Table 2: Impact of indirect driver on direct driver, and magnitude of the impact on nexus elements. Supporting information of assessment in Chapter 2, Figure 2.10, 2.11 & 2.12.

Trends in indicators of indirect drivers are summarised in Chapter 2 **Table 2.2** and the DMR 0_IPBES_NXS_DMR_2.5_indirect drivers.docx. Categories used in column 'Assessment of impact' are identical with the categories (arrows) used in Chapter 2 **Figure 2.10** (**Intensification**, **Modest intensification**, **Stable/little to no impact,** **Small reduction,** **Variable**).

Level of evidence statements refer to the impact of the indirect driver on the direct driver. The confidence that underpins the assessment of the paths that operate from changes in the indirect drivers via the direct drivers on nexus elements is difficult to estimate, especially in cases in which the indirect driver affects the nexus elements both via a change in the direct driver but also as a direct driver itself.

Indirect driver	Impact on direct driver	Supporting statement for impact of indirect on direct driver and nexus elements	Assessment of impact: How trends in indirect driver act on trend in direct driver	Summary of impacts on nexus elements (for additional information and references: see Table 3 of DMR 0_IPBES_NXS_DMR_2.5)	Level of evidence of impact
GDP	**Land/ sea use change**	Expansion of land and sea use is highly correlated with economic growth, a decoupling of GDP growth from resource and area use would be required to reduce environmental impacts (Hertel et al., 2019; IPCC, 2019, 2022). Land-cover changes have affected about 32% of the global land area between 1960 and 2019 (Winkler et al., 2021). Primary forests worldwide continue to being lost (e.g. > 80 mio ha since 1990); agricultural expansion is the main driver (FAO & UNEP, 2020; IPCC, 2019). In the ocean, sea-use change is still a new concept. Marine protected areas cover only ca >7% of open and coastal waters and of these, only half are truly implemented (Arneth et al., 2023; Maxwell et al., 2020). Bottom trawling is expanding to larger and deeper areas (Paradis et al., 2021). Metal mines alone impact by now close to 480 000 km of river channels and 164 000 km^2 of floodplains, on which ca, 23 Mio people live (Macklin et al., 2023), while pressure on altering the sea floor over large areas by mining is increasing (Raman, 2023).	**Intensification**: The increase in GDP reflects numerous economic processes that jointly have contributed notably to increasing area under land- and sea use. *(well established)*	Expanding agricultural area and marine fishing grounds help to sustain the worldwide increasing demand for calories, at the cost of biodiversity, although (on land) agricultural intensification has been more important for increasing food production. A larger area under use for food production does not affect food quality. Conversion of natural into agricultural area but also increasing area under dams affects water availability in variable ways (ie, water resources are redistributed with gains and losses), and overall reduces (via nutrient retention) water quality. Physical health impacts are variable: e.g., positive impacts through reduction of malnourishment are observed alongside negative impacts of overeating, but also via the spread of various types of diseases in agricultural landscapes. Loss of access to green spaces or sense of place affects mental health negatively.	*well established*
	Direct exploitation / utilization	Like expansion of area under use, intensification is highly correlated with trends in GDP (Hertel et al., 2019; IPCC, 2019, 2022). On land, humans appropriate ca 25% of net primary productivity; a large component (ca. 2/3) is embodied in trade, and both have been increasing with	**Intensification**: Processes underpinning GDP growth have contributed notably to intensity of land and sea use,	Intensive agriculture and fisheries, with mining, are well-known drivers of biodiversity loss. Increasing GPP is a well-known indicator for intensification to supply increasing per-	*well established*

		time (Haberl et al., 2012; Liang et al., 2023). Total catch (inland and marine, incl. aquaculture) has increased to nearly 180 mio t in 2020 (20 mio t in 1960), aquaculture is the fastest growing food production system globally (e.g., >400% in Africa, 2000-2020). More than one third of marine fish stocks are overexploited (Arneth et al., 2023; FAO, 2020). Agriculture in many regions of the world continues to contribute to environmental degradation (Arneth et al., 2021; Ramankutty et al., 2018).	and direct exploitation of resources more broadly. *(well established)*	capita (and total) demand for calories, but with variable impacts on food quality (homogenisation of crops negatively impacts nutrition *vs.* affordability of nutritious food at higher levels of income). The increasing water abstraction (irrigation, but also for mining) is unsustainable and intensifies impacts of pollution on freshwater and coastal systems. Positive health impacts through reduction of malnourishment are observed alongside negative impacts of overeating and/or the use of agro-chemicals; negative mental impacts of the direct exploitation of resources seem frequent in people directly working in the associated industries.	
	Climate change	GDP correlates strongly with total energy consumption and greenhouse gas emissions (especially CO_2) (IPCC, 2014, 2018). Progress in the decarbonisation of the economy so far is insufficient to slow climate warming.	▲▲ **Intensification**: GDP growth has been a main driver of continued GHG emissions. *(well established)*	Negative impacts of climate change on biodiversity are beginning to emerge in many world regions. Climate change impacts on yields are regionally highly variable, although CO_2 increases reduce nutritional quality. Both physical and mental health are increasingly negatively impacted, especially through climate-change-induced weather extremes. Impacts on freshwater availability are regionally variable, but assessed as overall negative, while impacts on (freshwater) water quality in the wake of extreme weather events are beginning to emerge.	***well established***
	Invasive alien species	Economic growth correlates with trade and hence has negative impact on the spread of IAS. It is also an important factor of additional socio-economic processes associated with species invasions e.g., by dedicated introduction for agri- or aquaculture, forestry or gardening (Epanchin-Niell, 2017; IPBES, 2023; McDermott et al., 2013).	▲ **Modest intensification**: GDP growth has supported several related processes (foremost trade (see below) but also e.g., species introduction for recreation or pets, international travel, etc.) that increase the establishment and spread of IAS (IPBES, 2023). *(well established)*	The largest (negative) impact on biodiversity and physical health in response to the spread of IAS is via trade and given trade's correlation with GDP the impact here is also negative (but less severe). Pressures on other nexus elements from IAS in response to processes fostered by GDP increase are considered small.	***well established***
	Pollution	The lack of decoupling growth from emissions and resources over-extraction results also in a continued increase (globally) of pollutants such as O_3 and particles,	▲▲ **Intensification**:	Economic growth and pollution continue to be correlated globally, with associated negative pollution-impacts on biodiversity	***well established***

		agrochemicals, plastics and others that arise from the production processes that underpin GDP growth (Basar & Tosun, 2021; IPBES, 2019; Mitic et al., 2022). Around 3 mio deaths annually have been attributed to air pollution (Lelieveld et al., 2019). The number of dead zones in marine systems continues to increase (Ripple et al., 2017). In most of the richer countries, economic growth has supported instalment of pollution control measures; but globally pollution impacts are still increasing. Approximately 23 mio people live on floodplains affected by past and present metal mining, with potentially dangerous concentrations of toxic waste (Macklin et al., 2023).	Even though in some regions some pollution control measures begin to take effect, a multitude of industrial processes that underpin GDP growth lead to globally still continuing air, soil and water pollution. *(well established)*	and yields, as well as water quality and physical health. Although increasing GDP corresponds also with e.g., capacity to waste-water treatments and/or access to health care, globally pollution impacts are still increasing. It is not to be expected that a change in pollution changes available water quantity.	
Material intensity	**Land/sea use change**	Evidence on the impact of material intensity on land/sea use is limited. Waste and losses in the food system, a measure of resource efficiency, remains at the high level of an estimated 30% of food produced for human consumption, and possibly contributing up to 50% of food system GHG emissions (Alexander et al., 2017; IPCC, 2019; Zhu et al., 2023).	▬ **Stable/little to no impact:** Material intensity has been declining over many years (but levelling off over last years), with impacts likely stronger on direct exploitation of resources, less so on area changes. *(inconclusive)*	Because of likely negligible impacts of decreasing material intensity on land- and sea-area uses impacts on nexus elements are also small/negligible. There is no reason to expect that stronger trends in material intensity would affect food quality via impacts on land/sea-use and food quality.	***inconclusive***
	Direct exploitation / utilization	Resource intensity is positively correlated with environmental costs (Fan et al., 2019; IPBES, 2018), material intensity is as meaningful as GDP itself as a driver of direct exploitation of resources. Increasing the efficient use of resources is seen as a main objective when aiming to support the needs of the human population while reducing negative impacts on the environment (Armeanu et al., 2018; Papież et al., 2022; Ringler et al., 2013). Globally, trends in material intensity have been overall negative (Figure 2.6), which is positive from an impact's perspective, but slowed down notably, especially in the recent decade. The regionally diverging trends in resource intensity so far are insufficient to take effect globally (Bithas & Kalimeris, 2018). Evidence for the existence of an environmental Kuznets Curve is contradictory because of very different assumptions and analytical approaches (Armeanu et al., 2018).	▼ **Small reduction:** Trends in material intensity have been negative – which is expected to have had a small but mostly positive impact, i.e. slowing direct exploitation and the intensity of land/sea use although material intensity since 2010 may have levelled off compared to longer-term trends. *(inconclusive)*	Given the overall small trend in material intensity and the large negative impacts the extraction of biological resources and mining have on most nexus elements, at least locally, declining intensities seemed to have been insufficient so far to slow the related biodiversity loss, water over-use and pollution. Resource efficiencies in the food system (e.g., harvest index, nitrogen use, irrigation efficiency) have been positive, albeit small. There is no literature that links trends in declining material intensity/more efficient resource use to mental health or physical health globally although in principle a strongly declining material intensity could have an impact.	***inconclusive***
	Climate change	Trends in material intensity are insufficient to notably affect GHG emissions (Akdoğan et al., 2023; Papież et al., 2022). For instance, using 2017 as base year, a truly successful decoupling would have to result in 2.6 times more GDP out of every ton of material use (Vaden et al., 2021). Examples of GDP growth coinciding with absolute	▼ **Small reduction:** Trends in material intensity have been negative – which is expected to have had a small positive impact on reducing GHG emissions and hence	Given the relatively small trends in material intensity and the relatively small and variable direct impacts of climate change on many nexus elements (compared with other direct drivers) we assess impacts to be negligible.	***inconclusive***

		reductions in emissions or resource use so far are rare (Haberl et al., 2020).	climate change although material intensity since 2010 may have levelled off compared to longer-term trends. *(inconclusive)*		
	Invasive alien species	There is no evidence that the small trend in material intensity is impacting the spread of Invasive Alien Species.	**Stable/little to no impact:** Declining material intensity may affect spread of IAS via its impact on trade, but the impact is expected to have been overall negligible globally. *(inconclusive)*	The small impacts on IAS arising from increasing resource use efficiency reverberate to little/no impact on nexus elements.	***inconclusive***
	Pollution	Evidence in the literature on the relationship between improving material intensity and pollution remains contradictory (Vaden et al., 2021). In Europe, for instance, the Environmental Kuznets curve theory has been confirmed for some pollutants such that emissions first increase and then decrease as GDP per capita increases (Haberl et al., 2020) . However, given that emissions of pollutants and GHG emissions in many cases are linked, similar arguments apply here as in the case of direct exploitation.	**Small reduction:** Trends in material intensity have been negative – which is expected to have had a small positive impact on pollution although material intensity since 2010 may have levelled off compared to longer-term trends. *(inconclusive)*	Impacts on nexus elements via improved material intensity impact on pollution mostly mirror those related to climate change, i.e. the trends in improved material intensity are too small to have altered trends in nexus elements notably.	***inconclusive***
Trade	**Land/sea use change**	Trade affects changes in land- and sea-use via regionally varying supply, demand and purchasing power, although quantitative evidence on area impacts is limited. Expansion of agricultural area is also driven by production for export, including displacement effects (e.g., Wood et al., 2018). International trade has been estimated to contribute 21-37% of global land area use (Armeanu et al., 2018). Trade is also a substantial driver of bottom trawling at sea.	**Intensification**: Trade of agricultural products and timber has been an important contributor to expanding area under human use. *(well established)*	Given that trade is one of the underlying causes for expansion of area under human use, and its strong links with GDP, the impacts on nexus elements are broadly similar to those assessed for GDP.	***well established***
	Direct exploitation /utilization	Trade in wood products increased by 143% to US$244 billion between 1990 and 2019, the global timber and wood product market is ca. 591 billion $US (2021), and timber demand continues to grow (Daigneault et al., 2022; FAO & UNEP, 2020). Ornamental fish trade, dominated by freshwater species, has been estimated as US $ 15-20 bill. p.a. (Jones et al., 2022). The global illegal trade in wild species has been valued at ca. 25 mio $US. Trade in wild plants, algae and fungi is increasing including as poached resources and contributes notably to the unsustainable use of ecosystem resources (IPBES, 2022). About 1/5 of global fish catches comes from unregulated/illegal operations (Cawthorn & Mariani,	**Intensification**: Trade of all types of goods (agricultural, forestry, mined goods) has been an important component of direct exploitation of resources. *(well established)*	Given that trade is one of the underlying causes for the direct exploitation of resources, and its strong links with GDP, the impacts on nexus elements are broadly similar to those assessed for GDP.	***well established***

		2017). Likewise, extractions of non-biological materials used in industry and construction continues to increase (Bendixen et al., 2021; Miatto et al., 2016; Rangel-Buitrago et al., 2023).			
	Climate change	23-33% of global CO_2 emissions are embodied in international trade (Wiedmann & Lenzen, 2018). GHG emissions caused by agricultural production for export been estimated as 0.7-1 Gt CO_2 a^{-1} (2010-14) (Pendrill et al., 2019). The share of actual transport emissions for trade of agricultural products is comparatively low at about 0.9 Gt CO_2 (about 5-8% of GHG emissions in the food system). However, if indirect emissions are included (e.g., transport of fertilizers, pesticides, machinery, provision of transport infrastructure), the estimates are significantly higher (3 Gt CO_2 a^{-1} or nearly 16-28% of emissions in the food system (Crippa et al., 2021; IPCC, 2019; M. Li et al., 2022)). Total emissions related to traded land-based goods (incl. timber) have been estimated to contribute up to 27% of total land-use change emissions (2004-2017), of which 75-81% are related to land-cover change, the remainder to production (Hong et al., 2022). Fishing overall is a substantial source of CO_2 (159 mio t in 2016; (Greer et al., 2019)). Between 1990 and 2011, emissions from the global fishing industry grew by 28% and were estimated to be then around 4% of total food production emissions (Parker et al., 2018); aquaculture emitted ca. 0.5% of total anthropogenic GHG emissions in 2017 (MacLeod et al., 2020), a number that excluded post-farm transport. Crustacean fisheries as well as fisheries for feed-purposes contribute notably to emissions, which may also indicate a large share of these being traded. Extreme weather events that can be attributed to climate change can cause regional harvest losses but the degree to which trade contributes to famine relief in these regions is debated (Hopewell & Margulis, 2023; Weinhardt & Schofer, 2022).	**Modest intensification**: The GHG emissions from trade overall including those linked to trade in agricultural goods are a notable component of overall anthropogenic emissions. *(well established)*	Trade is an important contributor to climate change. The impacts on nexus elements via the trade-climate change pathway are assessed smaller to or equal to impacts that operate via the trade-GDP-climate change pathway.	***well established***
	Invasive alien species	Trade of goods and people is amongst the most important factors fostering the spread of IAS (IPBES, 2023; Tobin, 2018). A very strong positive correlation exists between the first records of alien species in a region and the %-contribution of merchandise imports to GDP (for 1950 to 2000). New occurrences of alien species recorded increases now even more rapidly than the annual increase in international trade, almost 20-fold since the early 19th century (Hulme, 2021; IPBES, 2023).	**Intensification**: Trade has been shown in numerous studies to having been a major driver behind the spread of IAS. *(well established)*	IAS are negative for local biodiversity and can also interfere negatively with both food supply and physical health.	***well established***

	Pollution	Around 80-90% of global trade is by shipping, moving each year over 10 billion tonnes of containers across the world's ocean. In addition to contributing to CO_2 emission, combustion of shipping fuel contributes to emissions of particulate matter and sulphur along shipping routes (Ampah et al., 2021; Balcombe et al., 2019). Trade overall has been estimated to contribute to 22-30% of global air pollutant emissions and 30-67% of global mercury emissions (Wiedmann & Lenzen, 2018).	▲ **Modest intensification**: Movement of traded goods has been estimated to contribute notably to global air- and other forms of pollution. *(well established)*	Trade-impacts on nexus elements via impacts on pollution can be expected to be broadly similar to the pathway via GDP on pollution.	***well established***
Poverty	**Land/sea use**	Extreme poverty has been declining for several years although this trend has recently reversed (United Nations, 2023). Population growth and economic and political systems that perpetuate poverty but also income inequity are the underlying drivers of increasingly unsustainable resource depletion (IPBES, 2022). But per-capita consumption of area- and input-intensive goods correlates with income (IPCC, 2019). There is little evidence that the trend in decreasing poverty directly has been a driver of increasing (decreasing) land/sea area use over recent decades.	▬ **Stable/little to no impact:** The changes in poverty levels globally are too small to have affected sea- or land-area use notably. *(established but incomplete)*	The changes in poverty levels globally are too small to have affected sea- or land-area use notably. Changes in poverty are, however, also an important direct driver in that larger incomes allows people to increase access to sufficient, nutritious food, water and health care.	***established but incomplete***
	Direct exploitation / utilization	Population growth and economic and political systems that perpetuate poverty but also income inequity are the underlying drivers of increasingly unsustainable resource depletion (IPBES, 2022). There is little evidence that the trend in decreasing poverty directly has been a driver of increasing (decreasing) direct exploitation of resources over recent decades.	▬ **Stable/little to no impact:** The changes in poverty levels globally are too small to have affected direct exploitation of resources notably. *(established but incomplete)*	Declining poverty may not have affected direct exploitation of resources globally strongly (it will have resulted in both increasing and decreasing use of different goods). While protecting biodiversity and ecosystem services can contribute to alleviating poverty, the relationship between declining poverty and reducing negative impacts on biodiversity and other nexus elements is less established. Still, poverty alleviation in local communities has been shown to correspond with protecting biodiversity (obtaining higher income such as through tourism, which reduces the need for unsustainable extractive activities). Given the strong collocation with BD hotspots we assess a small positive impact overall.	***established but incomplete***
	Climate change	The world's poorest countries contribute least to total GHG emissions but are hit hard by climate change impacts (Friedlingstein et al., 2022; Hallegatte & Rozenberg,	▬ **Stable/little to no impact:** The changes in poverty levels globally have had no notable	The link from changes in poverty to nexus impacts via impact on climate change is too	***established but incomplete***

		2017). A tiny high-income proportion of the world's population is responsible for a very large share of GHG emission, this climate and carbon inequality is seen both between but also within countries (Chancel et al., 2023).	impacts on changing greenhouse gas emissions. *(established but incomplete)*	weak to have had noticeable impacts on nexus trends.	
	Invasive alien species	Poor societies may be disproportionally impacted by IAS (IPBES, 2023), but there is no evidence that the globally decreasing poverty has affected trends in IAS.	**Stable/little to no impact:** The changes in poverty levels globally are too small to have affected direct exploitation of resources notably. *(established but incomplete)*	The link from changes in poverty to nexus impacts via impact on IAS is too weak to have noticeable impacts on nexus trends.	***established but incomplete***
	Pollution	Higher income countries have resources needed to invest in clean technologies (while often outsourcing pollution via trade to production in poorer countries).	**Stable/little to no impact:** The changes in poverty levels globally have been too small to notably impact trends in pollution. *(inconclusive)*	The link from changes in poverty to nexus impacts via impact on pollution is too weak to have had noticeable impacts on nexus trends. It is not to be expected that a change in pollution changes available water quantity.	***inconclusive***
Population	**Land/sea use**	Population growth, jointly with increasing per capita consumption results in continued increasing demand for food (IPBES, 2019; IPCC, 2019).	**Intensification**: Human population growth has been one of the strongest drivers of increasing land/sea use. *(well established)*	Impacts of population growth that resonate to nexus elements via land- and sea-area use changes are expected to have been broadly similar to those e.g., seen also along the paths via GDP and trade.	***well established***
	Direct exploitation / utilization	Population growth, jointly with increasing per capita consumption results in continued direct extraction of abiotic materials, and plant and animal matter (IPBES, 2019; IPCC, 2019). The increasing global fish utilization is strongly correlated to human population growth (FAO, 2020).	**Intensification**: Human population growth has been one of the strongest drivers of increasing direct exploitation of resources. *(well established)*	Impacts of population growth that resonate to nexus elements via the direct exploitation of resources are expected to have been broadly similar to those e.g., seen also along the paths from GDP and trade.	***well established***
	Climate change	Population growth, jointly with increasing per capita consumption results in demand for energy, materials, intensification of agriculture and related GHG emissions (IPBES, 2019; IPCC, 2019; Wynes & Nicholas, 2017).	**Intensification**: Human population growth has been one of the strongest drivers of increasing GHG emissions. *(well established)*	Impacts of population growth that resonate to nexus elements via climate change are expected to have been similar to those e.g., seen also along the path from GDP.	***well established***
	Invasive alien species	A larger human population increases the risk that IAS are being introduced and passed on between individuals or settlements, but quantitative evidence for its importance - compared to other drivers of IAS spread- remains limited (IPBES, 2023; Seebens et al., 2018).	**Stable/little to no impact:** The spread of IAS has been fostered by interactions between people, but there is limited evidence that human population growth *per se* (i.e. aside of it being correlated with urbanization, trade and travel) has been a main contributor to trends in IAS.	Given the lack of evidence of population growth per se on the spread of IAS, impact on nexus elements also have been likely negligible.	***inconclusive***

			(inconclusive)		
	Pollution	Increasing demand for energy and goods, and their resource-intensive production leads to increase in pollution globally. Even though some forms of pollution in some regions have begun to decline (Sicard et al., 2023) there are many other forms that continue to increase (IPBES, 2019). For instance, the global flux of plastic waste to freshwater and ocean range from 9 - 23 mio t p.a., the waste emitted into land ecosystems is of similar magnitude (13 - 25 mio t p.a; (MacLeo et al., 2021)). Likewise, exposure to O_3 is also still globally on the rise (Sicard et al., 2023).	▲▲ **Intensification**: Increasing demand for energy and goods in a growing human population, and their resource-intensive production leads to increase in pollution globally. *(well established)*	Impacts of population growth that resonate to nexus elements via pollution are expected to be similar to those e.g., seen also along the path from GDP.	***well established***
Urbanization	**Land/sea use**	Even though recent urban growth is most rapid in relatively dry regions, urban land is still co-located with land that is (i) also suitable for agriculture and/or (ii) in coastal areas. Even though urban area globally is small, urbanization affects fertile land disproportionally (van Vliet et al., 2017), and competes for water used for irrigation. The expansion of urban land consumption outpaces population growth by as much as 50% (World Bank, 2023). Urban area growth jointly with inefficient use of urban area (declining population density in cities) led to an estimated 125 000 km^2 land converted that could have otherwise remained in cultivation or in a natural state (Güneralp et al., 2020). Cities also fundamentally alter coastal regions and deltas e.g., via ports or flood protection (Laignel et al., 2023).	▲ **Modest intensification**: Even though urban area globally is small, urban area expansion affects fertile land and coastal regions disproportionally. *(established but incomplete)*	Like other area-use changes, the expected impact is negative for biodiversity as well as -given the location of rapid urban growth- freshwater water availability near cities, as well as water quality by increasing wastewater flows. Despite urban areas encroaching on fertile land, globally the impact on food production and quality so far is expected to be small. Health impacts on people living in expanding urban environments are expected to be similar to those that impact health via changes in GDP.	***established but incomplete***
	Direct exploitation / utilization	Urbanization leads to increasing use of materials extracted, especially from land (Facchini et al., 2017; Jin et al., 2021; Krausmann et al., 2017), although also materials from marine systems are increasingly being explored (Sun et al., 2023). Global material consumption by cities could more than double from 2010 to 2050 (Milesi & Churkina, 2020). Cities contribute to soil degradation through extraction of building materials (Ortlepp et al., 2015). Still, urbanization alone could not explain increases in construction material demand, without also taken trends in prosperity into consideration (Schiller & Roscher, 2023). Likewise, the higher per-capita food consumption in cities correlates with higher incomes; if controlling for income the difference in total consumption are limited (Ambikapathi et al., 2022; B. Pandey et al., 2020).	▲ **Modest intensification**: Urbanization leads to increasing demand for materials and often to behaviour change such as increased per-capita food consumption, which corresponds also to typically larger income in people living in cities. *(established but incomplete)*	Similar to urban area expansion, the resource-use related to urban growth is negative for biodiversity as well as freshwater water availability and quality. City-dwellers have higher per-capita food consumption, but this is at least partially caused by higher incomes; impacts on food quantity and quality is thus assessed to be similar to GDP. Urbanization drives non-biological resource extraction to some degree, but the mental health impacts on people in mining industries arising from this component of total resource exploitation is smaller than e.g. from the overall global direct exploitation of resources driven by trends in GDP.	***established but incomplete***

	Climate change	The urban contribution to global GHG emissions is substantive and increasing (e.g., in 2015, 25 $GtCO_2$-eq or ca. 62% of the global total; in 2020, 29 $GtCO_2$-eq or ca. 70% of the global total) (Lwasa et al., 2022). These numbers reflect that most of the global GDP is created in and around cities (Di Clemente et al., 2021). Direct GHG emissions of 79 cities worldwide amounted to 10% of global emissions even though the cities' population was only 6% (Wiedmann et al., 2021). Most cities are heat islands, and many undergo unregulated sprawl thus contributing to local warming and the loss of climate-adaptive capacity (A. Otto et al., 2021).	▲ **Modest intensification**: Cities have had a direct impact on local climate as heat islands; people living in cities may have larger per-capita GHG emissions compared to people in rural environments. *(established but incomplete)*	Even though GHG emissions from cities may be slightly larger than from rural environments on a per-capita basis, the impact of cities on global climate is expected to have been so far too small to affect biodiversity, food or water – by contrast to health impacts in cities arising from e.g., heat island effects.	***established but incomplete***
	Invasive alien species	IAS can spread in cities due to urban microclimate, novel ecosystem types or the use of non-native, ornamental species in gardens or as pets (Cadotte et al., 2017; IPBES, 2023; Padayachee et al., 2017).	▲ **Modest intensification**: IAS can benefit from a number of specific factors in cities. *(established but incomplete)*	Urban environments promote spread of IAS with the associate negative effects on biodiversity and physical health.	***established but incomplete***
	Pollution	Cities are well known hotspots of air pollution but with variable trends. For instance, globally exposure to PM2.5 in urban areas decreased, while exposure to O_3 increased in the first two decades of the 21st century – regional variation in these trends is large (Murray et al., 2022; Sicard et al., 2023). Cities are also known for other forms of pollutions such as noise and light pollution.	▲ **Modest intensification**: Air in urbanised regions tends to be more polluted than rural environments. Light and noise pollution are also concentrated in urban environments. *(well established)*	The impact on the nexus elements via urban contribution to pollution is expected to be similar to those acting via GDP or trade.	***well established***
Regulations (environment al)	**Land/sea use**	Environmental policies and effective measures to put these in place are key to solving environmental and societal challenges (IPBES, 2019). Reliable regulations as to who has rights to use to land- and sea-area is a key factor for socio-economic development (Adamie, 2021; Auerbach & Azariadis, 2015; Besley & Ghatak, 2010). Protected areas, another important environmental regulation that affects land- and sea-area use have been increasing over recent decades, but are globally implemented inefficiently w.r.t. siting or financial resources required although some have achieved success locally (Arneth et al., 2023; Nowakowski et al., 2023). The still ongoing large conversion of natural land (legally or illegally) despite efforts to reduce it demonstrates that important regulatory barriers still have to be overcome (Kitsakis & Dimopoulou, 2020; Perino et al., 2022). Some progress has been made about upstream/downstream water access with respect to conflicts over dams (Zhao et al., 2022).	▬ **Stable/little to no impact:** The number of environmental regulations has increased since the 1980s. However, the continued unsustainable use of land and sea areas and resources, suggest that environmental regulations have had little positive impact globally so far. *(established but incomplete)*	Even though efficiency of protected areas is poor globally, the overall protected area, esp. those with a long history nevertheless have had some positive effects on biodiversity locally. Likewise, freshwater distribution has been regulated successfully in some regions of the world.	***established but incomplete***

	Direct exploitation / utilization	Environmental regulations can help to reduce illegal extraction of species and over-use of resources (Fukushima et al., 2021). These include regulations at the origin of resource over-use but also those that influence demand for resources (Fukushima et al., 2021; IPBES, 2022). Protected areas (marine and terrestrial) are too inefficient to have notably impacted unsustainable ecosystem uses although some have achieved success locally (Arneth et al., 2023; Nowakowski et al., 2023). The illegal trade in wild species and illegal fisheries (Cawthorn & Mariani, 2017; IPBES, 2022) are evidence that important regulatory barriers still have to be overcome for environmental regulations to be effective (Kitsakis & Dimopoulou, 2020; Perino et al., 2022). Some countries have begun to successfully tackle issues of irrigation water over-use (Gany et al., 2019; Mutambara et al., 2016).	**Stable/little to no impact:** The number of environmental regulations has increased since the 1980s. However, the continued unsustainable use of land and sea areas and resources, suggest little impact globally. *(established but incomplete)*	Even though environmental regulations that target the unsustainable use of resources have been inefficient on global average, there is evidence that some environmental regulation has benefited e.g., local biodiversity, and water abstraction.	***established but incomplete***
	Climate change	Regulations that seek to limit GHG emissions in principle should greatly help to mitigate climate change. However, neither the Kyoto protocol nor the Paris Agreement have so far resulted in national measures that lead to globally reduced emissions, although in some regions, positive impacts begin emerge (Friedlingstein et al., 2022; IPCC, 2022).	**Stable/little to no impact:** The continued increase of GHG emissions globally suggest little impact of climate change-related agreements and regulations. *(well established)*	Climate change is global, and locally effective measures to curb climate change are so far too few to have had impacts on nexus elements.	***well established***
	Invasive alien species	Regulations are expected to help to reduce introduction and spread of IAS and/or reduce impact of these locally but impacts have been shown to vary between regions and socio-economic contexts and success stories so far are few (Brenton-Rule et al., 2016; Evans et al., 2018; IPBES, 2023; Latombe et al., 2023; Venette et al., 2021). Conventions on reducing IAS impacts of shipping have not yet proven to have impact (Langlois et al., 2014).	**Stable/little to no impact:** The impact of regulations on reducing spread if IAS has been shown to be context-specific, but globally the pressure from IAs is still increasing. *(established but incomplete)*	Measures to prevent IAS and/or to early detect these have been increasingly developed but given the continued pressures from movement of goods and people remain so far without substantial impacts.	***established but incomplete***
	Pollution	Environmental regulations are key to implement pollution control measures (Han et al., 2021) with large challenges for global governance in case of transboundary pollutants (Boucekkine et al., 2021). Pollution-related policies are being increasingly implemented and have been success-cases regionally and for some pollutants, as seen e.g. in the slowly declining trend of deaths from indoor air pollution and some heavy metals (such as Pb and Zn; IHME, Global Burden of Disease, 2023; Y. Li et al., 2020). Still, levels of many pollutants are still increasing globally (Sicard et al., 2023).	**Stable/little to no impact:** In some regions and for some pollutants, exposure of humans and ecosystems to these is declining but these trends are too small to counter the globally still increasing levels of many pollutants. *(established but incomplete)*	Some implemented measures have led to reducing some types of pollution with positive impacts on water quality and physical health.	***established but incomplete***
Armed conflicts	**Land/sea use**	Number of armed conflicts can be interpreted as an indicator for trends in warfare more broadly, but also for instability and weak governance. Warfare has multiple and	**Variable:**	Given that armed conflicts impact nexus elements more strongly via interactions with direct exploitation of resources we	***unresolved***

		complex impacts on land-use (leading to e.g., loss of local agricultural land as well as relocation of areas under production), which manifest most imminently in densely populated regions but can result also in longer-term and/or tele-coupled changes (Glaser et al., 2019; Navarrete-Cruz et al., 2023; Zhang et al., 2023; Zheng et al., 2023). It seems plausible, however, that impacts on land-cover changes are smaller than those on the direct exploitation of resources. There is little evidence on sea use impacts of armed conflicts.	Over the last decades the number of armed conflicts have increased, in particular since 2010. Globally, warfare is expected to not have affected land- or sea-use change notably, but locally conflicts can lead to e.g. land abandonment or deforestation. *(unresolved)*	expect the path via land- and sea-area uses overall to be small. But armed conflicts are not only an indicator for institutional indirect drivers – they also are a strong direct driver impacting physical and mental health negatively.	
	Direct exploitation / utilization	Between 1950 and 2000, over 90% of major armed conflicts took place within countries containing bio-diversity hotspots (Hanson, 2018). Impacts on biodiversity as well as on direct exploitation of resources are highly variable (and depend on the type of conflict (Glaser et al., 2019; Navarrete-Cruz et al., 2023; Zhang et al., 2023; Zheng et al., 2023)) although the overall impacts w.r.t. deforestation appears to be negative (Landholm et al., 2019). Investment in mining is displaced in response to conflict (Blair et al., 2022). Armed conflicts can prevent food production, contribute to increased food prices and are a major factor of food insecurity, while impacts on water supply may overall be smaller (Alexander et al., 2022; Hasan et al., 2019; X.-Y. Li et al., 2022; Shemyakina, 2022).	**Variable:** Impacts of trends in warfare on direct exploitation of resources have been highly variable and depend on the type of conflict, and whether impacts are investigated during or after a conflict. *(established but incomplete)*	Impacts of armed conflicts via direct exploitation of resources on biodiversity are variable; impacts on food production and supply with nutritious food are assessed mostly negative, which also affect physical and mental health (in addition to the direct-driver impact on health in armed conflicts).	***established but incomplete***
	Climate change	Evidence on GHG emissions from the arms sector is sparse (Chang et al., 2023), there is no reporting on this sector under the UNFCCC. However, GHG emissions of the military sector have been estimated as up to 5% of total emissions (Conflict and Environment Observatory, 2021). The US Department of defence is the largest institutional consumer of fossil fuels in the world (Belcher et al., 2020) and military expenditure has increased over the last decade in some regions (Herre & Arriagada, 2023). Societal conditions that increase vulnerability to climate change also increase the likelihood of climate–conflict, with possibly amplifying feedbacks (Buhaug & Von Uexkull, 2021).	**Modest intensification**: The contribution of the military sector to GHG emissions is expected to be potentially considerable but uncertain as clear evidence is lacking by how much longer-term trends (and/or recent changes) in conflicts and industrial production related to warfare have accelerated climate change. *(inconclusive)*	Climate change attributable to armed conflicts (or the military sector more broadly) has been too small to impact nexus elements.	***inconclusive***
	Invasive alien species	There is little evidence that armed conflicts have a strong direct effect on IAS, but impacts e.g., through altered transport of goods and people have been reported (IPBES, 2023).	**Stable/little to no impact:** Impacts e.g., through altered transport of goods and people have been reported but the trend in armed conflicts is too small to	IAS (and their impacts) are affected by armed conflicts more locally.	***inconclusive***

			have impacted introduction or spread of IAS notably.		
	Pollution	Evidence for impacts of armed conflicts on pollution is limited, but contamination of water, air and soils in context of war can be substantial (depending on the type of conflict and weapons used (Sowers & Weinthal, 2021; Wenning & Tomasi, 2023)). Given the potentially large impact of the military sector on GHG emissions one might also expect a role of the military for pollution.	▲ **Modest intensification**: Locally, impact of conflicts can be substantial. Given the potentially large impact of the military sector on GHG emissions one might also expect a role of the military for trends in pollution but uncertain as clear evidence is lacking by how much longer-term trends (and/or recent changes) in conflicts and industrial production related to warfare have impacted pollution globally. *(inconclusive)*	By contrast to GHG emissions and climate change, which have a global impact, pollution is impacted by armed conflicts more locally; especially water quality and physical health can be expected to be negatively affected by this pollution (in addition to the direct health impacts of armed conflicts).	***inconclusive***
Literacy (knowledge)	**Land/sea use**	The magnitude of land- and sea-area use has likely not been affected in the past by the level of education directly. However, environmental education and knowledge of ecosystem dynamics in principle could support sustainable use of land and seas.	▬ **Stable/little to no impact:** Literature evidence is scarce as to whether past changes in land/sea use have been altered by past trends in education. *(inconclusive)*	The small impacts that education/literacy has had on land- and sea-area use goes hand in hand with assessed negligible impacts on the nexus elements.	***inconclusive***
	Direct exploitation / utilization	By providing knowledge to understand the consequences of over-use and to develop alternative strategies, education, from childhood to adulthood, should foster the more sustainable use of resources (Bates et al., 2022; Begum et al., 2022; McKenzie, 2021; Molina et al., 2023; Rad et al., 2022). For instance, water or food-label literacy can support water-saving activities and reduce food waste (Hoy & Stelli, 2016; Mariam et al., 2022; Russell et al., 2017; Tian et al., 2023; Wang et al., 2019; Willis et al., 2011; Zamri et al., 2020). The overall magnitude of the impact appears small, however, and depend on multiple socio-economic and cultural factors, and also how exactly educational measures are implemented.	▬ **Stable/little to no impact:** Literature evidence is scarce as to whether changes in the direct exploitation of resources have been affected by trends in education. *(inconclusive)*	Even though a clear positive relationship is expected, the existing literature suggest until now little impact of education and literacy on reducing unsustainable resource use, and thus on the nexus elements. Education may enhance people's choice of nutritious foods, but such a behavioural change could also reflect that education is often also correlated with income.	***inconclusive***
	Climate change	Education should provide pupils (and adults) with the knowledge that helps both mitigation climate change and adapting to it. So far, most curricula do not yet inform sufficiently on the true social, cultural, aesthetic and political impacts of climate change, and education alone seems insufficient to change students or pupils behaviour (Dawson et al., 2022; McGimpsey et al., 2023; Rousell & Cutter-Mackenzie-Knowles, 2020; Tolppanen et al.,	▬ **Stable/little to no impact:** Literature evidence indicates that education alone is insufficient to affect people's behaviour in that they take lasting climate change mitigation decisions. *(inconclusive)*	Given that so far educational programmes seemed to have had little impact on behavioural changes towards a more climate-concerned behaviour, there is also no impact via such a path on nexus elements.	***inconclusive***

		2022). However, it could also be shown that expansion in education compensated increases in per capita emissions related to economic growth (Balaguer & Cantavella, 2018).			
	Invasive alien species	There is little or no evidence that education or literacy so far had a direct impact on IAS, although lack awareness could be one of the factors that impedes good governance of biological invasions (IPBES, 2023).	**Stable/little to no impact:** Given that trade (and unintentional spread of species) is such a large driver of IAS it seems unlikely that education has made any impact on the spread of IAS (i.e. via reducing the number of deliberately released foreign species into the environment). *(inconclusive)*	Until now, no effects on nexus elements can be expected.	***inconclusive***
	Pollution	Scarce literature exists that demonstrates impact of education on pollution reduction (Liu et al., 2023). Using plastics as an example, Cordier et al. (2021) demonstrated in a model experiment that education can be an important factor to help reducing plastic waste in the ocean. Likewise, education can enhance public willingness to support air pollution improvement policies (Hu & Liao, 2023). "Green chemistry" has become a focus area of chemistry training such that solutions that emphasise its principles can support to reduce pollution impacts (R. K. Sharma et al., 2014).	**Stable/little to no impact:** Limited evidence indicates that education may have supported pollution reduction locally but impacts overall are small. *(inconclusive)*	There is limited evidence that education may have supported pollution reduction locally, which would have impacted water quality and physical health.	***inconclusive***
Per-capita consumption (animal protein)	**Land/sea use**	Per-capita consumption of animal protein is a key driver of land- and sea-use (FAO, 2016, 2020; IPBES, 2019; IPCC, 2019).	**Intensification**: Increasing per-capita consumption in economically wealthy societies has been one of the key drivers of past trends in land/sea-use change. *(well established)*	Jointly with population and economic growth, increasing per-capita consumption is in many regions of the world one of the most important drivers of unsustainable, and inequitable, area- and resource-uses. Impacts on nexus elements are expected to be broadly similar to those also assessed for impacts via GDP and trade.	***well established***
	Direct exploitation / utilization	Growing demand for food, fibre and wood products results in intensified harvest in existing managed systems (IPCC, 2019). For instance, the per capita consumption of aquatic foods (excluding algae) increased at an average annual rate of 3%, notably exceeding the rate of human population growth (FAO, 2020). HANPPP increased from 13.5% in 1910 to >20% in the early 21[st] century (Kastner et al., 2022; Krausmann et al., 2013), an increase that is fostered by land-use intensification. Nutrient use is levelling off in some regions, but in many others still too high and environmentally detrimental (GBO, 2020).	**Intensification**: Increasing per-capita consumption has been one of the key drivers of past trends in resource over-use. *(well established)*	Negative impacts are expected to have been considerable along the paths from per-capita consumption via direct exploitation of resources to many nexus elements. For food and health, increasing per-capita consumption reflects access to more food, which may or may not be more nutritious (impacting both malnutrition and overeating). Increasingly regular access to food would have removed food-related anxiety in people and with positive impacts on mental health.	***well established***

	Climate change	Per-capita consumption of energy, high-energy goods and ruminant protein is a main driver of climate change (C40 Cities, 2019; IPCC, 2019, 2022).	▲▲ **Intensification**: Increasing per-capita consumption has been one of the key drivers of continued greenhouse gas emissions. *(well established)*	Impacts on nexus elements from consumption-induced climate change are expected to be broadly similar to those from economic drivers such as GDP.	***well established***
	Invasive alien species	Consumption is regarded as a way to control the spread of certain edible IAS but likely with limited impact (Bouska et al., 2020; Nuñez et al., 2012). Some species that have been introduced deliberately for human consumption have turned out to be invasive (IPBES, 2023).	▲ **Modest intensification**: Given that trade in goods has been such a large driver behind the spread of IAS, it seems likely that increasing trends in per-capita consumptions also contribute to the increase in global number of IAS. *(inconclusive)*	Impacts on nexus elements from consumption-induced spread of IAS are expected to be broadly similar to those from economic drivers such as GDP.	***inconclusive***
	Pollution	Intensification of land use or aquaculture due to increased consumption contributes to the pollution of freshwater and coastal waters and air pollution. Fertilizer use has increased nearly ninefold (IPCC, 2019) since 1960; 50–70% N present in the fertilizers are either consumed by microbes or leached into the soil (i.e., not available to plants for consumption) (Tyagi et al., 2022). Accompanying intensification (and hence increased extraction of resources per area) is reflected in the use of agrochemicals (A. Sharma et al., 2020), although production-related pollution is also increasingly regulated in many regions and some novel agrochemicals deemed more environmentally friendly (Umetsu & Shirai, 2020). Pollution related to increasing per-capita consumption is also seen in other indicators, such as plastics, dyes in water, and mining (Islam et al., 2017; K. P. Pandey et al., 2023; Syed et al., 2022; Timsina et al., 2022).	▲▲ **Intensification**: Per-capita consumption of food and materials has been a main driver of pollution. *(well established)*	Impacts on nexus elements via the pathway population-growth to pollution are expected to have been broadly similar to those from economic drivers such as GDP in direction of impact.	***well established***
Renewable energy (solar and wind)	**Land/sea use**	The present area under solar panels is estimated as ca. 0.3-0.7 mio ha (Dunnett et al., 2020; Kruitwagen et al., 2021) and is rapidly increasing, with conflicts with area under cropland likely unless these are alleviated by deployment of agrivoltaics (Adeh et al., 2019; Kruitwagen et al., 2021; van de Ven et al., 2021). Modern biofuels so far have a relatively small contribution to the total global energy mix (World Bioenergy Association, 2018) but in some regions the area dedicated to bioenergy crops has increased substantially. For instance, area planted under sugarcane (mostly for biofuels) in Brasil has increased from 2 mio to 10 mio ha over the past four decades (by 2016) (R. Otto et	▲ **Modest intensification**: So far the impact on land use has been small globally, but is increasing rapidly, due to expansion of bioenergy crops but also ground-mounted solar panels. Oceans are mainly used for wind-turbines with small area impact. *(established but incomplete)*	Area-use for renewables so far has affected predominantly land-area use rather than sea-use, with negative impacts on biodiversity arising from expanding areas for bioenergy crops or -forests. The increasing competition between e.g. expansion of photovoltaics or renewable energy crops, has thus led to less land available for nature conservation but not to less food being produced. Freshwater availability is impacted irrigation water needs in bioenergy crops (e.g. maize).	***established but incomplete***

		al., 2016); in Germany, the area used for bioenergy crops in 2012 was >17% of its agricultural land (Lupp et al., 2014). However, use of bioenergy, especially 1st generation bioenergy has been attributed to cause direct and indirect land-use changes and increases in food prices, with related negative impacts on all nexus elements (Arima et al., 2011; Heck et al., 2018; Persson, 2015; Verstegen et al., 2016).		Physical health impacts through renewable-energy related area changes are negligible; loss of natural green space and sense of place could resonate to mental health impacts like in the case of urbanization but so far area changes have been too small and affecting fewer people (compared to growth of cities) to have large impacts. The direct and indirect land-use changes and increases in food prices related to the use of bioenergy, especially 1st generation bioenergy, are expected to have had negative impacts on all nexus elements.	
	Direct exploitation / utilization	The increasing deployment of solar panels and wind turbines leads to an increasing extraction of a wide range of materials mined from land and seas (C. Li et al., 2022; Mamanpush et al., 2023; Sonter et al., 2020; Spillias et al., 2020; Tao et al., 2011; Zuser & Rechberger, 2011), which is expected to further increase drastically. For instance, by 2024, off-shore wind has been estimated to require 0.5–1.0 Mt of copper and 0.3–0.5 Mt of aluminium, and a 10-30 fold of rare-earths (C. Li et al., 2022). Dedicated bioenergy crops contribute so far to provide only 1-2 % of the global energy demand (World Bioenergy Association, 2023) and technologies such as carbon capture and storage jointly with bioenergy are have not proven to be viable. Our assessment here concentrates on impacts of solar and wind.	▲▲ **Intensification**: Strong increase in demand for some materials has resulted in enhanced mining and extraction from natural ecosystems, although exact quantification for individual substances required in renewable technologies is still scarce. *(established but incomplete)*	Mining for resources to support renewable energy infrastructure impacts biodiversity and water quality in broadly similar ways as found for impacts via economic drivers such as GDP, but less severe as the increase in direct exploitation of resources so far is too small (relative to impacts of GDP trends overall). Food production and health are not expected to have been affected so far notably by the direct exploitation of resources to support renewable energy.	***established but incomplete***
	Climate change	Even though global GHG emissions are still increasing, the accelerated deployment of renewable energies has contributed to what otherwise would have been an even more rapid increase in global mean temperatures. Photovoltaics and onshore and offshore wind had in 2020 a share of ca. 10% of electricity produced (IPCC, 2022).	▼ **Small reduction:** The increasing share of renewable energy in total power production is dampening the increase in GHG emissions. *(well established)*	Similar to trends in material intensity, GHG emissions reduction and dampening of climate change by increasing use of renewables so far has been too small to have resulted in a noticeable impact in terms of reversing negative trends in nexus elements.	***well established***
	Invasive alien species	No evidence exists that increasing deployment of solar or wind-based renewable energy would impact IAS to large degree beyond the impact trade in materials, although marine renewable infrastructure may also provide habitat for IAS. Some foreign species that can act as IAS have been introduced as energy crops (IPBES, 2023).	▬ **Stable/little to no impact:** No strong evidence exists so far that increasing deployment of wind- or solar-based renewable energy has impacted IAS beyond the impact trade in materials, while the number of IAS that have been introduced to supply	Given the limited evidence for technology-based renewables and the globally small number of IAS introduced as bioenergy crops the impacts on nexus elements is considered negligible.	***inconclusive***

			bioenergy remains small globally.		
	Pollution	Due to the reduced need to combust fossil fuels for electricity, the increased share of renewable energy also helps to reduce air pollution (Ray, 2019; Spillias et al., 2020). However, mining and the extraction of materials is also a well-known contributor to pollution.	**Variable:** The impact of renewables varies strongly regionally and depending on the type of pollution. *(established but incomplete)*	Given both the positive and negative impacts of increasing use of renewables on pollution, impacts on nexus elements (especially biodiversity, yields, water quality and physical health) are also expected to be variable.	***established but incomplete***
Use of ICT (Information and computing technology)	**Land/sea use change**	ICT infrastructure impacts nexus elements via required infrastructure and by mined resources used in computers. The actual area needed for e.g., super-computing centres is small, impact of the increasing demand for ICT infrastructure is expected to be larger via direct exploitation of resources than land- and sea-area use (Al Kez et al., 2022; Blumenthal & Diamond, 2022).	**Stable/little to no impact:** Despite rapid increase in internet and data-related technology the impacts on land- and sea-area use so far have been negligible. *(inconclusive)*	Area changes related to mining for IT-related materials are small and not expected to have demonstrably affected nexus elements so far.	***inconclusive***
	Direct exploitation / utilization	While energy efficiency of data centres and the 'internet of things' is increasing, the material demand for the related computational infrastructure is large and is expected to contribute to direct exploitation of resources, although robust quantification is still absent (Al Kez et al., 2022; Blumenthal & Diamond, 2022). Positive impacts, for instance on irrigation water needs via computer-aided irrigation so far are small, but promising (Touil et al., 2022).	**Intensification**: The rapid increase in internet and data-related technology has contributed to increasing demand for materials. *(unresolved)*	Impacts on nexus elements are expected to be broadly similar to those along the paths from renewable energies and direct exploitation of resources. Impacts on water quantity are small as supercomputing centres are not water-cooled.	***unresolved***
	Climate change	Data centres are one of the fastest-growing electricity consumers, consuming ca. 1% of global electricity (Al Kez et al., 2022; Jones et al., 2022; Kamiya, 2020). Some have argued that this rapid increase translates directly into rapidly increasing energy consumptions, but others point out that these are dampened substantially by increases in efficiency (Masanet et al., 2020). Freitag et al. (2021) estimate ICT fraction of global GHG emission to 2.1 – 3.9% but report those figures to be debated in the literature.	**Stable/little to no impact:** Despite rapid increase in internet and data-related technology, the accompanying increase in energy efficiency makes it plausible that overall impact on climate change has been small. *(inconclusive)*	Given the overall small impacts on climate change, no change in trends of nexus elements is expected.	***inconclusive***
	Invasive alien species	Increasing deployment of ICT energy would not have impacted IAS directly but has opened new distribution channels (via e-commerce) and thus accelerated trade in species (Hulme et al., 2024).	**Modest intensification**: Increasing deployment of ICT has impacted IAS by e-commerce and enhanced trade. *(unresolved)*	The largest (negative) impact on biodiversity and physical health in response to the spread of IAS is via trade, and given the accelerated species trade in response to e-commerce the impact here is also negative (but less severe compared to trade overall).	***established but incomplete***
	Pollution	Electronic waste and pollution associated with mining for ICT has become a notable concern globally (Purchase et al., 2020; Rautela et al., 2021; Vishwakarma et al., 2022).	**Modest intensification**: The rapid increase in internet and data-related technology is	The waste and mining-related pollution from ICT components contributes to negative impacts on biodiversity, water and	***established but incomplete***

			contributing notably to electronic waste and pollution from production and mining. *(established but incomplete)*	quality (and hence physical health) but is too localised to affect the food system or mental health globally. Water quantity is not directly affected by pollution.	

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