which can increase			See main		water consumption if less water- intensive food/livestock				include measures to deal with pests, some of which		Will help increase						
	Reduced post-harvest	natural habitat (Tilman et al.			text on climate mitigation		needs to be produced (Tilman et al.				could be biological (Wilson &		global food supplies (Kastner et						
	losses	2001) Improved storage and distribution reduces food waste and the need for compensatory intensification	N/A	N/A	impacts	N/A	2001) Will reduce water	N/A Reduced food production	N/A	N/A	Pusey 1985)	N/A	al. 2012)	N/A	N/A	N/A	N/A	N/A	N/A
	Reduced food waste (consumer or retailer)	of agricultural areas thereby creating co- benefits for reduced land degradation (Stathers et al. 2013).			See main text on climate mitigation impacts		vancumption if less water- intensive food/livestock needs to be produced (Tilman et al. 2001)	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	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

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

241Table S3 Literature on Impacts on Nature's Contributions to People of integrated response options based on risk management

Integrated response options based on risk 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
Management of urban sprawl	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 (Pataki 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
Livelihood diversification	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Diversification is associated with increased access to income and additional food sources for the household (Pretty et al. 2003)	Diversification can increase access to materials (Smith et al. 2017)	N/A	N/A	N/A	N/A	N/A

		1		1	1	1		1	1			Local sands			1		i
Use of loc seeds	Use of commercial seeds can contribute to habitat loss cal (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 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	Local seeds can lead to more diverse 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 identifies for many (Coomes et al. 2015)	Food sovereignty movements have promoted saving of genetic diversity of crops through on-farm maintenance (Isakson 2009)
Disaster 1 managem	nent N/A	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 shar instrume		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 (Goodwin 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
	Increased food productivity	Increasing farm yields for smallholders contributes to poverty reduction (Irz et al 2001; Pretty et al 2003)	Increasing farm yields for smallholders reduces food insecurity (Irz et al 2001; Pretty et al 2003).	Increased food productivity leads to better health status (Rosegrant & Cline 2003; Dar & Gowda 2011)	N/A	Increased productivity can benefit female farmers, who make up 50% of agricultural labor in sub- Saharan Africa (Ross et al 2015)	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; Mueller et al 2012).	N/A	Increased agricultur al productio n generally (Lal 2006) contribute s to increased economic growth.	N/A	Increased agricultura l production can contribute to reducing inequality among smallholde rs (Datt & Ravallion 1998).	Increased food production can increase urban food security (Ellis & Sumberg 1998).	N/A	See main text on climate mitigati on and adaptati on	Increased food productivity might be achieved through increased pesticide or fertiliser use, which causes runoff and dead zones in oceans (Beusen et al 2016)	See main text on desertificati on and degradation	N/A	Improved agricultural productivity generally correlates with increases in trade in agricultural goods (Fader et al. 2013)
Agricu	Improved cropland management	Improved cropland management increases yields for smallholders and contributes to poverty reduction (frz et al 2001; Pretty et al 2003; Schneider & Gugerty 2011).	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 g agricultural production scale, improving rural production conditions and	Conservatio n agriculture contributes to improved health through several pathways, including reduced fertiliser/pes ticide use which cause health impacts (Erisman et al 2011) as well as improved food security.	N/A	NA	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 P losses from existing land use, to achieve	N/A	Increased agricultur al productio n generally (Lal 2006) contribute s to increased economic growth, mainly in smallhold er agricultur e (Abrahan and Pingali 2017).	N/A	Increased agricultura l production can contribute to reducing inequality among smallholde rs (Datt & Ravallion 1998, Abrahan and Pingali 2017)).	Ν/Α	Improve d conserv ation agricult ure contribu tes to sustaina ble producti on goals (Hobbs et al. 2008).	See main text on climate minon and adaptati on	N/A	See main text on desertificati on and degradation	N/A	Improved agricultural productivity generally correlates with increases in trade in agricultural goods (Fader et al. 2013)

		living environment, alle-viating				'good' water quality in											
		ecological risk and				catchment in New											
		supporting for rural				Zealand, United											
		development (Zhou et al. 2019).				Kingdom and United States (
Improved grazing land management	Increases yields for smallholders and contributes to poverty reduction (Boval & Dixon 2012)	Improved grassland management could contribute to food security (O'Mara 2012)	Improved livestock and grazing managemen t could contribute to better health among smallholder pastoralists (van't Hooft et al. 2012) but pathways are not entirely clear.	N/A	N/A	Grassland manageme nt practices can improve downstrea m and groundwat er water quality (Foster 2018).	N/A	Improved land managem ent for livestock can increase economic productivi ty, especially in global South (Pender et al 2006)	N/A	Improved pastoral manageme nt strategies can reducing inequality but are context specific (Lessorogol 2003)	N/A	Improve d grasslan d manage ment contribu tes to sustaina ble producti on goals (O'Mara 2012).	See main text on climate mitigati on and adaptati on	N/A	See main text on desertificati on and degradation	Grazing land management requires collective action and therefore can increase social capital and build institutions (Mearms 1996)	N/A
Improved livestock management	Improved livestock management (e.g. better breeding) can contribute to poverty reduction for smallholder pastoralists (van't Hooft et al. 2012)	Improved livestock management can contribute to reduced food insecurity among smallholder pastoralists (van't Hooft et al. 2012).	N/A	N/A	N/A	Improved industrial livestock production 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 manure manageme nt (Herrero & Thornton 2013)	N/A	Improved livestock managem ent can increase economic productivi ty and employm ent opportuni ties in global South (Mack 1990)	N/A	N/A	N/A	Sustaina ble livestoc k ment contribu tes to sustaina ble produci on goals (de Wit et al 1995).	See main text on climate mitigati on and adaptati on	N/A	See main text on desertificati on and degradation	N/A	Improved livestock productivity would likely correlate with increases in trade (Herrero et al. 2009)
	Agroforestry can be usefully used for poverty	Agroforestry contributes to food productivity and reduces	Agroforestr y positively contributes to food productivity and		Increased use of agroforestry can benefit female farmers as it requires low	Agroforest ry can be used to increase ecosystem services benefits,	Agroforestry	Agrofores try and other forms of employm ent in forest		Agroforest ry promotion can contribute to reducing		Agrofor estry contribu tes to sustaina ble producti	See main text on climate		See main		
	reduction (Leakey& Simons	food insecurity (Mbow et al.	nutritious diets (Haddad		overhead, but land tenure issues	such as water quantity	could increase biomass for energy (Mbow	managem ent make major		inequality among smallholde		on goals (Mbow et al	mitigati on and adaptati		text on desertificati on and		
 Agro-forestry	Simons 1997).	(Mbow et al. 2014).	(Haddad 2000)	N/A	must be paid	and quality	et al. 2014)	contributi	N/A	rs	N/A	et al 2014).	on	N/A	on and degradation	N/A	N/A

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						attention to	(Jose		ons to		(Leßmeist							
1						(Kiptot &	2009)		global		er et al							
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									2009;									
									Pingali &									
									Rosegrant									
									1995). It									
									allows									
1									farmers to									
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l									that both		1							
									increases		diversifica							
									resilience		tion can							
									and		contribute							
									provides		to							
									economic		reducing							
									benefits,		inequality							
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			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							
1		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		
1		et al. 2018;	spreading	for women					2011;		Weinberge					text on		
1		Weinberger		and children					Kremen		r &					desertificati		
			across															
Agricul		& Lumpkin	landscapes	(Pretty et al.					et al.		Lumpkin					on and		
diversif		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
		May reduce																
		land																
		available for																
		cropping or					Retaining											
		livestock for					grasslands											
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		poorer					contributes		Reduced									
		farmers ;					to better		cropland					See				
		some	Can affect				water		expansion					main				
		grassland	food security				retention		may					text on				
		restoration	when				and		decrease					climate		See main		
Avoida		programs in	competition				improved		GDP					mitigati		text on		
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	1 51011 01															on and		
convers							(Scanlon et		owski et					adaptati		on and		
		been detrimental	occurs (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

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contributes to global global investment economic		
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poverty in disease and watershed- ent.		
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and productivity 2018). for human coordin		
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rainfall equitable and trend that both women to address and threaten		of freshwater
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and water water resource two-thirds integrated scarcity, ental long- IWM	n	water
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provides a (as water for world's resources substantial) in the increase Water is a sustaina likely	,	substantially
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food security food stressed effectiveness suffering able economic IWM can help and climate runoff		suffering
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Integrated water (UNCTAD people (Lloy) (UNWater Green & (UNWater Water, & Varis supplies (Bao (Rassal adaptati Braim		Water,
management 2011 et al. 2013. 2015 N/A Baden 1995 2015. N/A 2015. N/A 2005. & Erag 2012 2016. on 2009	degradation	2015).

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							location,											
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							compound											
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							promote											
							rainfall											
			Forest				(Arneth et											
			expansion can				al. 2010).											
			affect crop				Trees											
			production				enhance											
1		1	when		1		soil		1	1	1			1		1		
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1		1	for land		1		and, under		1	1	1			1		1		
1					1				1	1	1			1		1		
1		May	occurs		1		suitable		1	1	1			1		1		
1		contribute to	(Angelsen		1		conditions,		1	1	1		Improve	1		1		
1		poverty	2010). An				improve						d forest	I				
1		reduction if	increase in				groundwat						manage	I				
1		conditions	global forest				er recharge						ment	I				
1		are right	area can lead				(Calder						contribu	I				
1		(Blomley &	to increases in				2005;						tes to	I				
1														I				
1		Ramadhani	food prices				Ellison et						sustaina	I				
1		2006;	through				al. 2017a;						ble	I				Sustainable
1		Donovan et	increasing			Women face	Neary et		Forest				producti	I				forest
1		al 2006), but	land		1	challenges	al. 2009b).		managem	1	1		on	1		1		management
1		conflicting	competition		1	in	Particular		ent often	1	1		goals,	1		1	Sustainable	can
1					1			SFM may		1	1			1		1		
1		data, as it	(Calvin et al.		1	sustainable	activities		require		1		e.g. thru			1	forest	contribute to
		may also	2014b;			forest	associated	increase	employm	Forestry		Community	certifica	See			management	increases in
		favor large	Kreidenweis			management	with forest	availability of	ent for	supplies		forest	tion of	main			often	demand for
		landowners	et al. 2016c;			(Mwangi et	landscape	biomass for	active	wood for		management	timber	text on			requires	wood
		who are less	Reilly et al.			al 2011), but	restoration,	energy	replanting	industrial		can contribute	(Ramets	climate		See main	collective	products (e.g.
	Forest	poor	2012b; Smith			N/A how	such as	(Kraxner et al.	, etc.	use			teiner	mitigati		text on	action	certification)
			et al. 2013a;									to stronger	and				institutions	(McDonald
I	management	(Rametsteine				SFM affects	mixed	2013;	(Ros-	(Gustavsso		communities		on and		desertificati		
Forestr	and forest	r and Simula	Wise et al.			gender	planting,	Sikkema et al.	Tonen et	n & Sathre		(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)

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							natural											
							regeneratio											
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							positive											
							implication											
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							(Ciccarese											
							et al. 2012;											
							Suding et											
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							Forests											
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							al. 2010c;											
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		May					piration,											
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		conflicting					c moisture,											
		data.					contributin											
		Although					g to											
		poverty is a		Reduced			rainfall											
		focus of		deforestatio	1		locally and			1								1
1	1	many		n can	1		in distant			1			1					1
1	1	REDD+		enhance	1		location,			1			1					1
		projects		human well-			and trees'			1	BFB-							1
1	1	(Arhin 2014),		being by	1	Unclear how	microbial			1	REDD+		1					1
1	1	evidence is		microclimat	1	avoided	flora and			1	has been		1					
		thin that		ic regulation		deforestation	biogenic			1	shown to							
1	1	poverty		for	1	might	volatile		Reduced	1	have no		1					
		reduction has		protecting		enhance	organic		forest	1	impact on							Likely to
		actually		people from	1	gender	compound		exploitati	1	inequality							contribute to
1	1	happened		heat stresses	1	equity, but	s can		on may	1	(Shresta et		1					decline in
		(Corbera et		(Locatelli et	1	REDD+	directly		decrease	1	al 2017) or							trade in
		al. 2017;	Avoided	al. 2015c)	1	projects	promote	Avoiding	GDP and	1	to increase							forest
1	1	Porkorny et	deforestation	and	1	need to pay	rainfall	deforestation	thus	1	inequality		1					products, but
1	1	al 2013;	can affect crop		1			can take		1			1	See				
		al 2013; Scheba 2018)		generally improve the		attention to gender	(Arneth et al. 2010).	biofuel land	needs to be	1	in some			main				increases in
1	1		production		1	0				1	project		1					partnerships
		and in some	when	cultural and		issues to be	Trees	out of	compensa	1	areas			text on				between
		cases benefits	competition	recreational		successful	enhance	production as	ted for	1	(Andersso			climate		See main		donors and
		have been	for land	value of		(Westholm	soil	they both tend	(e.g.	1	n et al			mitigati		text on		countries
	Reduced	captured by	occurs	ecosystems		& Arora-	infiltration	to compete for	REDD+)	1	2018;			on and		desertificati		with REDD+
1	deforestation	wealthier	(Angelsen	(Knoke et	1	Jonsson	and, under	land (Dixon et	(Motel et	1	Pelletier et		1	adaptati		on and		(Motel et al
1	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	degradation	N/A	2009).
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						improve											
						groundwat											
						er recharge											
						(Calder											
						2005;											
						Ellison et											
						al. 2017a;											
						Neary et											
						al. 2009b).											
						ai. 20090).											
			Reforestatio														
			n can														
			enhance														
			human well-														
			being by														
			microclimat														
		Forest	ic regulation			Particular											
		expansion can	for			activities											
		affect crop	protecting			associated											
						with forest											
		production	people from	1	1								1	1	1		1
	May	when	heat stresses	1	1	landscape	1	1	1	1		1	1	1	1		1
	contribute to	competition	(Locatelli et	1	1	restoration,							1	1	1		1
	poverty	for land	al. 2015c)	1	1	such as							1	1	1		1
	reduction but	occurs	and	1	1	mixed							1	1	1		1
	conflicting			1	1								1	1	1		1
		(Angelsen	generally	1	1	planting,							1	1	1		1
	data	2010). An	improve the	1	1	assisted							1	1	1		1
	(Tschakert	increase in	cultural and	1	1	natural							1	1	1		1
	2007). Many	global forest	recreational			regeneratio											
	projects for	area can lead	value of			n, and											
	reforestation	to increases in				reducing											
			ecosystems														
	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				
				1	1									1	6		1
	or lack of	2012b; Smith	Human	1	1	supply	availability of	active					climate	1	See main		1
	economic	et al. 2013a;	Developme	1	1	(Ciccarese	biomass for	replanting					mitigati	1	text on		1
	impacts	Wise et al.	nt Index	1	1	et al. 2012;	energy	, etc.					on and	1	desertificati		1
	(Jindal et al	2009b)	(Kauppi et	1	1	Suding et	(Swischer	(Jindal et					adaptati	1	on and		1
Reforestation	2008).	20070)	al. 2018).	N/A	N/A	al. 2015).	(3wischer 1994).	al 2008)	N/A	N/A	N/A	N/A	on	N/A	degradation	N/A	N/A
Reforestation	2006).			18/74	IN/A		1994).	ai 2008)	IN/A	IN/A	IN/A	IN/A	011	IN/A	degradation	IN/A	IN/A
		Future needs	Afforestatio	1	1	Afforestati	1	1		1		1	1	1	1		1
	Although	for food	n can	1	1	on using							1	1	1		
	some have	production are	enhance	1	1	some	1	1		1		1	1	1	1		1
	argued that	a constraint	human well-	1	1	exotic							1	1	1		
	afforestation			1	1								1	1	1		
		for large-scale	being by	1	1	species can	1	1		1		1	1	1	1		1
	can be a tool	afforestation	microclimat	1	1	upset the							1	1	1		1
	for poverty	plans	ic regulation	1	1	balance of	1	1		1		1	1	1	1		1
	reduction	(Locatelli et	for	1	1	evapotrans	1	1		1		1	1	1	1		1
		al. 2015c).	protecting	1	1	piration							1	1	1		1
1	(Holden et al		people from	1	1	regimes,							1	1	1		1
1 1	(Holden et al 2003)	Global food	People nolli	I	1								1	1	1		
	2003),	Global food	1		1	with	1			1		1	1	1	1		1
	2003), afforestation	crop demand	heat stresses				1	Afforestat	1	1		1	1	1	1		1
	2003), afforestation can compete	crop demand is expected by	(Locatelli et			negative			1	1	1	1	1	1	1	1	1
	2003), afforestation	crop demand				impacts on		ion often									
	2003), afforestation can compete with land	crop demand is expected by 50%–97%	(Locatelli et al. 2015c)			impacts on											
	2003), afforestation can compete with land available for	crop demand is expected by 50%–97% between 2005	(Locatelli et al. 2015c) and			impacts on water		requires					Saa				
	2003), afforestation can compete with land available for cropping and	crop demand is expected by 50%–97% between 2005 and 2050	(Locatelli et al. 2015c) and generally			impacts on water availability		requires employm					See				
	2003), afforestation can compete with land available for cropping and poor farmers	crop demand is expected by 50%–97% between 2005 and 2050 (Valin et al.	(Locatelli et al. 2015c) and generally improve the			impacts on water availability particularl	Afforestation	requires employm ent for					main				
	2003), afforestation can compete with land available for cropping and	crop demand is expected by 50%–97% between 2005 and 2050	(Locatelli et al. 2015c) and generally			impacts on water availability	Afforestation may increase	requires employm									
	2003), afforestation can compete with land available for cropping and poor farmers often do not	crop demand is expected by 50%–97% between 2005 and 2050 (Valin et al. 2014). Future	(Locatelli et al. 2015c) and generally improve the cultural and			impacts on water availability particularl y in arid	may increase	requires employm ent for active					main text on		See main		
	2003), afforestation can compete with land available for cropping and poor farmers often do not benefit from	crop demand is expected by 50%–97% between 2005 and 2050 (Valin et al. 2014). Future carbon prices	(Locatelli et al. 2015c) and generally improve the cultural and recreational			impacts on water availability particularl y in arid regions	may increase availability of	requires employm ent for active replanting					main text on climate		See main		
	2003), afforestation can compete with land available for cropping and poor farmers often do not benefit from afforestation	crop demand is expected by 50%-97% between 2005 and 2050 (Valin et al. 2014). Future carbon prices will facilitate	(Locatelli et al. 2015c) and generally improve the cultural and recreational value of			impacts on water availability particularl y in arid regions (Ellison et	may increase availability of biomass for	requires employm ent for active replanting , etc.					main text on climate mitigati		text on		
	2003), afforestation can compete with land available for cropping and poor farmers often do not benefit from afforestation projects	crop demand is expected by 50%–97% between 2005 and 2050 (Valin et al. 2014). Future carbon prices will facilitate deployment of	(Locatelli et al. 2015c) and generally improve the cultural and recreational value of ecosystems			impacts on water availability particularl y in arid regions (Ellison et al. 2017a;	may increase availability of biomass for energy use	requires employm ent for active replanting , etc. (Mather					main text on climate mitigati on and		text on desertificati		
Afforestation	2003), afforestation can compete with land available for cropping and poor farmers often do not benefit from afforestation	crop demand is expected by 50%-97% between 2005 and 2050 (Valin et al. 2014). Future carbon prices will facilitate	(Locatelli et al. 2015c) and generally improve the cultural and recreational value of	N/A	N/A	impacts on water availability particularl y in arid regions (Ellison et	may increase availability of biomass for	requires employm ent for active replanting , etc.	N/A	N/A	N/A	N/A	main text on climate mitigati	N/A	text on	N/A	N/A

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

·			man day of the				1	1	1	1	I	1		1			1
			productivity which may														
			have impact on diets.														
┝─────┤			on diets.			17							-				
						Various researchers											
						showed a											
						relationshi											
						p between											
						impact of											
						soil											
						erosion											
						and											
						degradatio											
						n on water											
						quality											
						indicating											
						the source											
						of											
1					1	pollutant		1		1	Particulate			1			
1						as					matter		1				
1					1	anthropoge		1		1	pollution, a			1			
1					1	nic and		1		1	main			1			
1						industrial					consequence of		1				
1			0		1	activities.		1		1	wind erosion,			1			
1			Contributes		1	in China		1		1	imposes severe			1			
		Contributes to	to food			(Issaka &					adverse						
	Can increases	agricultural	productivity and			Asheraf 2017).					impacts on materials,						
	yields for	productivity				2017). Managing					structures and		See				
	smallholders	and reduces	improves farmer			soil					climate which		main				
	and	food	health			erosion					directly affect		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).															
		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
		Holden 1999).	1999). Salinisation	N/A	N/A	et al 1995)	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
1		110iden 1999).	,	N/A	N/A	et al 1995)	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
		Holden 1999).	Salinisation	N/A	N/A	et al 1995)	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
	Salinisation	Holden 1999).	Salinisation is known to	N/A	N/A	et al 1995)	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
	can	Holden 1999).	Salinisation is known to have human health impacts:	N/A	N/A	et al 1995)	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
	can impoverish	100deff 1999).	Salinisation is known to have human health impacts: wind-borne	N/A	N/A	et al 1995)	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
	can impoverish farmers		Salinisation is known to have human health impacts: wind-borne dust and	N/A	N/A	et al 1995)	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
	can impoverish farmers (Duraiappah	Reversing	Salinisation is known to have human health impacts: wind-borne dust and respiratory	N/A	N/A		N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
	can impoverish farmers (Duraiappah 1998)	Reversing degradation	Salinisation is known to have human health impacts: wind-borne dust and respiratory health;	N/A	N/A	Manageme	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
	can impoverish farmers (Duraiappah 1998) therefore	Reversing degradation contributes to	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered	N/A	N/A	Manageme nt of soil	N/A	N/A	N/A	N/A		N/A		N/A		N/A	N/A
	can impoverish farmers (Duraiappah 1998) therefore preventing or	Reversing degradation contributes to food	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of	N/A	N/A	Manageme nt of soil salinity	N/A	N/A	N/A	N/A		N/A	on	N/A		N/A	N/A
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can	Reversing degradation contributes to food productivity	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito-	N/A	N/A	Manageme nt of soil salinity improves	N/A	N/A	N/A	N/A		N/A	on See	N/A		N/A	N/A
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases	Reversing degradation contributes to food productivity and reduces	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne	N/A	N/A	Manageme nt of soil salinity improves water	NA	N/A	N/A	N/A		N/A	See main	N/A		N/A	N/A
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for	Reversing degradation contributes to food productivity and reduces food	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases;	N/A	N/A	Manageme nt of soil salinity improves water quality and	N/A	N/A	N/A	N/A		N/A	on See main text on	N/A	degradation	N/A	N/A
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders	Reversing degradation contributes to food productivity and reduces food insecurity	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental	N/A	N/A	Manageme nt of soil salinity improves water quality and quantity	N/A	N/A	N/A	N/A		N/A	on See main text on climate	N/A	degradation	N/A	N/A
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health	N/A	N/A	Manageme nt of soil salinity improves water quality and quantity (Kotb et al.	N/A	N/A	N/A	N/A		N/A	on See main text on climate mitigati	N/A	degradation See main text on	N/A	N/A
Reduced soil	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995;	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc	N/A	N/A	Manageme nt of soil salinity improves water quality and quantity (Kotb et al. 2000;	N/A	N/A	N/A	N/A		N/A	on See main text on climate mitigation on and	N/A	degradation See main text on descrificati	N/A	N/A
Reduced soil salinisation	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (Jardine			Manageme nt of soil salinity improves water quality and quantity (Kotb et al.					2018)		on See main text on climate mitigati		degradation See main text on desertificati on and		
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty reduction.	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw &	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (Jardine et al 2007)	N/A N/A	N/A	Manageme nt of soil salinity improves water quality and quantity (Kotb et al. 2000; Zalidis et al 2002)	N/A N/A	N/A	N/A N/A	N/A		N/A N/A	on See main text on climate mitigati on and adaptati	N/A N/A	degradation See main text on descrificati	N/A N/A	N/A N/A
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw & Holden 1999).	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (Jardine et al 2007) Soil			Manageme nt of soil salinity improves water quality and quantity (Kotb et al. 2000; Zalidis et					2018)		on See main text on climate mitigati on and adaptati		degradation See main text on desertificati on and		
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases and contributes to poverty reduction. Soil	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw &	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (Jardine et al 2007) Soil			Manageme nt of soil salinity improves water quality and quantity (Koth et al. 2000; Zalidis et al 2002) Manageme nt of soil					2018)		on See main text on climate mitigati on and adaptati		degradation See main text on desertificati on and		
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty reduction. Soil compaction	Reversing degradation contributes to food insecurity (Pimiental et al. 1995; Shiferaw & Holden 1999). Compactions reduces	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (Jardine et al 2007) Soil			Manageme nt of soil salinity improves water quality and quantity (Kotb et al. 2000; Zalidis et al 2002) Manageme nt of soil compactio					2018)		See main text on climate mitigati on and adaptati on		degradation See main text on desertificati on and		
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty reduction. Soil compaction and other	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw & Holden 1999). Compactions	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered eology of mosquito- borne diseases; and mental health consequenc es (Jardine et al 2007) Soil compaction has human			Manageme nt of soil salinity improves water quality and quantity (Koth et al. 2000; Zalidis et al 2002) Manageme nt of soil					2018)		on See main text on climate mitigati on and adaptati		degradation See main text on desertificati on and		
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty reduction. Soil compaction and other forms of	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw & Holden 1999). Compactions reduces agricultural	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecclogy of mosquito- borne diseases; and mental health consequenc es (Jardine et al 2007) Soil compaction has human health			Manageme nt of soil salinity improves water quality and quantity (Kotb et al. 2000; Zalidis et al 2002) Manageme nt of soil compactio n improves					2018)		on See main text on climate mitigati on and adaptati on See		degradation See main text on desertificati on and		
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty reduction. Soil compaction and other forms of degradation	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw & Holden 1999). Compactions reduces agricultural productivity	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (Jardine et al 2007) Soil compaction has human health			Manageme nt of soil salinity improves water quality and quantity (Kotb et al. 2000; Zalidis et al 2002) Manageme nt of soil compactio n improves water					2018)		on See main text on climate adaptati on and adaptati on See main		degradation See main text on desertificati on and		
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty reduction. Soil compaction and other forms of degradation can	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw & Holden 1999). Compactions reduces agricultural productivity and thus	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (2007) Soil compaction has human health consequenc es as it			Manageme nt of soil salinity improves water quality and quantity (Kotb et al. 2000; Zalidis et al.2002) Manageme nt of soil compaction n improves water quality and					2018)		on See main text on climate mitigati on and adaptati on See main text on		degradation See main text on desertificati on and degradation		
salinisation	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty reduction. Soil compaction and other forms of degradation can impoverish farmers (Scherr	Reversing degradation contributes to food productivity and reduces food insecurity (Pimiental et al. 1995; Shiferaw & Holden 1999). Compactions reduces agricultural productivity and thus contributes to food	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (ardine et al 2007) Soil compaction has human health consequenc es as it contributes to runoff of water and			Manageme nt of soil salinity improves water quality and quantity and quantity and quantity and al 2002; Manageme nt of soil compactio n improves water quality and quantity (Soane and van					2018)		See main text on climitate mitigati on and adaptati on See main text on climate mitigati on and		degradation See main text on desertificati on and degradation See main text on desertificati		
	can impoverish farmers (Duraiappah 1998) therefore preventing or reversing can increases yields for smallholders and contributes to poverty reduction. Soil compaction and other forms of degradation can impoverish farmers	Reversing degradation contributes to food productivity and reduces food (Pimiental et al. 1995; Shiferaw & Holden 1999). Compactions reduces agricultural productivity and thus contributes to food	Salinisation is known to have human health impacts: wind-borne dust and respiratory health; altered ecology of mosquito- borne diseases; and mental health consequenc es (Jardine et al 2007) Soil compaction has human health consequenc es as it contributes to runoff of			Manageme nt of soil salinity improves water quality and quantity (Kotb et al. 2000; Zalidis et al 2002) Manageme nt of soil compactio n improves water quality and quantity (Soane and					2018)		on See main text on climate mitgati on and adaptati on See main text on climate main text on climate main		degradation See main text on descrificati on and degradation See main text on		

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

			Larssen et														
			al 1999)														
								IAS									
						IAS like		removal									
	Invasive	IAS can				the golden apple		policies can									
	species	compete with	IAS have			snail/zebra		increased									
	removal	crops and	strong			mussel		employm					See				
	policies have	reduce crop	negative			have		ent due to					main				
	been	yields by	effects on			damaged		need for					text on				
	beneficial to	billions of	human well-			aquatic		labor (van					climate		See main		
Management of	the poor (van Wilgen &	dollars annually	being (Pejchar &			ecosystems (Pejchar &		Wilgen & Wannenb					mitigati on and		text on 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				1											
	poor design can	affect agriculture/fis	Wetlands contribute														
	impoverish	heries	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 2011). Can	for land occurs, or	and restoration			Wetlands		often require	coastal wetlands					can play a large role in			
	also decrease	could increase	generally			store		employm	may reduce				See	providing			
	vulnerability	food	improve the			freshwater		ent for	infrastructu				main	habitat for			
	to coastal	production	cultural and			and		active	re projects				text on	marine fish			
	storms,	when	recreational			enhance		replanting	in coastal				climate	species	See main		
Restoration and avoided	however (Jones et al.	ecosystems are restored	value of ecosystems			water quality		, etc. (Crooks	areas (e.g. sea dikes,				mitigati on and	(Bobbink et al 2006;	text on 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				Peatland											
		crop				restoration											
		production when				will improve											
		competition				water	Peatlands in										
		for land				quality as	tropics are	Reduced									
		occurs,				they play	often used for	peatland									
	May reduce land	although much use of				important roles in	biofuels and palm oil, so	exploitati					See main				
	available for	peatlands in				water	may reduce	on may decrease					text on				
	smallholders	tropics is for				retention	the	GDP in					climate		See main		
Restoration and	in tropical	palm oil, not				and	availability of	Southeast					mitigati		text on		
avoided	peatlands	food				drainage	these	Asia (Koh					on and		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
peauanus	2014)	al 2011) Biodiversity,	N/A Biodiversity	IN/A	IN/A	1991). 33 out of	ai 2006).	2011)	IN/A	IN/A	IN/A	IN/A	011	IN/A	degradation	N/A Indigenous	IN/A
		and its	, and its			105 of the									Indigenous	peoples	
		management,	managemen			largest								Biodiversity	peoples'	commonly	
		is crucial for	t, is crucial			urban areas	_							conservatio	roles in	link forest	
	There is	improving	for			worldwide	Some							n measures	biodiversity	landscapes	
	mixed evidence on	sustainable and	improving sustainable			rely on biodiversit	biodiversity conservation							like protected	conservatio n can	and biodiversity	
	the impacts	diversified	and			y	measures							areas can	increase	to tribal	
	of	diets (Global	diversified			conservati	might increase							increase	institutions	identities,	
	biodiversity	Panel on	diets			on	access to							ocean	and conflict	association	
Bio dimon-14-	conservation	Agriculture	(Global Banal an			measures	biomass							biodiversity (Salia at al	resolution	with place,	
Biodiversity conservation	measures on poverty	and Food Systems for	Panel on Agriculture	N/A	N/A	such as protected	supplies (Erb et al. 2012)							(Selig et al 2014)	(Garnett et al. 2018)	kinship ties, customs and	
consci vation	Poverty	Systems for	Agriculture	19/1	11/11	Protected	or al. 2012)		1	1	1		1	2014)	ai. 2010)	castonis and	

r		1									1		1		1			
			Nutrition	and Food			areas for										protocols,	
			2016).	Systems for			some, or										stories, and	
			Indirectly, the	Nutrition			all, of their										songs	
			loss of	2016).			drinking										(Gould	
			pollinators				water										2014; Lyver	
			(due to				(Secretaria										et al. 2017a,	
			combined				t of the										b).	
			causes,				Conventio										·	
			including the				n on											
			loss of				Biological											
			habitats and				Diversity											
			flowering				2008)											
			species)				2008)											
			would															
			contribute to															
			1.42 million															
			additional															
			deaths per															
			year from															
			non-															
			communicable								1							
			and								1							
			malnutrition-								1							
			related								1							
			diseases, and															
			27.0 million															
			lost disability-															
			adjusted life-															
			years															
			(DALYs) per															
			year (Smith et															
			al. 2015).															
			However, at															
			the same time,															
			some options															
			to preserve															
			biodiversity,															
			like protected															
			areas, may															
			potentially															
			conflict with															
			food															
			production by															
			local															
			communities															
			(Molotoks et															
			al. 2017)								1							
							Mineral											
l							weathering			Will								
							can affect			require			1		1			
l							the			developme				See				
							chemical			nt of new			1	main	1			
l							compositio			technologie				text on				
1							n of soil			s			1	climate		See main		
							and surface			(Schuiling			1	mitigati		text on		
	Enhanced						waters			and				on and		desertificati		
	weathering of						(Katz			Krijgsman			1	adaptati		on and		
	minerals	N/A	N/A	N/A	N/A	N/A	(Ratz 1989)	N/A	N/A	2006)	N/A	N/A	N/A	on	N/A	degradation	N/A	N/A
		Bioenergy	Biofuel	BECCS			Will likely	BECCS and	Access to	2000)		- ****	Switchi			acgradation		- ****
1														See	Paduations			
1		production	plantations	could have			require	biofuels can	clean,	DECCS			ng to	See	Reductions			
1		could create	may lead to	positive			water for	contribute up	affordable	BECCS			bioener	main	in carbon			
1		jobs in	decreased	effects			plantations	to 300 EJ of	energy	will require			gy	text on	emissions			
1		agriculture,	food security	through			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	
1		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	for land with	for land	and water	(IPCC	(IPCC	models	chapter box 7	(IPCC	s (Smith et	(IPCC	interaction	natural	adaptati	. See main	on and	(IPCC	interaction
CDR	BECCS	alternative	(Locatelli et	quality	2018).	2018).	show high	on bioenergy);	2018).	al. 2016c).	2018).	(IPCC 2018).	resource	on	text on	degradation	2018).	(IPCC 2018).

	uses.	al. 2015c).	(IPCC		risk of	bioenergy can			s (IPCC	climate		1
	Therefore,	BECCS will	2018), but		water	provide clean,			2018).	mitigation.		1
	bioenergy	likely lead to	BECCS		scarcity if	affordable			2010).	iniugution.		
	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									1
			2018).									

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

					1													1
Integrated									0017.0				0011 10					
response									GOAL 8:				GOAL 12:	GOAL			GOAL 16:	
options				GOAL 3:			GOAL 6:		Decent Work	GOAL 9:		GOAL 11:	Responsible	13:			Peace and	GOAL
based on			GOAL 2:	Good Health	GOAL 4:	GOAL 5:	Clean Water	GOAL 7:	and	Industry,	GOAL 10:	Sustainable	Consumption	Climat	GOAL 14:		Justice	Partnersh
value chain		GOAL 1: No	Zero	and Well-	Quality	Gender	and	Affordable and	Economic	Innovation and	Reduced	Cities and	and	e	Life Below	GOAL 15:	Strong	to achi
management		Poverty	Hunger	being	Education	Equality	Sanitation	Clean Energy	Growth	Infrastructure	Inequality	Communities	Production	Action	Water	Life on Land	Institutions	the G
				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			
		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;			
		reduced demand	countries	disease and			lower GHG				will reduce food	most needed	sustainable		Mathijs			
		for livestock will	(Rosegrant	mortality			emissions,				inequality by	in urbanised,	consumption		2015).			
		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			
		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			
		inputs (grains) that	goals	5.1 million	1		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		
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		1
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

-				1	r –		water and											1 1
							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; Temba et al.			(2012a)		In East and									
				2016; Stathers			reported that 24% of		In East and Southern									
				et al. 2013;			global		Africa,									
				Tirado et al.			freshwater		postharvest									
				2010)		Postharvest	use and 23%		loss for six									
			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 availability,	(Bradford et al. 2018). The		(Kaminski and	to food		of total		Poorer households tend							
		distribution operation can	availability, nutrition,	al. 2018). The perishability		and Christiaensen	losses. Reduced post	Reduced losses	production 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
	luced	(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
	t-harvest	2018; Temba et al. 2016)	Affognon et al. 2015)	2018; Ingram et al. 2016a).	but no data available	(Rugumamu 2009)	and	US (Cuéllar and Webber 2010)	PHL (Hodges et al. 2011)	(Parfitt et al. 2010)	(Hodges et al. 2011).	N/A	goals (Parfitt et al. 2010)	adaptati	N/A	and degradation	N/A	(Tefera 2012)
loss	ses	2016)	People who	et al. 2010a).	available	2009)	irrigation. Kummu et al.	webber 2010)	Waste	2010)	2011).	IN/A	al. 2010)	on	N/A	degradation	IN/A	2012)
			are already				(2012a)		generation			There have						
			food	Food waste			reported that		has grown			been large						
			insecure tend	can increase			24% of		faster than			increases in						
			not to waste	with healthier			global		GDP in recent			the						
		Food waste tends	food	diets (Parizeau		Reducing	freshwater		years			throughput of						
		to rise as incomes	(Nahman et	et al. 2015).		food waste	and 23% of		(Thogerson			materials						
		rise (Parfitt et al. 2010; Liu et al.	al. 2012). Reduced	Health and		within households	global fertiliser is		1996). Households in			such as the	Post-consumer					
		2010; Liu et al. 2013), so it is not	food waste	safety standards can		often falls to	used in the		the UK throw			food-waste stream,	food waste in		Reducing			
		clear what the	would	restrict some		women	production of		out US\$745			import and	industrialised		food waste			
		relationship to	increase the	approaches to		(Stefan et al.	food losses,		of food and			solid-waste	countries (222		may be			
1		poverty is. Could	supply of	reducing food		2013) and can	so reduction	Reduced losses	drink each			accumulation	million ton) is		related to			
		be potentially	food (FAO	waste		increase their	in food waste	would reduce energy	year as food			in urban areas	almost as high		food			
		beneficial as it	2011; Smith	(Halloran et al.		labor	could	demands in	waste; South	Food waste		(Grimm et al.	as the total net		packaging,			
		would free up	2013), but it	2014).		workload	provide	production; 2030 +-	Africans	could be an	W 141	2008).	food		which is a			
		money to spend on other activities	is unclear if this would	Changes in packaging to		(Hebrok and Boks 2017).	significant co-benefits	160 trillion BTU of energy were	throw out \$7billion US	important source of	Wealthier households tend	Reducing compostable	production in sub- Saharan		major source of			Food waste
		(Dorward 2012).	benefit those	reduce waste		Women also	co-benefits for	emergy were embedded in wasted	worth of food	needed	to waste more	food waste	Africa (230	See	source or ocean			can
		Redistribution of	who are food	might have		generate more	freshwater	food in 2007 in the	per year	chemicals for	food (Parfitt et	reduces need	million ton).	main	pollution,			contribute to
		food surplus to the	insecure in	negative		food waste	provision and	US (Cuéllar and	(Nahman and	industrial	al. 2010), but	for landfills	(FAO 2011),	text on	but			higher food
		poor could also	developing	health impacts		and could be a	on nutrient	Webber 2010). Food	de Lange	development in	unclear how	(Smit and	thereby	climate	relationship	See main text		prices and
Red	luced	have impacts on	countries	(e.g. increased		site for	cycling	waste can be a	2013).	resource	reducing waste	Nasr 1992;	reducing waste	mitigati	is not	on		constraints
1 .	d waste	poverty	(Hertel and	contamination)		intervention	(Kummu et	sustainable source of	Reductions of	constrained	may contribute	Zaman and	contributes to	on and	known	desertification		on trade
1000				(C1) 11	1	(Thuhana and	al. 2012).	biofuel (Uckun	postconsumer	countries (Lin et	to reducing	Lehmann	sustainable	adaptati	(Hornweg			(Tefera
(cor	nsumer retailer)	(Papargyropoulou et al. 2014)	Baldos 2016).	(Claudio 2012)	N/A	(Thyberg and Tonjes 2016)	Muller et al.	Kiran et al. 2014)	waste would	al. 2013)	inequality.	2011)	consumption.	on	et al 2013)	and degradation	N/A	2012)

			1				1	(2017b)		increase		1	1			1	1		1
								(2017b) found that		household									
								lower impact		income									
								agriculture		(Hodges et al.									
								could be		(Houges et al. 2011)									
								practiced if		2011)									
								dietary											
								change and											
								waste											
								reduction											
								were											
								implemented,											
								leading to											
								lower GHG											
								emissions,											
								lower rates											
								of											
								deforestation,											
								and											
								decreases in											
								use of											
								fertiliser											
						1		(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)	2000, Opton et al. 2008)	(Moore et al. 1996)	Solberg 2005)	N/A	2013)	2006)	on	(Doney et al. 2009)	degradation	N/A	N/A
		substitution	N/A	Poor farmers	INT	IN/A	19/14	2011)	2008)	1990)	3010erg 2003)	N/A	2013)	2000)	on	al. 2009)	uegrauation	IN/A	IN/A
			Value adding has	can benefit								Value-adding							
			been promoted as	from value-								can be an							
			a successful	adding and								important							
			poverty reduction	new markets			Women are					component of							
			strategy in many	(Bamman			highly					additional							
			countries (Lundy	(Baniman 2007) and			employed in					employment for							
			et al. 2002;	may help to		1	value-added					poorer areas, and							
			Whitfield 2012:	improve		1	agriculture in					can contribute to							
			Swanson 2006).	food security			many					reductions in							
			Volatility of food	by		1	developing				Value adding	overall							
			boot to volume v				ueveloping				can create	inequality.							
											Call CICAIC	inequality.	1		1		1		
			supply and food	increasing its			countries, but				incentives to	Howayar date							
			supply and food price spikes in	increasing its economic			countries, but do not always				incentives to	However, data	Value_adding						
1			supply and food price spikes in 2007 increased the	increasing its economic performance			countries, but do not always gain			Volue addin-	improve	shows high-	Value-adding						
			supply and food price spikes in 2007 increased the number of people	increasing its economic performance and revenues			countries, but do not always gain substantive			Value-adding	improve infrastructure in	shows high- value agriculture	can increase	Value adding					
			supply and food price spikes in 2007 increased the number of people under the poverty	increasing its economic performance and revenues to local			countries, but do not always gain substantive benefits			and export	improve infrastructure in processing	shows high- value agriculture is not always a	can increase incentives to	Value-adding					
			supply and food price spikes in 2007 increased the number of people under the poverty line by between	increasing its economic performance and revenues to local farmers			countries, but do not always gain substantive benefits (Dolan and	Value - 11-1		and export diversification	improve infrastructure in processing (Delgado 2010).	shows high- value agriculture is not always a pathway toward	can increase incentives to keep peri-	in agriculture					Value e ¹ Value
			supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people	increasing its economic performance and revenues to local farmers (Reidsma et	Value chains	Value	countries, but do not always gain substantive benefits (Dolan and Sorby 2003).	Value-added		and export diversification generates	improve infrastructure in processing (Delgado 2010). Expanding	shows high- value agriculture is not always a pathway toward enhanced	can increase incentives to keep peri- urban	in agriculture (.e.g. fair trade,					Value-adding
			supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people (Ivanic and Martin	increasing its economic performance and revenues to local farmers (Reidsma et al. 2010).	Value-chains	Value-	countries, but do not always gain substantive benefits (Dolan and Sorby 2003). Value-chains	products		and export diversification generates additional	improve infrastructure in processing (Delgado 2010). Expanding value chains can	shows high- value agriculture is not always a pathway toward enhanced welfare (Dolan	can increase incentives to keep peri- urban agriculture,	in agriculture (.e.g. fair trade, organic) can be	See				has a strong
			supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people (Ivanic and Martin 2008) to 450	increasing its economic performance and revenues to local farmers (Reidsma et al. 2010). However,	can help	adding can	countries, but do not always gain substantive benefits (Dolan and Sorby 2003). Value-chains that target	products might require		and export diversification generates additional employment	improve infrastructure in processing (Delgado 2010). Expanding value chains can incorporate new	shows high- value agriculture is not always a pathway toward enhanced welfare (Dolan and Sorby 2003),	can increase incentives to keep peri- urban agriculture, but faces	in agriculture (.e.g. fair trade, organic) can be an important	See				has a strong relationship
			supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people (Ivanic and Martin 2008) to 450 million people	increasing its economic performance and revenues to local farmers (Reidsma et al. 2010). However, much value-	can help increase the	adding can increase	countries, but do not always gain substantive benefits (Dolan and Sorby 2003). Value-chains that target women could	products might require additional		and export diversification generates additional employment and expands	improve infrastructure in processing (Delgado 2010). Expanding value chains can incorporate new sources of food	shows high- value agriculture is not always a pathway toward enhanced welfare (Dolan and Sorby 2003), and much value-	can increase incentives to keep peri- urban agriculture, but faces threats from	in agriculture (.e.g. fair trade, organic) can be an important source of	main				has a strong relationship to expanding
			supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people (Ivanic and Martin 2008) to 450 million people (Brinkman et al.	increasing its economic performance and revenues to local farmers (Reidsma et al. 2010). However, much value- adding is	can help increase the nutritional	adding can increase income	countries, but do not always gain substantive benefits (Dolan and Sorby 2003). Value-chains that target women could increase	products might require additional water use		and export diversification generates additional employment and expands GDP in	improve infrastructure in processing (Delgado 2010). Expanding value chains can incorporate new sources of food producers into	shows high- value agriculture is not always a pathway toward enhanced welfare (Dolan and Sorby 2003), and much value- adding is	can increase incentives to keep peri- urban agriculture, but faces threats from rising land	in agriculture (.e.g. fair trade, organic) can be an important source of sustainable	main text on				has a strong relationship to expanding trade in
			supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people (Ivanic and Martin 2008) to 450 million people (Brinkman et al. 2009), and caused	increasing its economic performance and revenues to local farmers (Reidsma et al. 2010). However, much value- adding is captured	can help increase the nutritional status of food	adding can increase income that could	countries, but do not always gain substantive benefits (Dolan and Sorby 2003). Value-chains that target women could increase gender equity,	products might require additional water use (Guan and		and export diversification generates additional employment and expands GDP in developing	improve infrastructure in processing (Delgado 2010). Expanding value chains can incorporate new sources of food producers into industrial	shows high- value agriculture is not always a pathway toward enhanced welfare (Dolan and Sorby 2003), and much value- adding is captured not by	can increase incentives to keep peri- urban agriculture, but faces threats from rising land prices in	in agriculture (.e.g. fair trade, organic) can be an important source of sustainable consumption	main text on climate		See main text		has a strong relationship to expanding trade in developing
			supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people (Ivanic and Martin 2008) to 450 million people (Brinkman et al. 2009), and caused welfare losses of	increasing its economic performance and revenues to local farmers (Reidsma et al. 2010). However, much value- adding is captured upstream,	can help increase the nutritional status of food reaching	adding can increase income that could be spent on	countries, but do not always gain substantive benefits (Dolan and Sorby 2003). Value-chains that target women could increase gender equity, but data is	products might require additional water use (Guan and Hubacek		and export diversification generates additional employment and expands GDP in developing countries in	improve infrastructure in processing (Delgado 2010). Expanding value chains can incorporate new sources of food producers into industrial systems of	shows high- value agriculture is not always a pathway toward enhanced welfare (Dolan and Sorby 2003), and much value- adding is captured not by smallholders but	can increase incentives to keep peri- urban agriculture, but faces threats from rising land prices in urban areas	in agriculture (.e.g. fair trade, organic) can be an important source of sustainable consumption and production	main text on climate mitigati		on		has a strong relationship to expanding trade in developing countries in
			supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people (lvanic and Martin 2008) to 450 million people (Brinkman et al. 2009), and caused welfare losses of 3% or more for	increasing its economic performance and revenues to local farmers (Reidsma et al. 2010). However, much value- adding is captured upstream, not by poor	can help increase the nutritional status of food reaching consumers	adding can increase income that could be spent on education,	countries, but do not always gain substantive benefits (Dolan and Sorby 2003). Value-chains that target women could increase gender equity, but data is scare	products might require additional water use (Guan and Hubacek 2007), but		and export diversification generates additional employment and expands GDP in developing countries in particular	improve infrastructure in processing (Delgado 2010). Expanding value chains can incorporate new sources of food producers into industrial systems of distribution	shows high- value agriculture is not always a pathway toward enhanced welfare (Dolan and Sorby 2003), and much value- adding is captured not by smallholders but higher up the	can increase incentives to keep peri- urban agriculture, but faces threats from rising land prices in urban areas (Midmore	in agriculture (.e.g. fair trade, organic) can be an important source of sustainable consumption and production (de Haen and	main text on climate mitigati on and		on desertification		has a strong relationship to expanding trade in developing countries in particular
Supj	ply nagement	Sustainable sourcing	supply and food price spikes in 2007 increased the number of people under the poverty line by between 100 million people (Ivanic and Martin 2008) to 450 million people (Brinkman et al. 2009), and caused welfare losses of	increasing its economic performance and revenues to local farmers (Reidsma et al. 2010). However, much value- adding is captured upstream,	can help increase the nutritional status of food reaching	adding can increase income that could be spent on	countries, but do not always gain substantive benefits (Dolan and Sorby 2003). Value-chains that target women could increase gender equity, but data is	products might require additional water use (Guan and Hubacek	N/A	and export diversification generates additional employment and expands GDP in developing countries in	improve infrastructure in processing (Delgado 2010). Expanding value chains can incorporate new sources of food producers into industrial systems of	shows high- value agriculture is not always a pathway toward enhanced welfare (Dolan and Sorby 2003), and much value- adding is captured not by smallholders but	can increase incentives to keep peri- urban agriculture, but faces threats from rising land prices in urban areas	in agriculture (.e.g. fair trade, organic) can be an important source of sustainable consumption and production	main text on climate mitigati	N/A	on	N/A	has a strong relationship to expanding trade in developing countries in

																-		
		(Zezza et al.	and															
		2009).	Schneider															
			2011b).															
			Food prices															
			strongly															
			strongry															
			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															
			food security															
			(Timmer															
			2009;						1	1	1		1	1				
			Torlesse et															
			al. 2003b;															
			Raleigh et al.															
			2015b).															
										Excessive								
										disruptions in								
										food supply can								
		Reducing food								place strains on								
		transport costs								infrastructure								
		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						
					Deduction							food						Dattan
		poverty reduction	management		Reduction					infrastructure	inequality							Better
		and better	practices		in staple					(Akkerman et	(Baldos and	distribution						transport
		transport could	(James and		food price				Food supply	al. 2010;	Hertel 2015;	can contribute						improves
		increase the	James		costs to				instability is	Shively and	Frank et al.	to better food						chances for
		amount generated	2010a;		consumers				often driven	Thapa 2016).	2017; Porter et	access and						expanding
		(MacGregor and	Bradford et	Access to	in				by price	For example,	al. 2014;	stronger	1	1				trade in
		Vorley 2006;	al. 2018;	quality food is	Bangladesh				volatility,	weatherproofing	Wheeler and von	urban	1	1				developing
		Muriithi and Matz	Temba et al.	a major	from food		Food imports		which can be	transport	Braun 2013).	communities						countries
		2015). Volatility	2016;	contributor to	stability		can		driven by	systems and	Improved food	(Kantor 2001;	Improved					(Newfarmer
		of food supply and	Stathers et	whether a diet	policies		contributed		rapid	improving the	distribution	Hendrickson	storage and					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					Well-planned
		in 2007 increased	Tirado et al.	not (Neff et al.	households							· · · · · ·						
							scarcity		growth and	food trade	inequality in	Food price	likely to	1		1	1	trade systems
		the number of	2010). There	2009).	\$887		through		which can	(Ingram et al.	access to high	spikes often	contribute to	1		1	1	may act as a
		people under the	is some	Increased	million		"embodied"	Food supply chains	contribute to	2016a; Stathers	quality nutritious	hit urban	sustainable					buffer to
		poverty line by	limited	distribution	total	Women and	or "virtual"	and flows have	consumer	et al. 2013)	foods. Food	consumers	production by					supply food
		between 100	evidence that	and access of	(Torlesse	girls are often	water	adverse effects due	price inflation	especially in	insecure	the hardest in	impacting					to vulnerable
		million people	improved	packaged	et al.	the most	accounting	to reliance on non-	and higher	countries with	consumers	food	biomass of					regions
		(Ivanic and Martin	transport on-	foods however	2003b), but	effected ones	(Yang and	renewable energy	import costs	inadequate	benefit from	importing	paper/card and	See				(Baldos and
		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				Hertel 2015;
		million people		health	increased	when there	2002; Guan	2017). Shifts to		and weak food	distribution (e.g.	increasing	iron-ore	text on				Frank et al.
			increases						percentage of							6		
		(Brinkman et al.	food security	outcomes	spending	are food	and Hubacek	biofuels can	GDP leading	distribution	elimination of	stability can	mining used	climate		See main text		2017; Porter
		2009), and caused	in	(Galal et al.	on	shortages	2007; Hanjra	destabilise food	to account	systems	food deserts)	reduce risk of	for food	mitigati		on		et al. 2014;
	Management	welfare losses of	developing	2010;	education	(Kerr 2005;	and Qureshi	supplies (Tirado et	deficits	(Vermeulen et	(Ingram 2011;	food riots	packaging	on and		desertification		Wheeler and
	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		von Braun
	chains	poor households	(Hine 1993).	2011)	households	2008)	2009)	et al. 2009)	Morgan 2010)	strengthen	O'Dwyer 2009)	Garrett 2010)	2016a).	on	N/A	degradation	N/A	2013).
· · · · · ·			•			•			•	•	•	•	•	•		•	•	

									climate resilience								
									against future climate-related								
									shocks (Ingram et al. 2016a;								
									Stathers et al. 2013).								
		Food insecurity in							, , , , , , , , , , , , , , , , , , ,								
		urban areas															
		is often invisible															
		(Crush and															
		Frayne 2011).														Building a	
		Improved	Since urban													resilient	
		urban food systems	poor spend a great deal of													regional food system	
		manage	their budget on													requires	
		flows of food into,	food and urban diets are													adjusting to the social	
		within, and	exposed to		Urban and											and cultural	
		out of the cities and	more unhealthy 'fast		Peri-urban Agriculture											environment and locally-	
		have large	foods' (Dixon		and Forestry											specific	
		role to play in reducing	et al. 2007), local urban		(UPAF) addresses			Urban food systems have								natural resource	
	Regional food	urban food	food systems		gender-based	Water access		as one aim to stimulate								base and building	
	systems present opportunities for	security (Smit 2016;	can contribute to enhanced		differences in accessing	often a constraint on		local								local	
	interconnectedness of the food	Benis and Ferrão	nutrition in urban areas		food since	urban agriculture		economic								institutions (Akhtar et	
	system's	2017a;	(Tao et al.		women play an important	(de Bon et al.		development and increase								(Akmar et al. 2016).	
	component resilient food	Brinkley et al. 2016;	2015; Maxwell		role in the provisioning	2010; Badami and		employment in urban			UFS aim at					Production of food	
	supply systems	Rocha 2016;	1999; Neff et	School	of urban food	Ramankutty		agriculture			improving the					within cities	
	and city-regions have an important	Maxwell and Wiebe	al. 2009). However,	feeding programs	(Tao et al. 2015; Binns	2015). Urban agriculture	Local food production and use	and food processing	Urban food	Many UFS in	health status of urban					can potentially	
	role (Brinkley et	1999),	local urban	in urban	and Lynch	can	can reduce energy	(Smith 1998).	provisioning	global South	dwellers,			Overall		lead to less	
	al. 2016; Rocha 2016). However,	particularly in fostering	agriculture also may	areas can increase	1998). Women also	exacerbate urban water	use, due to lower demand of resources	As many as 50% of some	creates demands for expanded	(e.g. Belo Horizonte,	reducing their exposure to	UFS aim to combine	See	reduced emissions		likelihood of urban	
	mixed evidence on	regional	introduce	educational	dominate	pollution	for production,	cities' retail	infrastructure in	Brazil) have	pollution	sustainable	main	would		food	
	if urban agriculture	food self- reliance	pollution into food system	attendance and	informal urban food	problems (pesticide	transport and infrastructure (Lee-	jobs are in food-related	processing, refrigeration,	goals to reduce inequality in	levels, and stimulating	production and consumption	text on climate	decrease rate of	See main text	shortages and	
	contributes to	(Aldababseh	through toxins	outcomes	provisioning	runoff, etc)	Smith 2010), but	sector	and	access to food.	economic	with local	mitigati	ocean	on	conflicts	
Enhanced urban food	poverty reduction (Ellis and	et al. 2018; Bustamante	in soil and water (Binns	(Ashe and Sonnino	(wet markets, street food)	(Pothukuchi and Kaufman	depends on context (Mariola 2008;	(Pothukuchi and Kaufman	transportation (Pothukuchi and	(Dixon et al. 2007; Allen	development (Tao et al.	foodsheds (Tao et al. 2015;	on and adaptati	acidification (Doney et	desertification and	(Cohen & Garrett	
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	2010).	N/A
			Improved processing and			Food processing		Phytosanitary barriers									
		Efficiency in	distribution			and		currently									
		food processing	&storage systems can			packaging activities		prevent much food export									
		and supply	provide safer		Improved	such as		from									
		chains can contribute to	and healthier food to		food processing	washing, heating,		developing countries, and									
		more food	consumers		can displace	cooling are	Food processing and	improvements	Improvements		Improved			Overall			Improved
	Food processing has been a useful	reaching consumers	(Vermeulen et al. 2012a) and		street venders and informal	heavily dependent on	packaging activities such as heating and	in processing would	in processing, refrigeration,		food transport can reduce		See	reduced emissions			processing increases
	strategy for	and	reduce food		food sellers,	freshwater so	cooling are heavily	increase	and		cities'	Improved food	main	would			chances for
	poverty reduction in some countries	improved nutrition	waste and health risks		who are predominantly	improved postharvest	dependent on energy so improved	exports and GDP (Henson	transportation will require		ecological footprints and	processing and agro-retailing	text on climate	decrease rate of	See main text		expanding trade in
Improved	(Weinberger and	(Vermeulen	associated		women	storage and	efficiency could	and Loader	investments in		reduce overall	contributes to	mitigati	ocean	on decentificantion		developing
food processing	Lumpkin 2007; Haggblade et al.	et al. 2012a; Keding et al.	with poor storage		(Smith 1998; Dixon et al.	distribution could reduce	reduce energy demand (Garcia and	2001; Jongwanich	improved infrastructure		emissions (Du et al.	sustainable production	on and adaptati	acidification (Doney et	desertification and		countries (Newfarmer
and retailing	2010)	2013)	management	N/A	2007)	water	You 2016).	2009).	(Ingram 2011)	N/A	2006)	(Ingram 2011)	on	al. 2009)	degradation	N/A	et al. 2009)

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

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

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

								(Godschalk			2006; Andersson						
								2003)			2006)						
				More													
				diversified													
		D . 10															
		Diversification		households						The							
		is associated		tend to be	Women are					relationship							
		with increased		more affluent,	participants					between							
		access to	More	& have more	in and					livelihood							
		income and	diversified	disposal	benefit from					diversificati	One part of urban	Livelihood					
		additional	livelihoods	income for	livelihood					on and	livelihoods in	diversification					
		food sources	have	education	diversificatio					inequality is	developing	does not always					
		for the	diversified	(Ellis 1998;	n, such as					inconclusiv	countries are	lead to					
	Diversification	household	diets which	Estudillo and	having					e (Ellis	linkages between	sustainable					
	is associated	(Pretty 2003);	have better	Otsuka 1999;	increased					1998). In	rural and urban	production and					
	with increased		health	Steward			A	Livelihood									
		likely some			control over		Access to			some cases	areas through	consumption					
	welfare and	food security	outcomes	2007), but	sources of		clean energy	diversification		diversificati	migration and	choices, but it					
	incomes and	benefits but	(Block and	diversification	HH income		can provide	by definition		on reduced	remittances	can strengthen					
	decreased	diversification	Webb 2001;	through	(Smith		additional	contributes to		inequality	(Rakodi 1999;	autonomy					
	levels of	can also lead	Kadiyala et	migration	2015),		opportunities	employment		(Adams	Rakodi & Lloyd	potentially	See main				
	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		See main		
	several country	purchased	particularly	educational	can increase	affordable water	diversification	additional		in others	livelihood	choices	climate		text on		
	studies (Arslan	(unhealthy)	for women	outcomes for	their labor	may inhibit	(Brew-	work		cases it	diversification can	(Elmqvist and	mitigation		desertific		
	et al. 2018b;	foods (Niehof	and children	children	requirements	livelihood	Hammond	opportunities		increases it	strengthen urban	Olsson 2007;	and		ation and		
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
 uiversincation	2018).	et al. 2001)	Local seed	2014)	Thii 2009)	(Calow et al. 2010)	et al. 2015)	INICIIOI 2004)	INA	ai 2000)	2012)	Niederie 2010)	11	N/A	on	IN/A	19/74
	Many hundreds of millions of smallholders still rely on local seeds; without them they would have to find money to buy commercial	Local seeds revive and strengthen local food systems (McMichael and Schneider 2011b) and lead to more diverse and healthy food in areas with strong food sovereignty networks (Coomes et al. 2015a; Bisht et al. 2018). However local	associated with fewer pesticides (Altieri et al. 2012b); loss of local seeds and substitution by commercial seeds is perceived by farmers to increase health risks (Mazzeo and Brenton 2013), although overall literature on links between		Women play important roles in preserving and using local seeds (Ngcoya and Kumarakulas ingam 2017; Bezner Kerr 2013) and sovereignty movements	Local seeds often have lower water		Food sovereignty supporters believe protecing smallholder agriculture provides more employment		Seed sovereignty advocates believe it will contribute to reduced inequality (Wittman 2011: Park	Seed sovereignty can help sustainable urban gardening (Demailly and Darly 2017) which	Locally developed seeds can both help protect local agrobiodiversity and can often be more climate resilient than generic commercial varieties, leading to more sustainable production	See main text on		See main	Seed sovereignty is positively associated with strong local food movements, which contribute to social capital (McMichael and Schneider 2011)	Seed sovereignty could be seen as threat to free trade and imports of genetically modified seeds (Kloppenbe
	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		text on	2011b;	rg 2010;
	al. 2012b;	less	sovereignty		attention to	as less use of		commercial		but there is	sustainable city by	2015a; van	mitigation		desertific	Coomes et al.	Howard
	McGuire and	productive	and health is		gender needs	pesticides that can		agriculture		inconclusiv	providing fresh,	Niekerk and	and		ation and	2015a; Grey	2015;
Use of local	Sperling 2016;	than improved	weak (Jones		(Park et al.	contaminate water		(Kloppenberg		e empirical	local food (Leitgeb	Wynberg	adaptatio		degradati	and Patel	Kloppenbur
seeds	Howard 2015)	varieties.	et al. 2015)	N/A	2015)	(Adhikari 2014)	N/A	2010)	N/A	evidence.	et al. 2016).	2017a).	n	N/A	on	2015).	g 2014)

																	1
Disaster risk management	DRM can help prevent impoverishment a major factor in poverty (Basher 2006; Fothergill and Peek 2004)	Famine early warning systems have been successful to prevent impending food shortages (Genesio et al. 2011; Hillbruner and Moloney 2012)	EWS very important for public health to ensure people can get shelter and medical care during disasters (Greenough et al. 2001; Ebi and Schmier 2005)	N/A	Women often disproportion ately affected by disasters; gender- sensitive EWS can reduce their vulnerability (Enarson and Meyreles 2004; Mustafa et al. 2015)	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 (Hasan et al. 2009; Hou et al. 2013)	N/A	DRM can help minimise damage from disasters, which impacts economic growth (Basher 2006)	DRM can help protect infrastructures from damage during disaster (Rogers and Tsirkunov 2011)	EWS can ensure inequality is taken into account when making predictions of impacts (Khan et al. 1992)	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; Djordjević et al. 2011)	DRM can make sustainable production more possible by providing farmers with advance notice of environmental needs (Stigter et al. 2000; Par et al. 2003)	See main text on climate mitigation and adaptatio n	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; Lauterjung et al. 2010)	See main text on desertific ation and degradati on	DRM can reduce risk of conflict (Meier et al. 2007), increase resilience of communities (Mathbor 2007) and strengthen trust in institutions (Altieri et al. 2012b)	N/A
management	Peek 2004)	2012)	2005)	N/A	al. 2015)	Hou et al. 2013) Crop insurance can be indexed to	N/A	(Basher 2006)	Tsirkunov 2011)	1992)	2011)	al. 2003)	n	et al. 2010) 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;	on	20126)	N/A
Risk sharing	Crop insurance reduces risks which can improve poverty outcomes by avoiding catastrophic losses, but is often not used by poorest people (Platteau	Availability of crop insurance has generally lead to (modest) area and area and increased food production (Claassen et al. 2011; Goodwin et al.	General forms of social lead to better health outcomes; unclear how much crop insurance contributes (Tirivavi et	Households insurance may withdraw children from school after crop shocks (Jacoby and Skoufias 1997; Bandara et al.	Women farmers vulnerable to crop shocks, but tend to be more risk- averse and skeptical of commercial insurance (Akter et al. 2016; Fietschner and Kenney	the indexed to weather and water access and thereby increase adapation to water stress (Hoff and Bouwer 2003). Subsidised insurance can also be linked to reductions in pesticide use to reduce non-point source pollution, which has shown success in the US and China (Luo et		Subsidised crop insurance contributes to growth in the US (Atwood et al. 1996) but at considerable cost to the governance (Glauber				Crop insurance has been implicated as a driver of unsustainable production and disincentive to diversification (Bowman and Zilberman 2013), although community risk sharing might increase diversification	See main text on climate mitigation and adaptatio	pontution, however, some government s re requiring reductions in nonpoint source pollution from farms otherwise farmers lose crop insurance (lho et al.	See main text on desertific ation and degradati	Community risk sharing instruments can help strenthen resilience and institutions (Agrawal	Subsidised crop insurance can be seen as a subsidy and barrier to trade (Young and Westcott