SHERPA

Rural Science-Society-Policy Interfaces

SHERPA Discussion Paper

CLIMATE CHANGE AND ENVIRONMENTAL SUSTAINABILITY

SHERPA receives funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 862448

Authors:

James Hutton Institute	David Miller, Maria Nijnik, Katherine Irvine
Ecorys	Olivier Chartier, Giulia Martino, Julie Bourneix
Thünen-Institute of Farm Economics	Gerald Schwarz
Wageningen University & Research	Daan Verstand

With contributions from members of the SHERPA team

Citation: Miller, D., Nijnik, M., Irvine, K., Chartier, O., Martino, G., Bourneix, J., Schwarz, G., Verstand, D. (2021) Climate change and environmental sustainability. SHERPA Discussion Paper. DOI: 10.5281/zenodo.4905655

Paper finalised in May 2021

Sustainable Hub to Engage into Rural Policies with Actors (SHERPA) is a four-year project (2019-2023) with 17 partners funded by the Horizon 2020 programme. It aims to gather knowledge thatcontributes to the formulation of recommendations for future policies relevant to EU ruralareas, by creating a science-society-policy interface which provides a hub for knowledge andpolicy. Find out more on our website:

www.rural-interfaces.eu

Table of contents

Summary 4

Introduction 5

1. International Pathways to Tackling Climate Change 9

2. European Union Climate Commitments and Strategies 12

2.1 European Union Green Deal 12

2.2 Common Agricultural Policy and climate neutrality 15

2.3 Long-term Vision for Rural Areas 16

2.4 EU Climate Pact 17

2.5 Just Transitions to climate neutral continent 2050 18

2.6 Climate law 19

3.7 Europe showing a global lead 19

3. Climate change and EU rural areas 20

4. Interventions supporting mitigation and adaptation to climate change, enhancing associated environmental services 30

4.1 Adaptation in rural areas 30

4.2 Land Use and water 31

4.3 Social innovation and partnerships 34

4.4 Food and diet 36

4.5 Business and finance 37

4.6 Open science 38

5. Conclusions 39

6. Acknowledgements 39

References 40

Summary

The European Commission's strategic priorities for 2019 to 2024 set out aspirations for building a climate-neutral, green, fair and social Europe. It foresaw greater investment in initiatives that promoted sustainable agriculture and preserved environmental systems and biodiversity, the creation of a circular economy, a faster transition to renewables and energy efficiency, all consistent with the European Pillar of Social Rights.

Recognising the imperative of tackling climate change, and commitment to the Paris Agreement, the ambition is for Europe to be the world's first climate-neutral continent by 2050. Alongside reducing greenhouse gas emissions, the aims are to be a climate-resilient society, with just transitions for all sectors.

The SHERPA process will support the gathering of evidence from across Europe, at multiple levels, regarding the types of transformational changes which are appropriate and feasible to contribute to transitions to climate neutrality by 2050.

SHERPA Multi-Actor Platforms (MAP) are invited to discuss three key questions:

1) What transitions are required to achieve climate neutrality in the context of the MAP?

2) How can policy interventions enable or facilitate these transitions, considering the solutions needed at local and national levels, and the related implications for the wider policy framework (EU and global)?

3) What are the research needs and gaps?

This draft SHERPA Discussion Paper provides a synthesis of international and EU policy aims, and mechanisms as they relate to rural areas, and findings from research on transitions, impacts and approaches to adaptation to achieve a climate-neutral continent by 2050.

Introduction

"*Little time is available for corrective action*", was a message of the World Commission on Environment and Development: Our Common Future (1988), referred to as the 'Brundtland Report'. It continues, "*while scientists continue to research and debate causes and effects, in many cases we already know enough to warrant action. This is true locally and regionally in the cases of such threats as desertification, deforestation, toxic wastes, and acidification; it is true globally for such threats as climate change, ozone depletion, and species loss.*"

The principles of sustainable development, as outlined by Brundtland, were the focus of the United Nations 'Rio Earth Summit' in 1992, which led directly to conventions on climate change (United Nations, 1992a) and biological diversity (United Nations 1992b), and their evolution to the present day Intergovernmental Panel on Climate Change (IPCC) and the Convention on Biological Diversity (CBD).

The same principles have evolved into the current UN Agenda 2030 Sustainable Development Goals. Of those Goals, several have significance in relation to climate change and the impacts with which it may be associated, notably SDG 13 (Climate Action), SDG 15 (Life on Land), SDG 4 (Quality Education), SDG 12 (Responsible Production and Consumption), and SDG 17 (Multi-stakeholder partnerships). Similarly, the CBD identifies ecosystem-based climate mitigation strategies for restoring degraded ecosystems (Aichi Target 15), halting the conversion of natural terrestrial ecosystems (Aichi Targets 5 and 11), and Strategic Goal B of reducing the direct pressures on biodiversity and promote sustainable use, in line with the post-2020 Global Biodiversity Framework.

The significance of research on themes relating to climate change, and operationalisation on-the-ground, was a core tenet of the EU Horizon 2020 Research and Innovation Research Programme (2014-20). In its Introduction it notes that one of its Societal Challenges was dedicated to "... moving to a greener, more resource efficient and climate-resilient economy in sync with the natural environment, demonstrating a strong commitment to supporting the UN's Sustainable Development Goals (SDGs) and the targets of the COP21 Paris Agreement" (European Commission, 2014). That area of research has supported 659 projects, with an EU contribution of €2.32Bn, involving 7 727 different organisations.

The European Union Green Deal sets out a strategy to transform the EU into a "fair and prosperous society", "resource-efficient and competitive economy", with "no net emissions of greenhouse gases in 2050", and economic growth decoupled from resource use. In its Strategic Plan for Horizon Europe (2021-2027), the EU sets out the aims of its research innovation programme which includes: the promotion of green transitions through human-centred technologies and innovations, restores Europe's ecosystems and biodiversity, making Europe the first digitally enabled circular, climate-neutral and sustainable economy, and creating a more resilient, inclusive and democratic European society, prepared and responsive to threats and disasters, addressing inequalities and providing high-quality health care.

In its vision for rural areas of Europe, co-constructed by actors in policy, science and civil society, Chartier *et al.* (2021; H2020 SHERPA), identify, responding to climate change, as one of the major drivers of a green transition and the environmentally sustainable management of rural areas. To tackle the challenge of climate change, approaches would be required that enable and support transitions towards environmental sustainability with commensurate management of environmental services and assets to contribute to aims of climate neutrality.

The OECD (2001) defines **environmental services** as: "qualitative functions of natural non—produced assets of land, water and air (including related ecosystem) and their biota". The three types of environmental services they identified are:

> (a) disposal services which reflect the functions of the natural environment as an absorptive sink for residuals;
>
> (b) productive services which reflect the economic functions of providing natural resource inputs and space for production and consumption;
>
> (c) consumer or consumption services which provide for physiological as well as recreational and related needs of human beings.

The Millennium Ecosystem Assessment (2005) progressed the concepts and the approach to environmental services, into the wider concept of ecosystem services. It defines **ecosystem services** as "the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth."

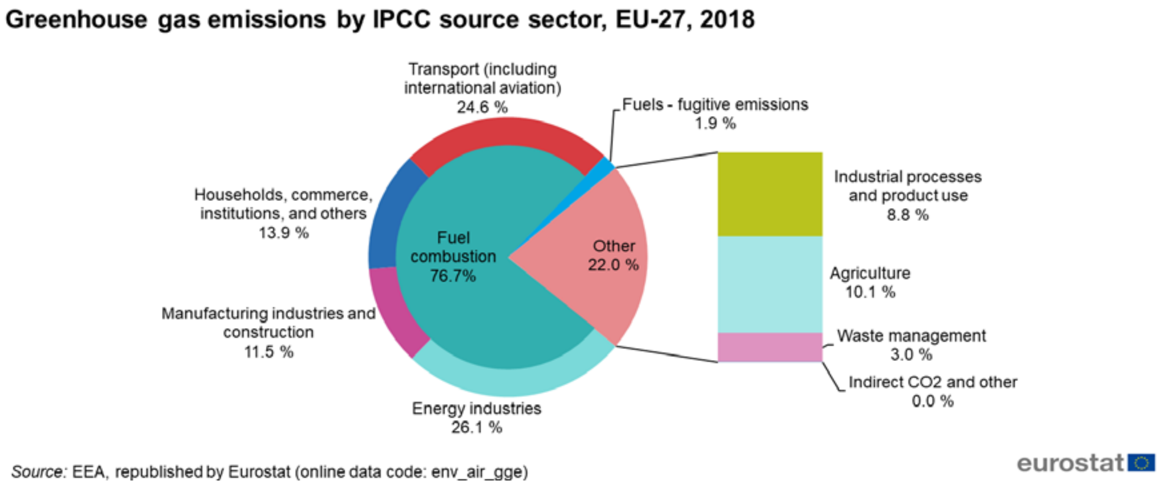
The UK National Ecosystem Assessment (UKNEA, 2011), focusing on understanding nature's value to provide an in-depth assessment of the benefits to society and economic prosperity of the natural environment. Recognising the threats to those key resources, it defined **ecosystem service degradation**, with respect to each of the four ecosystem services, as "For provisioning services, decreased production of the service through changes in area over which the services is provided, or decreased production per unit area. For regulating and supporting services, a reduction in the benefits obtained from the service, either through a change in the service or through human pressures on the service exceeding its limits. For cultural services, a change in the ecosystem features that decreases the cultural benefits provided by the ecosystem."

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is the intergovernmental body which assesses the state of biodiversity and of the ecosystem services it provides to society, in response to requests from decision makers. To guide its work, IPBES developed a conceptual framework in which it sets out six interlinked elements of a socio-ecological system, operating at various scales in time and space. They define the **environmental assets** in such systems as: "Naturally occurring living and non-living entities of the Earth, together comprising the bio-physical environment, that jointly deliver ecosystem services to the benefit of current and future generation."

One of the elements in its conceptual framework is that of Nature's Contributions to People (NCP). Diaz *et al.* (2018) describe the role of the nature's contributions to people (NCP), which builds on the ecosystem service concept, but increases the recognition of the importance of cultural themes in defining links between people and nature, and the significance of local and indigenous knowledge. In its report on the decline in biodiversity and impacts on nature, IPBES (2019) note the threats posed by climate change as one of five direct drivers of changes in nature (the others being, the uses of land and sea; direct exploitation of organisms; pollution, and (5) invasive alien species). They report that "even for global warming of 1.5 to 2°C, the majority of terrestrial species ranges are projected to shrink profoundly."

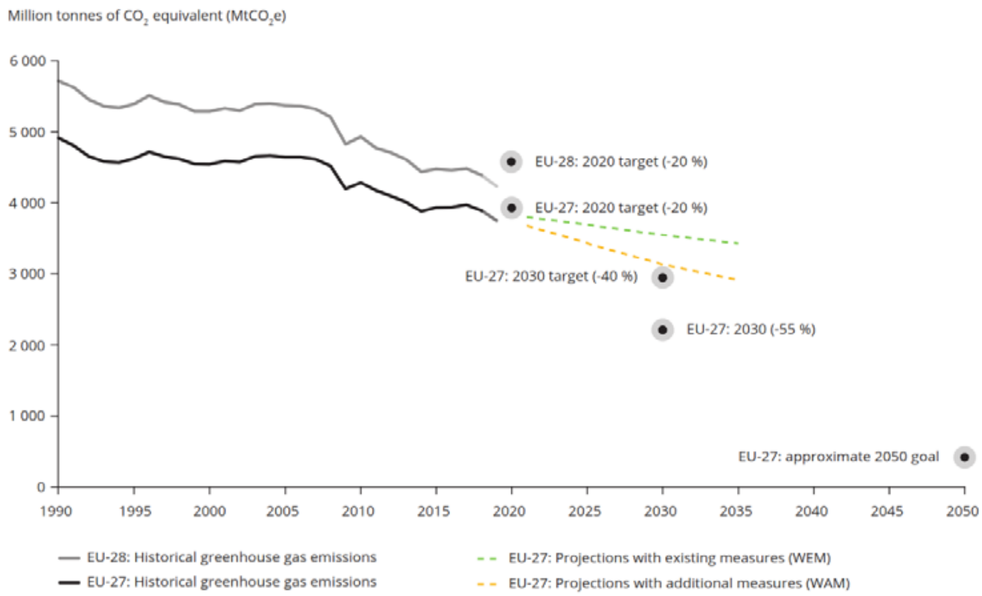
As of 2018, the European Environment Agency (2020) estimated that 76.7% of greenhouse gas emissions were from the consumption of fuel from transport, households, manufacturing and energy sectors, and that agriculture contributed 10.1% (Figure 1). IPBES (2018) reports that anthropogenic causes have led to an observed warming of approximately 1.0°C by 2017 relative to pre-industrial levels. Over the last 30 years, those changes are measured as approximately 0.2°C per decade, and the global average sea level risen by 16 to 21 cm since 1900.

Figure 1. Sources of Greenhouse gas emissions in the EU-27 by Intergovernmental Panel on Climate Change Sector (source: European Environment Agency, 2020a).



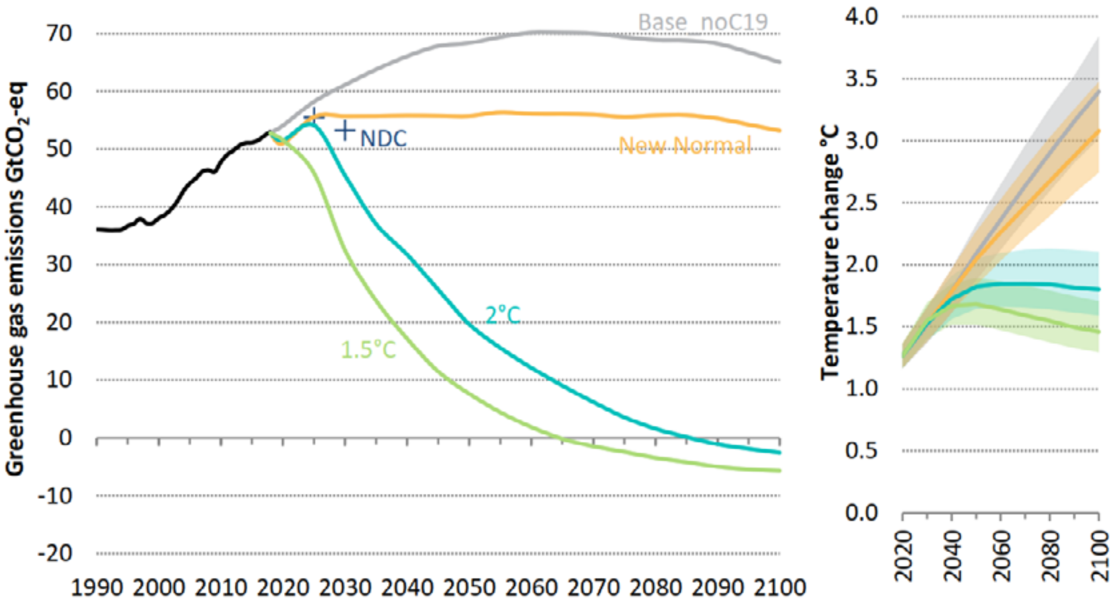
The European Environment Agency (2020a) reports that by 2018, greenhouse gas (GHG) emissions in the EU-27 were 1 billion tonnes lower than 1990 levels (21%). Preliminary estimates show a further reduction of 3.6% between 2018 and 2019, which would result in levels that are 26% below 1990 (Figure 2). However, although this exceeds the target of a reduction by 20% by 2020, the rate of reduction is projected to slow by 2030, based on the Member States under the Monitoring Mechanism Regulation (EU) No 525/2013 (EEA, 2020). That compounds the challenge of achieving the target of a reduction of 40% by 2030, making achievement of the target of climate neutrality by 2050 more difficult.

Figure 2. Greenhouse gas emission targets, trends, and Member States MMR projections in the EU, 1990-2050 (Source: European Environment Agency, 2020).



The EC Joint Research Centre, in its Global Energy and Climate Outlook 2020 (Keramidas *et al.*, 2021), reports on the trajectory of emissions taking account of changed context due to COVID-19. They conclude that global GHG emissions are likely to be 2% to 9% less in 2030 that previously projected. However, that significant change in trajectory is insufficient to limit global warming to below 1.5°C or 2°C (Figure 3).

Figure 3. Global GHG emissions and global mean temperature increase under scenarios leading from COVID-19 (Source: Keramidas *et al.*, 2020).



Note: Base_noC19 is a hypothetical projection without the inclusion of Covid-19 effects. New Normal is but one possible pathway of future post-Covid development, it differs from the Base_noC19 scenario in three groups of modelled parameters: macroeconomic parameters; transport changes; and new policies. The 2°C and 1.5°C scenarios were designed with a probability not to exceed their temperature change at the end of the century of 66% and 50%, respectively. NDC is the NDC scenario from GECO 2019.

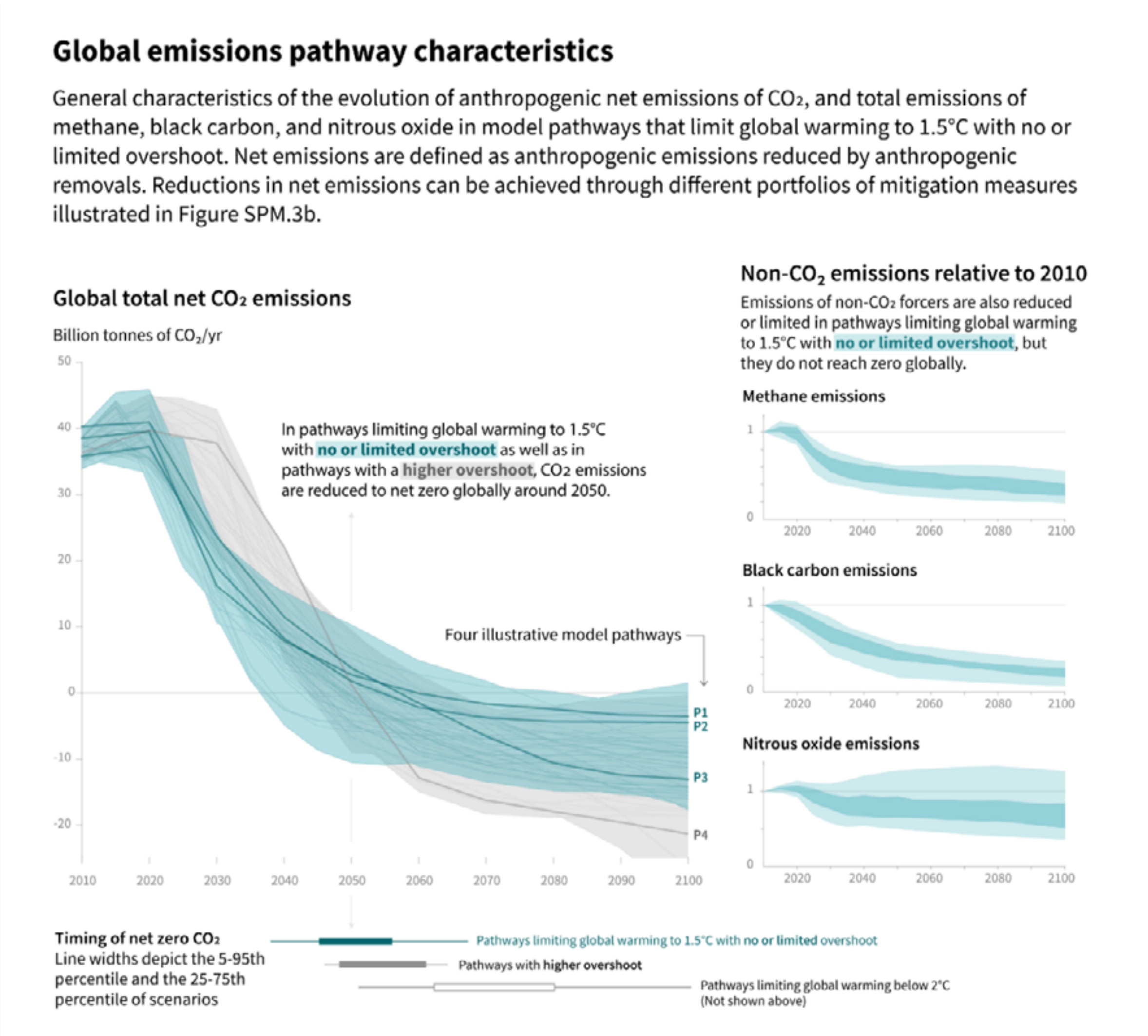
This Discussion Paper sets out the aims and main approaches of policy in relation to tackling climate change, as they affect rural areas. SHERPA Multi-Actor Platforms (MAP) are invited to discuss local threats, challenges and opportunities for living and working in ways that enable transitions to climate neutrality by 2050. The approach will follow the SHERPA process of: (i) preparation of a SHERPA Discussion Paper, (ii) adaptation of the Discussion Paper by each regional or national MAP, (iii) consultation with MAP participants, (iv) summary of the discussions in a MAP Position Paper, (v) synthesis of the regional and national MAP Position Papers for discussion at EU level (EU MAP and annual conference).

1. International Pathways to Tackling Climate Change

The Intergovernmental Panel on Climate Change (2018) reported the reductions in GHG emissions relative to 2010 which would be required to limit global warming to 1.5°C as set out in the United Nations Paris Agreement (United Nations, 2015). Their analysis showed the pathways that would be required to achieve the agreed aim through to 2100 (Figure 4). Their conclusion was that anthropogenic emissions of CO2 would require to half by 2030, be net-zero by 2050 and continue to reduce through the remainder of the century.

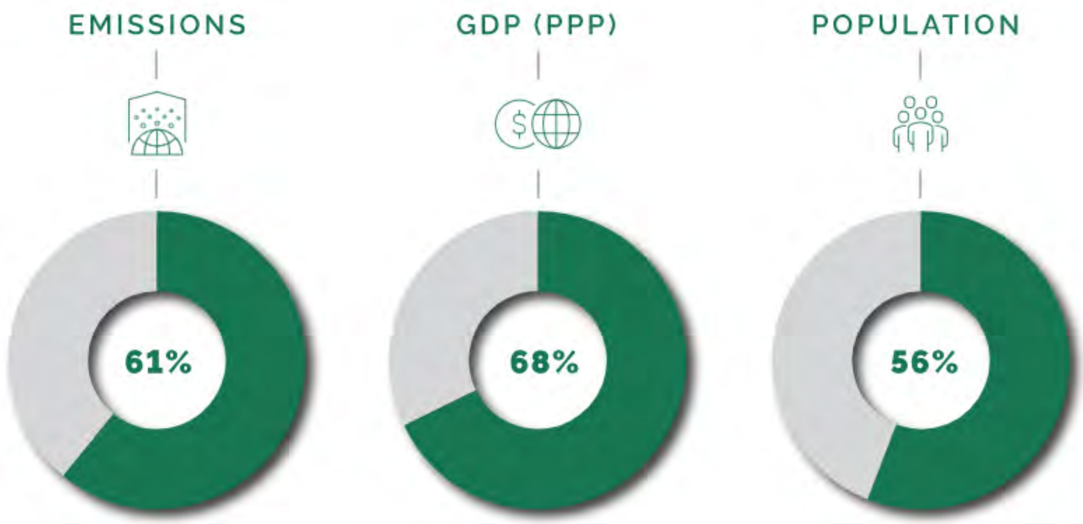
Broadly, the pathways of change show net-zero reached by 2070, considering all GHGs, converted to their CO2 equivalent. Subsequently, the EU, UK and other countries set more demanding interim targets for 2030, and supported those with legal instruments in their jurisdictions (e.g. European Union Climate Law, 2020).

Figure 4. Characteristics of global emissions pathways (Source: Intergovernmental Panel on Climate Change, 2018). Figure 3. Global GHG emissions and global mean temperature increase under scenarios leading from COVID-19 (Source: Keramidas *et al.*, 2020).



The University of Oxford (Black *et al.*, 2021) provide an in-depth study of progress towards net zero GHG emissions. They report that the three largest emitters of GHGs (USA, China and Europe) are now covered by targets and strategies for achieving net-zero by mid-century. They summarise that national commitments to net-zero cover 61% of global GHG emissions, covering also 68% of global GDP and 56% of the world's population (Figure 5). In their analysis, they point to Sweden as an example of a country setting an aim of transitioning towards net negative GHG emissions.

Figure 5. Proportions of anthropogenic greenhouse gas emissions, Gross Domestic Product per annum and world's population covered by countries or regions with commitments to net zero (Reproduced courtesy of Black *et al.*, 2021).



The analysis of Hepburn *et al.* (2020) estimates that if the global recovery from COVID-19 follows a 'historically green or dirty pathway' compared to green pathway 'amounts to a difference of 230 GtCO2 entering the atmosphere by 2050' which they describe as approximately 'twice the potential impact of the shock alone'. They argue that the evidence shows that significant investment in decarbonisation could bend down the emissions curve requires charting a totally new course.'

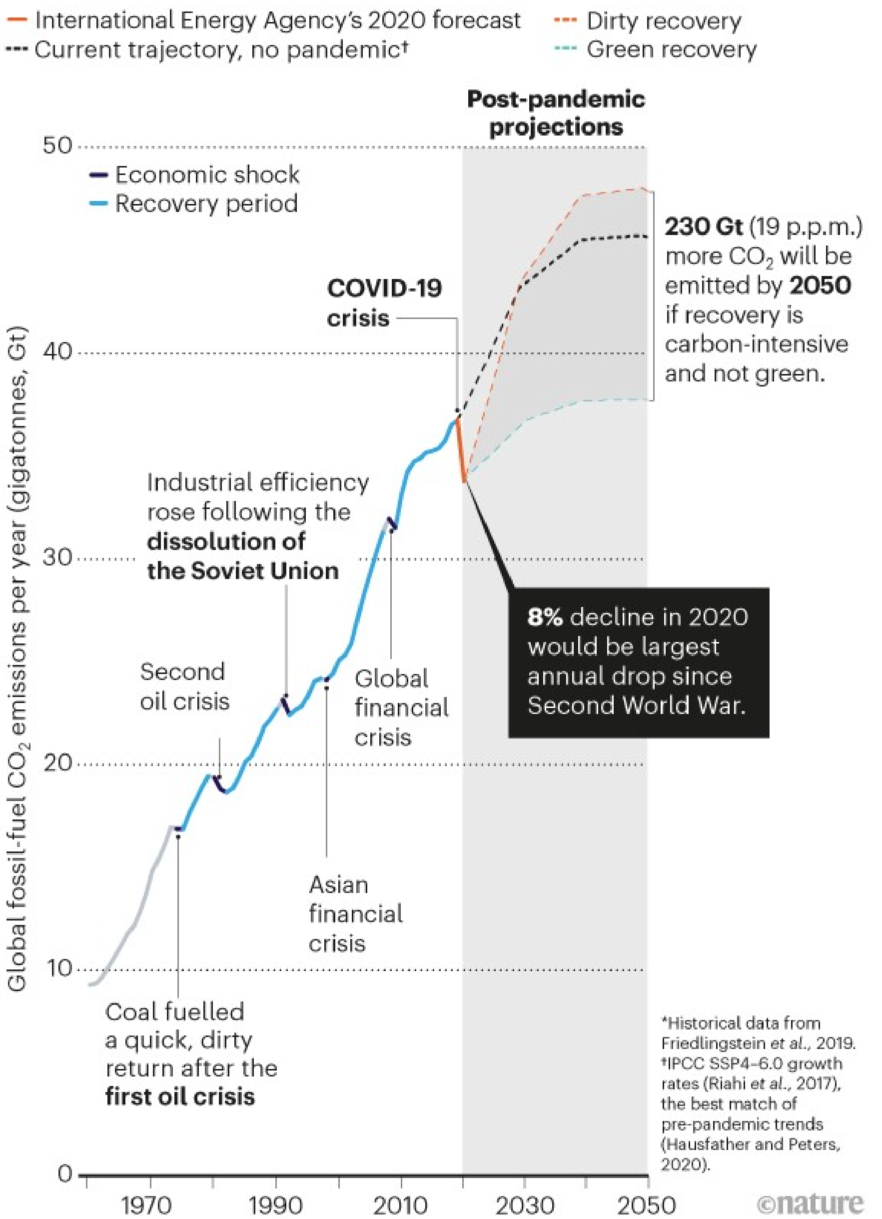
The significance of the use of climate investments to support the economic recovery and jobs and ensuring there is no 'lock-in' of greenhouse gas emissions or increased climate risk during recovery from COVID-19 is illustrated by Hanna *et al.* (2020), in their review of the historical pattern of GHGs in periods of recovery post economic shocks (Figure 6). They conclude that "shocks, although painful, are political and industrial turning points if they come with incentives for low-carbon infrastructure."

In support of the aims of net-zero, the United Nations instigated a 'Race to Zero' campaign, to be achieved by the time of the Convention of the Parties (COP) 26, scheduled to be held in Glasgow, UK, in November 2021. The 'race' comprises four principles, in all of which the EU has shown a lead of *Pledge* (net-zero by mid-century, EU target of climate neutrality by 2050); *Plan* (steps to achieving net-zero, EU Climate Action Plan); *Proceed* (taking action consistent with achieving interim targets, e.g. the Innovation Actions in the Horizon 2020 calls for proposals relating to the European Green Deal (published October 2020); and *Publish* (reporting progress, with promotion of platforms such as Climate Adapt and the Open Science Cloud).

Analysis of the UNFCCC Global Climate Action Portal, as of April 2021, shows 11 076 actors in 13 315 actions in the EU Members States. These actions cover a very wide range of topics, many similar in aims or content, but tailored to specific geographic and socio-economic contexts. Broadly, an equivalent portal for Europe is Climate Adapt. And as of April 2021, Climate Adapt contains information and links to 184 information portals, 105 case studies on climate adaptation, and 646 research and knowledge projects.

The efforts to reverse the loss of biodiversity and degradation of ecosystems follow a similar narrative. Maes *et al.* (2020), in their major assessment of ecosystem services in Europe compared to a baseline of 2010, report that "More efforts are needed to bend the curve of biodiversity loss and ecosystem degradation and to put ecosystems on a path to recovery".

Figure 6. Historic patterns of shock and recovery in terms of global fossil fuel CO2 emissions per year (Source: Hanna *et al.*, 2020).



Sources: P. Friedlingstein *et al. Earth Syst. Sci. Data* **11**, 1783–1838 (2019)/K. Riahi *et al. Glob. Environ. Change* **42**, 153–168 (2017)/Z. Hausfather & G. Peters *Nature* **577**, 618–620 (2020). analysis by R. Hanna *et al.*

2. European Union Climate Commitments and Strategies

The European Union is a signatory to international conventions whose aims are tackling climate change and the associated protection of environmental services. Such commitments are delivering to the United Nations Sustainable Development Goals, the Paris Agreement on Climate Change, Aichi targets on biodiversity, and Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters. Delivery on these conventions and agreements is embedded in European, national and regional policies.

The Paris Agreement (United Nations, 2015) set the goal to limit global warming to well below 2°C or 1.5°C above pre-industrial levels. The long-term low greenhouse gas emission development strategy of the EU of achieving a climate-neutral continent by 2050 was submitted in March 2020. The Nationally Determined Contributions (NDCs) and long-term strategies from all signatory countries are due to be submitted for assessment in the UN Climate Change Conference 2021, (26th Conference of Parties; Glasgow, UK, 2021).

Tackling climate change intersects with all six of the priorities set out in the EU Strategic Agenda (2019-2024), most directly with the aim of a climate-neutral, green, fair and social Europe. The EU Climate & Energy framework for 2030 targets a reduction in greenhouse gas emissions of at least 40% compared to 1990 levels. However, in light of the evidence of the trajectory of emissions, the European Union 2030 Climate Target Plan sets out a new EC proposal of cutting greenhouse gas emissions trajectory by at least 55% by 2030, an increase of the previous target of at least 40% by 2030. EU Strategies are building towards that aim, across domains that have significant representations in rural areas such as land use, agriculture, biodiversity, waters, energy production, rural development, business and innovation. Several themes are cross-cutting, obliging adherence to standards of environmental management (e.g. 8th Environment Action Programme), social rights (e.g. EU Pillar of Social Rights) and environmental justice (e.g. Aarhus Convention; UNECE, 1998).

2.1 European Union Green Deal

The European Green Deal has overarching aims of no-net emissions of greenhouse gases by 2050, economic growth is decoupled from resource use, and no person and no place is left behind, with a European Climate Law to support that aim (Figure 7). It sets out the increased climate ambitions of the EU of a transition to 2050, preserving and restoring ecosystems and biodiversity, zero pollution, and mobilising industry for a clean and circular economy.

Figure 7. Overview of the components of the European Green Deal.

The Green Deal sets out nine main themes for action that contribute to achieving its aims, all of which have significance for the rural areas of Europe:

- Biodiversity - Measures to protect our fragile ecosystem;
- From Farm to Fork - Ways to ensure more sustainable food systems;
- Sustainable agriculture - Sustainability in EU agriculture and rural areas thanks to the Common Agricultural Policy (CAP);
- Clean energy - Clean energy;
- Sustainable industry - Ways to ensure more sustainable, more environmentally-respectful production cycles;
- Building and renovating - The need for a cleaner construction sector;
- Sustainable mobility - Promoting more sustainable means of transport;
- Eliminating pollution - Measures to cut pollution rapidly and efficiently;
- Climate action - Making the EU climate neutral by 2050.

The Green Deal recognises that "Climate change and environmental degradation are an existential threat to Europe and the world" (European Commission, 2019a). It recognises that "active public participation and confidence in the transition is paramount if policies are to work and be accepted". It also identifies the need for a new pact "to bring together citizens in all their diversity, with national, regional, local authorities, civil society and industry working closely with EU institutions and consultative bodies."

To achieve its objectives will require coherence in policy areas at an EU level of Climate action, and Eliminating pollution; Biodiversity; Sustainable Agriculture (e.g. aim of the CAP of 'social, economic, and environmental approaches on the path towards achieving a sustainable system of agriculture'); Agriculture and Biodiversity; and Farm to Fork (e.g. aim of 'designing a fair, healthy and environmentally-friendly food system').

Achieving the objectives of the EU Green Deal in tackling climate action and reducing human impacts on the environment will require changes in individual and collective behaviours. Pathways and transitions to climate neutrality are inherently linked to shared interests across generations. Recognising those interests requires actions on the ground to mitigate and adapt to climate change, managing environmental services, and providing infrastructures that motivate and enable transitions to climate neutral ways of working and living.

The delivery of such actions is one aim of the EU and is aided by A new push for European democracy, in particular the European democracy action plan (published on 2 December 2020), with its protocols for citizen-led collection of environmental data, quality control and co-interpretation of results, and the identified need for the co-design of solutions to support behavioural changes towards reducing environmental footprints and improve lifestyle quality.

It also requires working between generations. The Next Generation European Union describes the need for "advancing climate action and promoting environmental and biodiversity protection" and a "greener, more digital, more resilient and better fit for the current and forthcoming challenges". This is reflected in A Europe fit for the digital age, with its aim of "increasing training in digital skills for the workforce and for consumers". The development of digital technologies can also provide new opportunities for civil engagement and promoting active citizenship amongst young people in line with the EU Youth Strategy (2019-2027).

The Green Deal also contributes to the EU plans emerging for a Green Recovery from COVID-19 with their alignment of approaches to reducing GHG emissions, and nature-based approaches, and the opportunities set out by Hepburn *et al.* (2020) to build networks "of interactions through which information, knowledge and talent flow in systems of sustained value co-creation."

The European Union 8th Environment Action Programme (scheduled to be adopted in 2021) sets objectives aligned to the Green Deal. These include achieving the targets for reducing GHG emissions for 2030, and climate neutrality by 2050; enhancing adaptive capacity of society, and strengthening resilience and reducing vulnerability to climate change; an ambition for zero-pollution, including for air, water and soil and protecting the health and well-being of Europeans; and, of protecting, preserving and restoring biodiversity, enhancing natural capital (air, water, soil, natural or semi-natural vegetation and forests, freshwater, wetland and marine ecosystems). The definition of natural capital used by the EU is set out in its 7th Environment Action Programme (EAP) as "biodiversity, including ecosystems that provide essential goods and services, from fertile soil and multi-functional forests, to productive land and seas, from good quality fresh water and clean air to pollination and climate regulation and protection against natural disasters."

An overview of work on assessing and mapping natural capital, as of 2019, is described in a European Commission report on 'Natural Capital Accounting: Overview and Progress in the European Union'. It includes a summary of the approach of the Integrated system of Natural Capital and ecosystem services Accounting in the EU (INCA) project, and the links to the MAES reporting of ecosystem services.

The Integrated system of Natural Capital and ecosystem services Accounting in the EU (INCA) project addresses the design and implementation of an integrated accounting system for ecosystems and their services to inform decision making in the EU. It is a joint project of Eurostat, DG Environment, DG Research and Innovation, the Joint Research Centre of the European Commission and the European Environment Agency. Its key objectives are to: develop a system of natural capital accounting, focusing on ecosystems; address EU policy needs; integrate existing georeferenced data from EU databases and reporting by Member States; identify data gaps and how they can be addressed; developing a geo-spatial data platform for a regular production of accounts. The aims and overall approach are described by Vyšná, V. (2019), and details of data used and captured on topics such as land cover, soils, transport infrastructure, with links to relevant input datasets are accessible here.

The Biodiversity Information System for Europe is a partnership between the European Commission and the European Environment Agency. It provides an overview of the functions and significance of biodiversity across all sectors, and a context for the in-depth assessment of ecosystems at the EU level of Maes *et al.* (2020) of the 2020 Mapping and assessment of ecosystems and their services (MAES) Report. An example of a pilot mapping of ecosystems at a regional level is of the Limburg Province, The Netherlands (de Jong *et al.*, 2016), and reported by UNEP in Towards natural capital accounting in the Netherlands (unep.org). The pilot applies the SEEA–EEA approach to the Limburg Province, producing the output of 'Ecosystem Unit (EU_NL) Map', consistent with the mapping approaches of MAES.

2.2 Common Agricultural Policy and climate neutrality

Agriculture is assessed as responsible for approximately 10% of the GHG emissions from the EU (European Environment Agency, 2020a). One objective of the Common Agricultural Policy (CAP) is to support social, economic, and environmental approaches on the path towards achieving a sustainable system of agriculture. The Roadmap to the Green Deal (European Commission, 2019a) seeks to increase the adoption of "... sustainable practices, such as precision agriculture, organic farming, agro-ecology, agro-forestry and stricter animal welfare standards."

The updated aims of the EU Climate Target Plan 2030 intersect with the transition to agro-ecological farming systems with the creation of "new, sustainable and local jobs, more sustainable food, a lower energy import bill and more energy, security, greener transport and more energy-efficient home." A subsequent communication from the European Commission in January 2020 indicated that the EU's 2021-2027 budget will allocate 40% of its total envelope (i.e. agricultural and rural development) to support climate-related objectives. When reviewing CAP National Strategic Plans of Member States, the European Commission will verify they are consistent with targets of the Green Deal, and monitor progress towards their achievement.

The combination of the transition to climate-neutrality and reversing the loss of biodiversity is reflected in several of the eco-schemes under discussion for inclusion in National CAP Strategic Plans having potential for mitigating GHG emissions through changed land management practices: agro-forestry (e.g. H2020 AFINET, EIP Agri Focus Group Agroforestry, 2017); precision farming (e.g. H2020 BIOMAP2SOIL); agro-ecology (e.g. H2020 LIFT, Landert *et al.*, 2020; H2020 UNISECO); organic farming practices (e.g. H2020 UNISECO); and protecting water resources (e.g. H2020 CERES).

Further EU-funded research into climate smart agriculture and land systems commenced in 2020, H2020 AGROMIX (AGROforestry and MIXed farming systems - Participatory research to drive the transition to a resilient and efficient land use in Europe), and H2020 MIXED (Multi-actor and transdisciplinary development of efficient and resilient MIXED farming and agroforestry-systems). The findings from these projects will further inform the approaches that can be taken by agriculture to contribute towards climate neutrality.

More broadly, components of the Rural Development Programmes can contribute to various elements of delivery to the aims of climate neutrality. Mechanisms foreseen in the Rural Development Programmes which should help deliver policy aims relating to climate and environment include Agricultural Knowledge and Innovation Systems and agri-environment climate measures (e.g. protecting carbon-rich soils), with other schemes anticipated to support innovation and new thinking towards land management (European Commission, 2020b).

2.3 Long-Term Vision for Rural Areas

In September 2019, the new European Commission (2019 to 2024) announced the preparation of a Long-Term Vision for Rural Areas, to be coordinated by the Commissioner for Democracy and Demography, Dubravka Šuica, with the Commissioner for Agriculture and Rural Development, Janusz Wojciechowski, and the Commissioner for Cohesion and Reforms, Elisa Ferreira. The aim was to stimulate a debate on the future of rural areas and the roles they have to play in European society.

Throughout 2020, actors in policy, science and society engaged in processes of dialogue to identify challenges, themes and approaches to developing a vision for rural areas, including harvesting evidence form EU projects in a Rural Policy Day (November 2020), a public engagement tool, launched at the 3rd Annual Citizen Engagement and Deliberative Democracy Festival (December 2020), and sharing a sharing of ideas at a Rural Vision Week (March 2021).

Chartier *et al.* (2021; H2020 SHERPA) articulates the outputs of a structured process of engagement undertaken by H2020 SHERPA, through which the visions of 20 local Multi-Actor Platforms, and one with an EU level perspective were brought forward. They identified climate change as one of the main challenges faced by the rural areas of Europe. Issues such as extreme weather events (drought, forest fires, floods) threaten the human health and well-being, livelihoods and infrastructure for residents and visitors. In some areas, climate change could threaten entire sectors of activity (e.g. fruit sector, in the Netherlands), or threaten sectors through the vulnerability of crops and species to pests and disease.

Climate change was also seen as a driver of a green transition and the environmentally sustainable management of rural areas, adapting to circular and bio-economies, new and revitalised structures of governance that enable local ownership of resources, and scope for cross-sectoral approaches and collaboration that involves all relevant sectors and levels of government.

Participants in the Multi-Actor Platforms also identified needs for "public support for producers whose investments promote climate change mitigation, directly or indirectly (e.g. sustainable agricultural practices, cleaning of land and forests, extensive animal production systems, agroforestry systems)." (Chartier *et al.*, 2021; H2020 SHERPA). To tackle the challenge of climate change, approaches would be required that enable and support transitions towards environmental sustainability with commensurate management of environmental services and assets to contribute to aims of climate neutrality.

The draft EU Long-Term Vision for Rural Areas is scheduled to be published in summer 2021.

2.4 EU Climate Pact

The EU Climate Pact is an EU-wide initiative inviting people, communities and organisations to participate in climate action and build a greener Europe. They are invited to learn about climate change, to share knowledge and establish connections between groups, and to develop and scale up solutions to fight climate change. It has 4 focus areas, all of which have relevance to rural Europe.

- Green areas - more green areas to build resilience against threats of climate change and to people's health; reflected in topics of nature-based solutions in the H2020 calls for the Green Deal and the aims of the draft EU Forestry Strategy of planting 3 billion trees by 2030.
- Green transport – promoting changed behaviours of increased use of cycling, public transport, car-pooling and car sharing services, the role of citizen-science in the mix of approaches to encourage such change (e.g. Green Driving Tool), while recognising the practicalities of access and transport in rural areas.
- Green buildings – making all buildings (i.e. for living, working, learning, leisure), more resilient to the effects of climate change such as floods and heatwaves, and energy efficient. Initiative encouraging includes conversations on developing sustainable places in a new European Bauhaus (e.g. renovating small aging town of Gyermely, in Hungary)..
- Green skills – to promote and support green employment, address the skilling and reskilling of workers, anticipate changes in workplaces of the future. Encouraging learning through school curriculums and life-long is one part of developing understanding, linked to the design and running of developing skills and the new knowledge required for stimulating a green economy. This theme is accompanied by a Just Transition Mechanism, to ensure change takes place in a fair way and that no-one is left behind, funded by €150 billion over the period 2021-2027.

2.5 Just Transitions to climate neutral continent 2050

The Paris Agreement sets out a principle of a 'just transition' for 'workers and communities as the world's economy responds to climate change.' The EU set up a Just Transition Mechanism which comprises three pillars: i) Just Transition Fund, value €40 billion; ii) investEU Just Transition Scheme; and iii) EIB public sector loan facility, value €10 billion. Combined, the €50 billion of these mechanisms is expected to lever approximately €160 billion of investments. Member States can access funds under the Just Transition Mechanism through territorial Just Transition Plans. These Plans should identify the territories on which to target most support in addressing social, economic and environmental challenges through to 2030.

The aims of these funds and creating the conditions for investment opportunities include ensuring Europe's most vulnerable citizens are protected, in terms of health, well-being, livelihoods, ways of life, and that there are equal opportunities (e.g. employment opportunities in new sectors and those in transition, with associated re-skilling).

Amongst its objectives, the Just Transition Mechanism(s) are to support the adoption of low-carbon technologies and economic diversification, stimulate new businesses (SMEs, start-ups), and investment in research and innovation activities, particularly in areas with a high dependence on fossil fuel and carbon-intensive industries, and improve digital connectivity, energy infrastructure, and transportation networks.

Alongside supporting business and technological opportunities, transitions are required in societal expectations (e.g. ways of living and working), and access to information to support plans and decisions by individuals, business and civil society. This is consistent with implementation of the Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (UNECE, 1998), and the principles of the European Pillars of Social Rights. Respecting social rights includes recognition of the diversity of citizens, and that people with different backgrounds have different attitudes and perspectives to offer on the use and meaning of land and towards the transition to climate neutrality.

2.6 Climate law

The aim of an EU Climate Law is to place a legally binding target of net-zero greenhouse gas emissions on the EU as a whole by 2050. The plan is for the Climate Law to set the "direction of travel for achieving climate neutrality by 2050", mainstreamed through all policies in a 'socially-fair and cost-efficient manner', ensure the transition is irreversible, create systems for monitoring of progress towards climate-neutrality, and providing 'predictability for investors and other economic actors'.

The Paris Agreement on Climate Change includes a principal of 'non-regression', which is that any changes in law or policy should maintain or increase level of environmental protection, and not allow any deterioration. The monitoring will review the trajectory to climate neutrality by 2050, and is an assessment of consistency of the measures of the EU and Member States with achieving that aim. The first assessment is scheduled to be complete by September 2023, and reviewed every 5 years, thus synchronised with the requirements of the 5-year cycle set out in the Paris Agreement.

The approaches to monitoring will require linking existing systems, such as the mapping and assessments of natural capital, or ecosystem services, and is being undertaken by several EU-level initiatives or individual projects developing concepts, testing and implementing methods, and reporting on changes in relating to drivers such as climate change and economic activities. Two linked major initiatives are the Integrated system of Natural Capital and ecosystem services Accounting in the EU (INCA) and Mapping and Assessment for Integrated ecosystem Accounting (MAIA). The Mapping and Assessment for Integrated ecosystem Accounting (MAIA) project, coordinated by Wageningen University, aims to "mainstream natural capital and ecosystem accounting (NCA) in EU Member States". It applies the United Nations System of Environmental Economic Accounting – Ecosystem Accounting (SEEA-EA) as the basis of its methodology for natural capital accounting (NCA). This is a spatial approach which uses data and models as inputs to the preparation of accounts.

3.7 Europe showing a global lead

Three other strategic aims of the EU cohere around showing leadership (A stronger Europe in the world, Promoting our European way of life, A new push for European democracy). Delivering on these aims is consistent with the types of broader policy contexts required to tackle climate change. For example, through enhancing relations with neighbouring countries and partners, recognising dependencies across borders, within continental river systems, and international trade and the networks of supply chains (H2020 UNISECO); upholding fundamental rights and the rule of law as a bastion of equality, tolerance and social fairness (H2020 SIMRA); strengthening Europe's democratic processes and engaging more widely with EU citizens in shaping the EU's future, including the roles of Open Science and citizen science.

Support of the DeSIRA international partnership on Development Smart Innovation through Research in Agriculture, the aim of which is to "contribute to climate-relevant, productive and sustainable transformation of agriculture and food systems in low and middle-incomes countries", and contributed to several Sustainable Development Goals, including SDG13 on Climate Action.

3. Climate change and EU rural areas

IPBES (2019) identifies climate change as one of the direct drivers of change that have accelerated during the past 50 years (i.e. since 1970). They conclude that the "goals for conserving and sustainably using nature and achieving sustainability cannot be met by current trajectories, and goals for 2030 and beyond may only be achieved through transformative changes across economic, social, political and technological factors."

Worldwide, climate change in rural areas is taking place in the context of other economic, social and land-use trends. In 2014, the Intergovernmental Panel on Climate Change (2014a) reported that major impacts of climate change in rural areas would be evident on water supplies, food security and agricultural incomes. Those effects are becoming evident on the agriculture, forestry, fishing and mining sectors as a consequence of increasing frequency and intensity of extreme weather events (OECD, 2019).

In the chapter of Maes *et al.* (2020) dedicated to climate change (Hagyo *et al.*, 2020). It summarises high-level trends determined as significant in their bioclimatic indicators for assessing ecosystem condition:

i) increase in annual mean temperature of 0.325°C per decade (2016 to 2018);

ii) mean temperature of the warmest quarter, of 0.325°C per decade (2016 to 2018);

iii) mean temperature of the coldest quarter, of 0.325°C per decade (2016 to 2018);

iv) effective rainfall, of 0.325°C per decade (2016 to 2018);

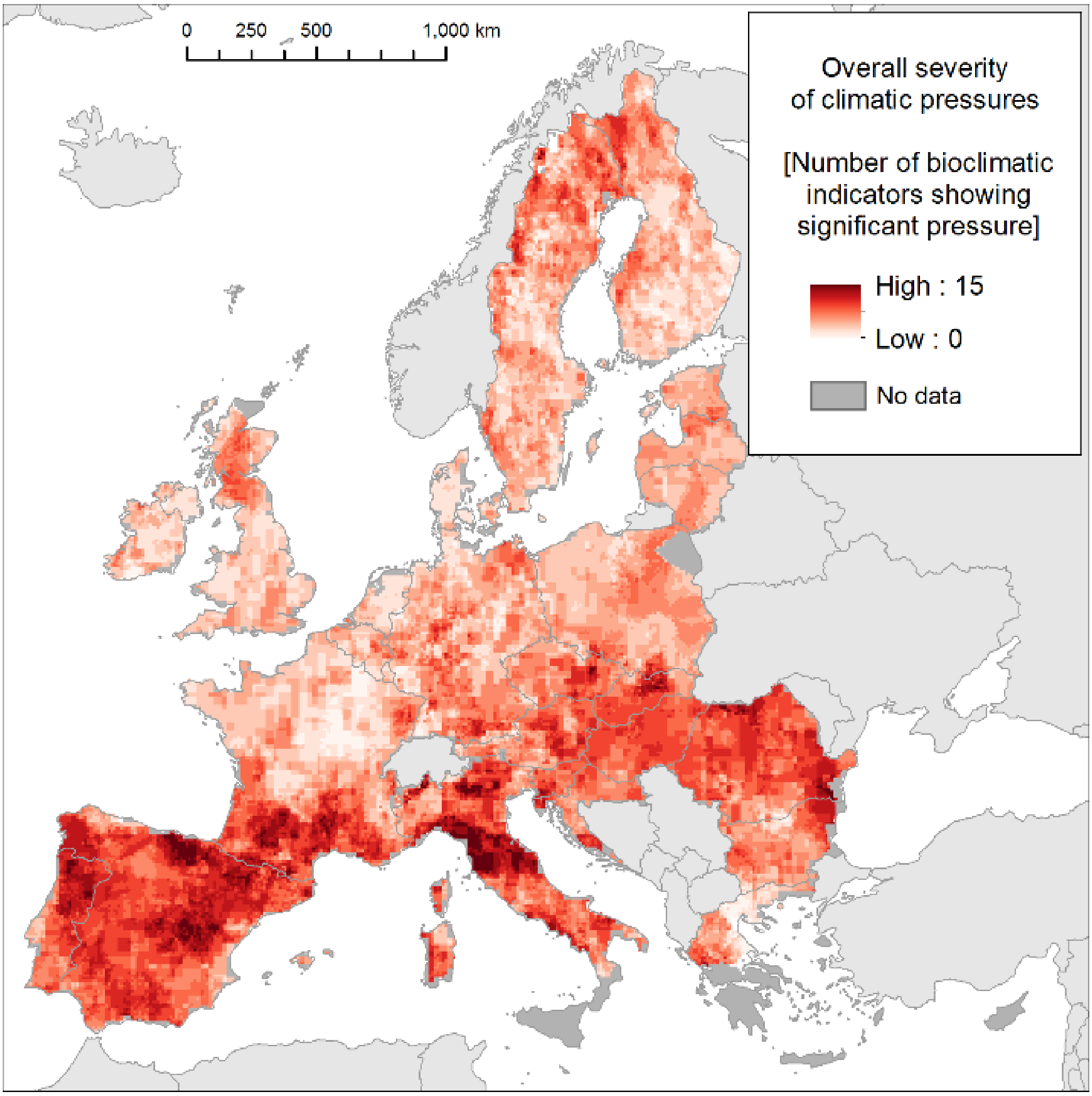
v) extreme drought events, of 0.325°C per decade (2016 to 2018);

vi) number of days where daily maximum temperature > 25°C, of 0.325°C per decade (2016 to 2018);

vii) length of growing season (days), of 0.325°C per decade (2016 to 2018).

They note that "annual and seasonal temperatures are among the most important climatic factors shaping species distributions". Figure 8 shows the geographic distribution of the severity of climatic pressures across the EU-28. They report that across the EU-28 land area, 38% is affected by at least seven significant climate pressures, 50% by four to six climate pressures, and 12% between one and three climate pressures.

Figure 8. Number of bioclimatic indicators (all indicators) that pose a significant pressure on ecosystems and biodiversity (Source: Haygo *et al.*, in Maes *et al.*, 2020).



Climate change is affecting European regions differently based on their geography, location, climate and population, and may increase future intra-regional disparities (European Commission, 2021; Intergovernmental Panel on Climate Change, 2014a). Expectations are that the magnitude of impacts will increase in the future, and that their effects will be unequally distributed across Europe. Measures to mitigate the impacts of climate change in the EU will not stop climate impacts that are already in train, which are projected to increase in coming decades (European Commission, 2021).

Under the best-case scenario of limiting temperature-rise to 1.5°C, there will still be severe and unequally distributed impacts on agriculture, food systems, infrastructures, ecosystems, natural capital and human health (Intergovernmental Panel on Climate Change, 2018). Direct impacts of climate change on agriculture are on the phenology and crop calendars, displacement of cultivation areas and soil loss, changes in water supply and irrigation demand, and direct effects of increased levels of CO2 on growth. Impacts on agricultural production will have economic and social impacts on people whose livelihoods are linked to the farming sector (European Environment Agency, 2020c).

Globally a rise in sea levels between 0.29 and 1.10m is projected over the 21st century (Intergovernmental Panel on Climate Change, 2019). The rise in sea level relative to land along most European coasts is projected to be similar to the global average, with the exception of northern Baltic Sea and the northern Atlantic coast, which are experiencing considerable land rise as a consequence of post-glacial rebound (European Environment Agency, 2020c).

Extreme weather events will lead to adverse impacts on ecosystems, economic sectors and human health and well-being (European Environment Agency, 2020b), with such events reported as increasing in recent years (European Environment Agency, 2020c). For example, heatwaves are projected to become more frequent and longer lasting in Europe, particularly in southern and south-eastern Europe (European Environment Agency, 2020b). Other potential impacts of climate change in rural areas include increased physical isolation (e.g. destruction of transport and communications infrastructure), and perceptions of isolation. Adverse impacts on human physical and mental health can be significant, and long term. Research evidence is beginning to emerge from the experiences of COVID-19of how to maintain good mental health during social isolation (Diamond and Willan, 2020) which has some potential to inform strategic planning and investment of support mechanisms in rural areas, and local implementation of approaches.

Figure 9 shows the observed and projected climate change and impacts for the main biogeographical regions in Europe (European Environment Agency, 2017). In the Arctic region, temperature rises will reduce ice coverage on land and at sea, adversely impacting on the permafrost, releasing carbon from peat and permafrost (Wild *et al.*, PNAS, 2019; H2020 CC-TOP), and creating risks to livelihoods of indigenous peoples. It also creates opportunities for new transport routes and trade, and economic activity through exploitation of natural resources.

In mountain regions, temperature rises will reduce the volume of ice in glaciers, increase water flow and soil erosion, change efficiency of hydro-power production, change the spatial distributions of plant and animal species to higher elevations, increase risks of pest and disease in plants, and extinctions of species, and reduce scope for winter tourism.

In the Atlantic region increases are projected for precipitation and river flows, creating risks of flooding, coastal erosion, and storm events. Prospectively, demand for energy for heating could reduce due to increased temperatures. In coastal zones and regional seas, sea level rises, coastal flooding and changes in water temperatures and increase risks of water-bourne diseases are threatening coastal ecosystems, the fishing industry, water resources through salinisation, settlements, infrastructure and human lives (European Environment Agency, 2020b, 2020c).

In the Boreal region, increases in the frequency and magnitude of precipitation events, and decrease in the cover of snow and ice will increase risks of flood events, damage from winter storms, and increase risks of pest and disease on crops and natural habitats. There are also projected increases in crop yields whereas those in mid-latitudes would experience the opposite effect (Ferreira, 2019; European Environment Agency, 2020c; Intergovernmental Panel on Climate Change, 2014b), potential for hydropower, reduced demand for energy for heating and potential for increased summer tourism.

Figure 9. Key observed and projected climate change for the main regions in Europe (European Environment Agency, 2017).

An increase in fire danger, with a substantial expansion of the fire-prone area and longer fire seasons, is projected in most regions of Europe, in particular in southern Europe and western-central Europe (European Environment Agency, 2020b). Floods are also projected to intensify in most parts of Europe, with the largest increase in magnitude of heavy rain in central and north-eastern Europe (European Environment Agency, 2020b, 2020c).

The frequency of droughts is expected to increase in central and western Europe, whereas it may decrease in some limited regions of northern Europe. However, it is in southern Europe that the Intergovernmental Panel on Climate Change (2014a) expect climate change to impede economic activity more than in other sub-regions. The largest increase in drought conditions is projected for southern Europe, where crop productivity is projected to reduce most competition between water users such as agriculture, industry, tourism and households will increase, and the decline in economic activity may lead to an increase in rural depopulation and harm the development of rural communities in southern Europe (Intergovernmental Panel on Climate Change, 2014b). Increasing drought risk in various regions in Europe is also expected to reduce livestock productivity through negative impacts on grassland productivity and animal health (European Environment Agency, 2020c).

Climate change is affecting a wide range of economic sectors and human activities, including agriculture, forestry, fisheries, water management, coastal and flood protection, energy, transport, tourism and construction (European Environment Agency, 2020c). The net loss in welfare from climate change in the EU by the late 21st century is estimated at 1.9 % of GDP under a high warming scenario and at 0.7 % under a 2 °C scenario. Southern and central-southern Europe are projected to suffer the greatest losses as a percentage of GDP (JRC PESETA III project).

Human health and well-being are being impacted upon more widely by climate change. Direct impacts include the effects of extreme events through floods, wildfires, and heatwaves, and indirectly by changing the distribution and seasonal pattern of some human infections (Intergovernmental Panel on Climate Change, 2014b; European Environment Agency, 2020c). The projected increase in the frequency and magnitude of heat waves will lead to a large increase in mortality over the next few decades, especially in vulnerable population groups (European Environment Agency, 2020b). Higher exposures and vulnerabilities to climate health hazards in southern Europe, due to higher proportions of elderly, rural and low-income people, who are particularly vulnerable (Marí-Dell'Olmo *et al.*, 2019; Intergovernmental Panel on Climate Change, 2014b).

Figure 10(a). Aggregate potential impact of climate change in the EU28 (source: ESPON 2011).

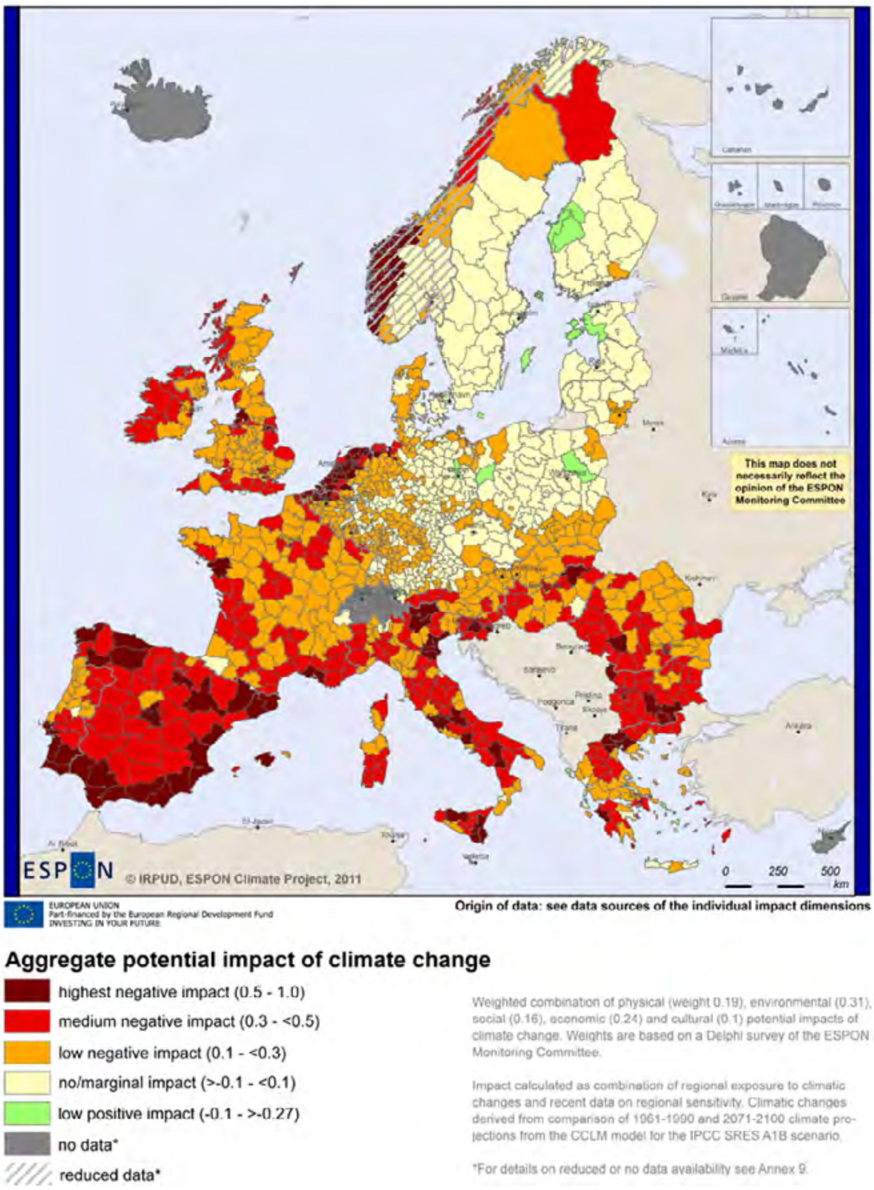
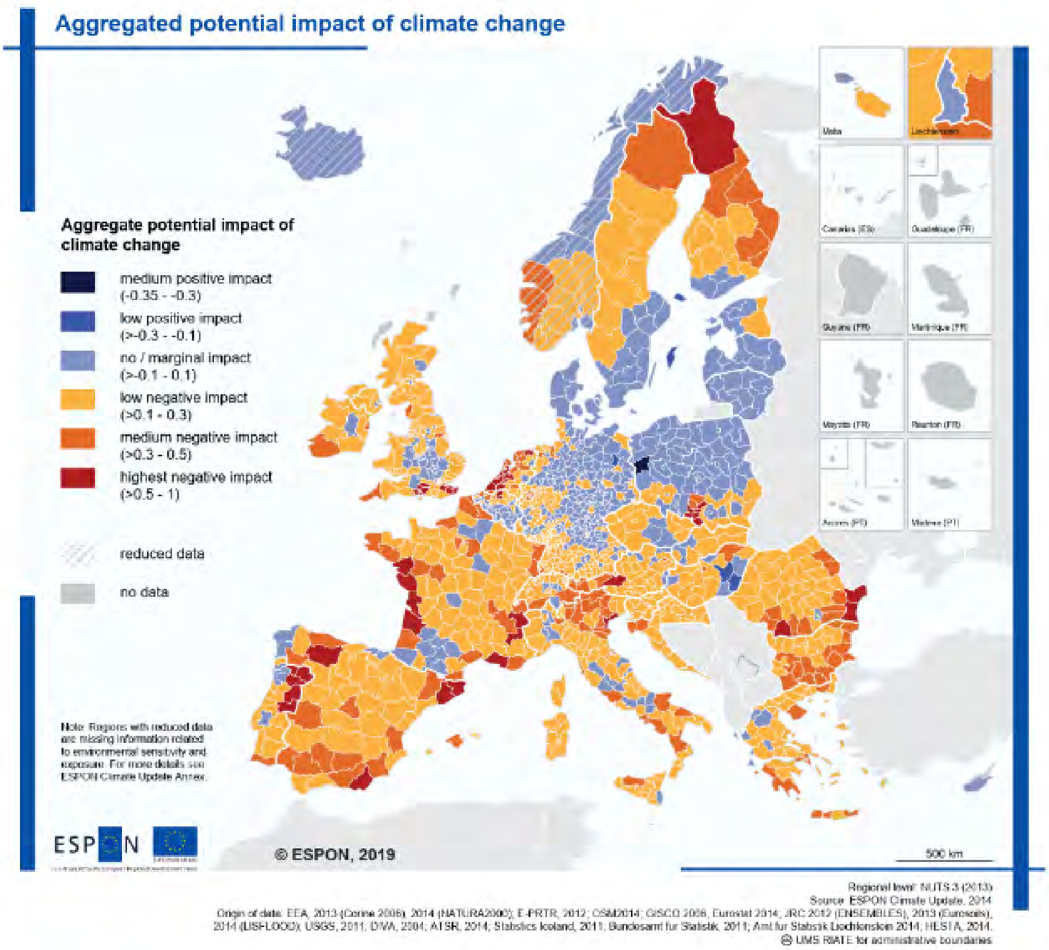


Figure 10(b). Aggregate potential impact of climate change in the EU28 (source: ESPON, 2019).



Figures 10(a) and (b) show two assessments of the aggregate potential impact of climate change on Europe. The details of the assessments in 2011 and 2019 show change, but broadly that the impacts are greatest in southern Europe and the Mediterranean basin, mountainous areas, coastal zones and floodplains (ESPON, 2011, 2019).

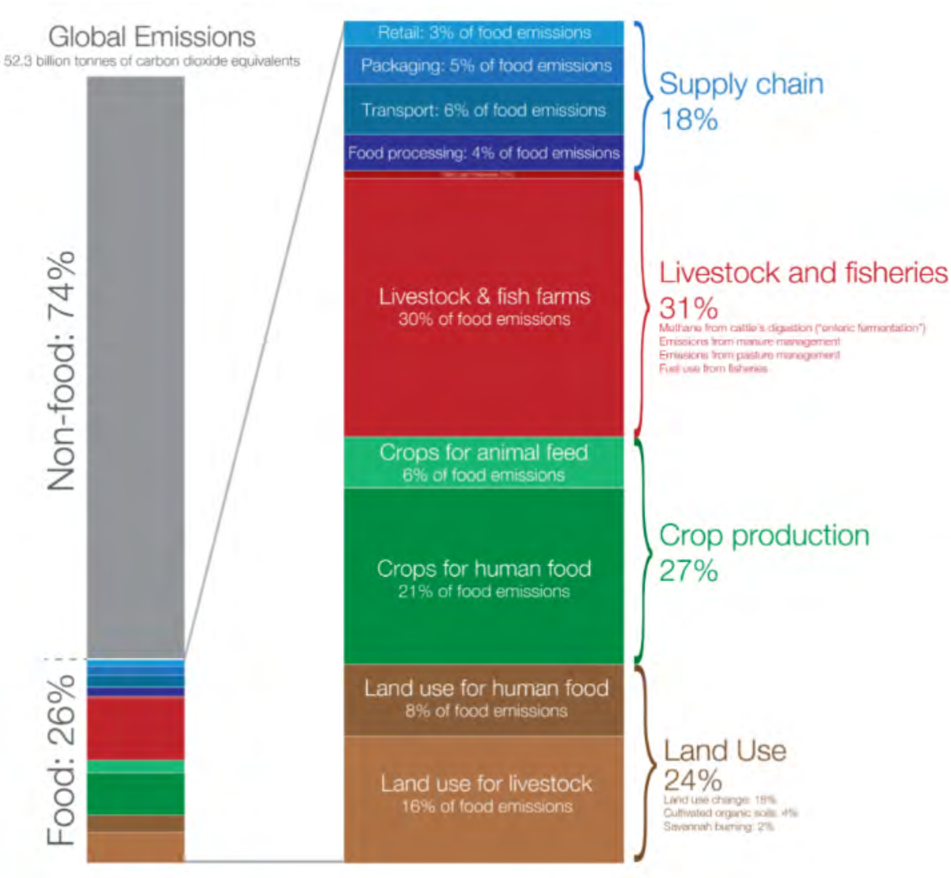
Changes in the world economy are accelerating the transformation of landscapes, as recognised by the European Landscape Convention (Council of Europe, 2000). Competition for land is intensifying land use for agriculture, housing, woodlands, renewable energy, transport infrastructure, and creating impacts on cultural landscapes (Smith *et al.*, 2010; Roth *et al.*, 2018, COST RELY; Plieninger *et al.*, 2014).

To achieve the targets of climate neutrality will require increasing the rate of development of renewable energy. Along with economic and environmental consideration, such transformation will need public acceptance and so rely on the attitudes of new generations of citizens towards energy generation and use, and its implications for land uses and landscapes. Miller (2018a; COST RELY) notes that land managers, residents and tourists will be the agents of the European Landscape Convention statement that "protection, management and planning entail rights and responsibilities for everyone".

Opportunities can be taken to build landscapes into solutions tackling social challenges such as climate change. Such opportunities are the design and implementation of nature-based solutions using collaborative, place-based approaches which respect the natural and cultural environment and heritage, in line with Place Principle (Miller *et al.*, 2020). Such solutions can reflect concepts of adaptive capacity, in which landscape and land use can be re-configured "without significant changes in crucial functions or declines in ecosystem services" (Resilience Alliance, Gunderson and Holling, 2002).

Of the 26% of greenhouse gases associated with food production (Figure 11), 31% is from livestock and fisheries. Yet, the United Nations estimate that the consumption of beef and dairy products is set to almost double by 2050. The H2020 ZELP report that methane is "85 times worse for global warming than carbon dioxide due to the way it traps heat", and that "methane emissions from 1.5 billion cows in the world represent the carbon equivalent of the entire transport industry"'. So, addressing the emissions of greenhouse gases by animals, managing the food system, and changing consumer preferences and diet are all likely to be required to ensure this source of emissions is in line with the transitions to a climate-neutral future.

Figure 11. Global Greenhouse Gas Emissions from Food Production (source: Poore and Nemecek, 2018).



To achieve the target of climate neutrality by 2050, strategies for tackling climate change will have to be designed to deliver multiple benefits. Approaches are required, in the short and medium term, that counter the effects of specialised, intensive agriculture which has contributed to reduced adaptive capacity to stresses related to climate-change, as well as decreasing levels of agrobiodiversity with associated risks of epidemics of pests and disease due to greater genetic vulnerability. Tackling barriers of gaps in knowledge, and culture and mindset could increase the use and conservation of wild plant species closely related to crops (Crop Wild Relatives, e.g. wild turnip, crab apple), which can provide benefits of adaptability to climate and resistance to pests and disease. That would be consistent with the EU Farm to Fork and Biodiversity Strategies, and deliver to related Aitchi targets (e.g. Target 4, sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limit; Target 15, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced; Target 19, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied).

Decisions relating to land use with objectives of tackling climate change affect other environmental and socio-economic services of biodiversity, energy, water and food security, employment and development in rural areas. Ongoing public debate can be expected to be required regarding the trade-offs between different environmental services (e.g. uses of land for wood fuel, impacts on landscapes, etc.), with consideration to be taken of potential implications for social equity and fairness, locally, nationally and in the context of global changes in climate.

Roth *et al.* (2018; COST RELY) describe the environmentally, cultural and economic importance of Europe's landscapes. The impacts of climate change will have direct effects on each type of rural landscape, varying upon location and locally specific drivers (IPCC, 2014b). It will also have indirect effects by modifying relative land values, and hence competition, between different land uses (Smith *et al.*, 2010). Miller *et al.* (2018; COST RELY) describe the adaptation of landscapes to such changes, particularly with respect to the transition to renewable energy. They note that the path dependencies, in place and time, that can be embedded in spatial strategies, "leading to development in one era evolving, maturing and requiring replacement or reinvestment during subsequent eras". For example, timescales for different types of renewable energy systems (their planning, development, operation and decommissioning or reinvestment) having a strong influence on the types of uses of land in areas for different time periods, with large scale hydro power operating over a long time period, and biofuels a short term. In particular they note the potential for renewable energy to co-exist with other land uses, and that in some areas, "the adaptation of landscapes to renewable energy systems is a return to those which existed previously, in others it is a pathway to systems new to those areas."

Figure 12 shows the proportions of renewable energy consumed in the European Union in 2018 and 2019, and the target for 2020 for each Member State. By 2019, 13 countries had reached their targets for 2020 (Sweden, Finland, Denmark, Croatia, Estonia, Lithuania, Romania, Bulgaria, Greece, Italy, Slovakia, Czechia and Cyprus) up from 11 countries in 2016 (Miller, 2018; COST RELY). Targets are being updated for 2030 to reflect the more rapid transition required to achieve the aim of climate neutrality by 2050. For the EU-27, Eurostat report that in 2018, gross final energy consumption was 18.9% and 19.7% in 2019.

Figure 12. Share of energy from renewables in the European Union for 2018 and 2019, and target for 2020 (source: European Environment Agency, 2021).

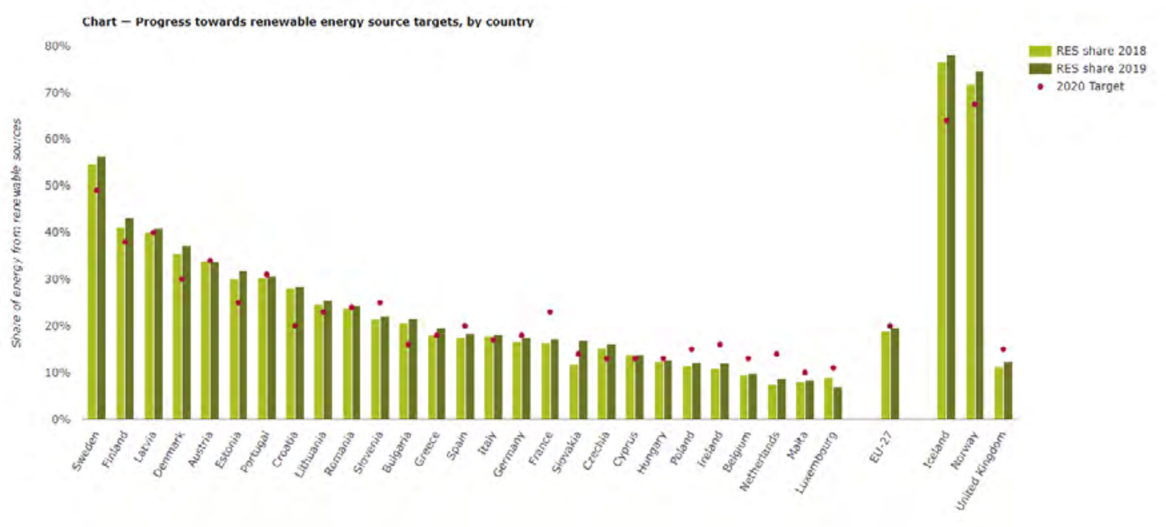
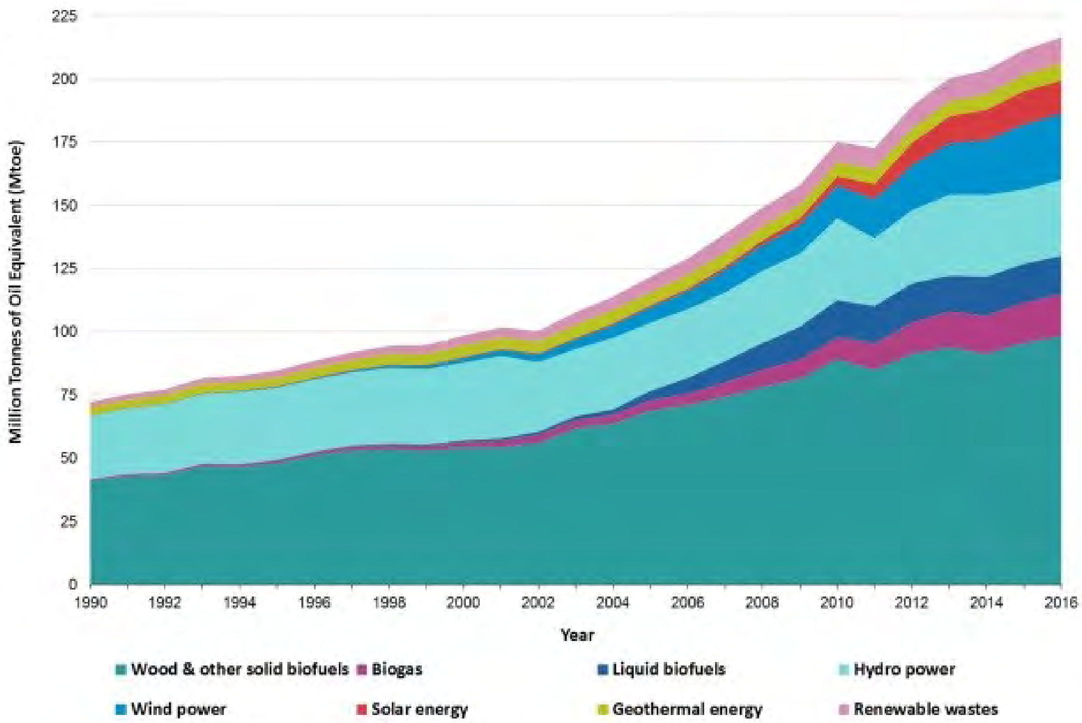


Figure 13 shows the changes in proportion of types of renewable energy to total production between 1990 and 2016. The increase in renewable energy produced reflected the significant contribution of wind energy, from 22.2 TWh in 2011 to 302.9 TWh in 2016; solar increasing from 0.1 TWh in 2000 to 110.8 TWh in 2016); and the doubling of output from wood and solid biofuels (Miller, 2018; COST RELY). The trajectories of production of renewable energy were projected to achieve the targets set for 2030 for renewable energy. However, they are likely to be required to increase in order to achieve the targets of climate neutrality.

Figure 13. Primary production of renewable energy in the EU: 1990 to 2016 (Mtoe) (source: Eurostat, 2018). (Note: indicator discontinued in 2021).



Rural areas can be hotspots of innovation, with evidence of resilience and adaptability in coping with global challenges, and collective processes of envisioning the future, acting as engines of revitalizstion (H2020 RURALIZATION; H2020 RURITAGE). Support for access to knowledge and information, forms a key element in the development of citizen awareness, capabilities and confidence to take responsibilities to tackle climate change and manage environmental services (Górriz-Mifsud *et al.*, 2019; Slee *et al.*, 2020; H2020 SIMRA).

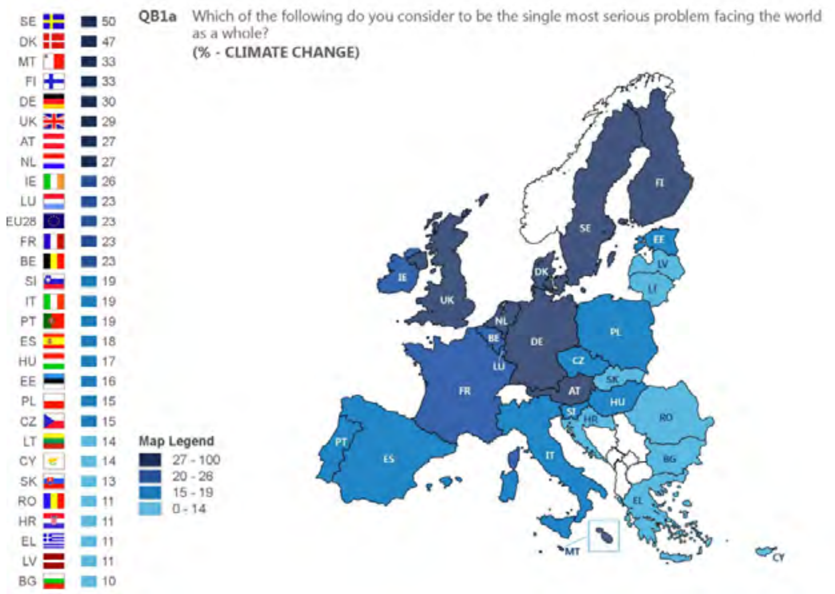
Access to reliable observations of meteorological variables provides data with which citizens can learn more about their local contexts, with the network of meteorological stations in most areas of the world being an early example of citizen science. Currently, access to data can be facilitated through the Copernicus Climate Change Service (C3S) database, as one example of a public source of data which be used to scale climate variables (e.g. used in H2020 DRAGON). For example, in January 2021, the Climate Change Service reported 'Copernicus: 2020 warmest year on record for Europe; globally, 2020 ties with 2016 for warmest year recorded'.

The adoption of services providing information about climate change or environmental variables can be expected to be informed by the attitudes of people towards the principal challenge, of climate change. The Eurobarometer Survey on 'Attitudes of European citizens towards the Environment' (European Commission, 2020b) reports 94% of European population saying that 'protecting the environment is important to them personally', with climate change ranked the most significant problem (76% of respondents).

In response to the question 'How serious a problem do you think climate change is at this moment', 76% of respondents in the EU-27 answered that it was 'A very serious problem' (the same percentage for the EU-28), ranging from 46% in Estonia to 90% in Spain. Ninety six percent of respondents claimed to have taken at least one action to reduce their negative impacts on the environment, with 21% claiming 'many actions (7 to 14)'. The findings suggest a willingness to take action by a considerable majority of people. However, there is no insight as to whether an action is repeated or maintained over a long-term, or the trigger or motivation for such actions.

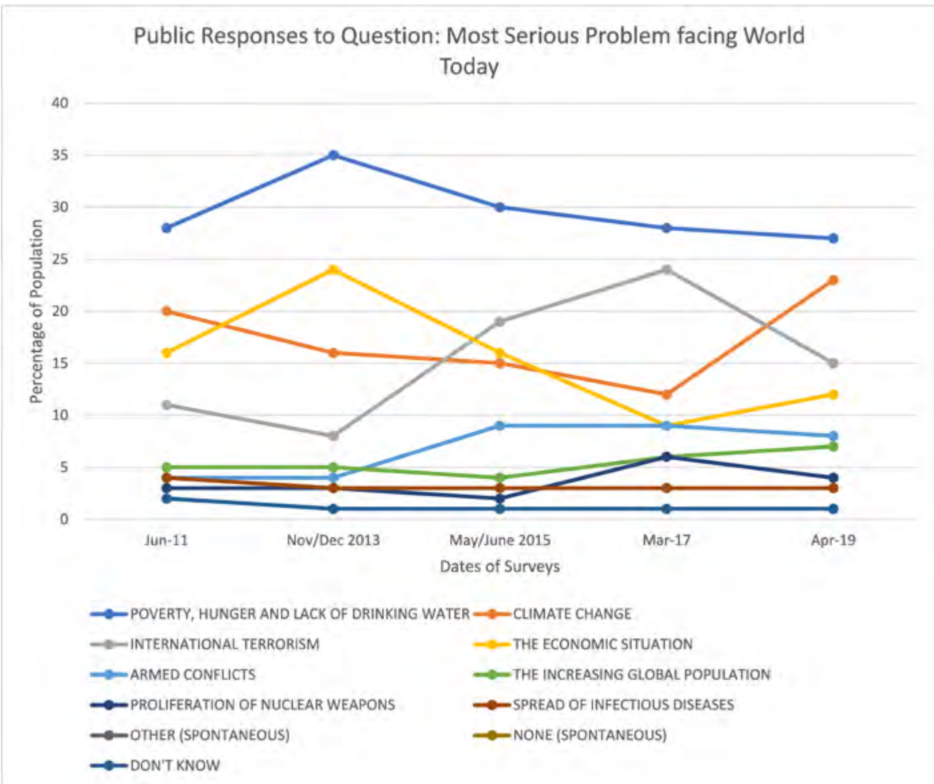
Eurobarometer Survey 490 on Climate Change (European Commission, 2019) reported 23% of people in the EU-28 considered climate change to be the most serious problem facing the world as a whole, in 2019. Between countries, this opinion ranged from 10% in Bulgaria to 50% in Sweden (Figure 14).

Figure 14. Percentage of people, by country, who think that climate change is the most serious problem facing the world as a whole in 2019 (Source: European Commission, 2019).



The attitudes of people in the EU-28 towards climate change as the most serious problem facing the world as a whole have changed through time (2011 to 2019; Figure 15), when comparing that with other problems. When provided with a set of issues, the topic of poverty, hunger and lack of drinking water was consistently scored as the most serious problem, with climate change dropping from 20% in 2011, down to 12% in 2017, but up to 23% in 2019.

Figure 15. Public identification of the most serious problem facing the world as a whole, in 5 surveys from 2011 to 2019 (Source: European Commission, 2019).



4. Interventions supporting mitigation and adaptation to climate change, enhancing associated environmental services

4.1 Adaptation in rural areas

Rural areas are the site of some of the key environmental goods and services that can help mitigate the impacts of, or adapt to, climate change, providing new opportunities for development. As conditions change, so competition for land is likely to arise due to different perspectives and knowledge of what can be undertaken where, and of the types of benefits that may be realised.

While this has prompted awareness of the need to develop appropriate responses at local level, lagging rural areas are hindered by a lower adaptation capacity (Esparcia, 2014; OECD 2018). For example, carbon intensive rural industries (agriculture, mining and energy) are often essential parts of local economies with a low number of alternative employment opportunities. Therefore, phasing out certain industries to decarbonise the economy threatens the livelihood of local people, while introducing carbon prices will increase transport costs for rural households and enterprises which are more reliant on transportation by vehicles (OECD, 2019). As a result, climate change is believed to affect territorial cohesion more adversely in these territories.

Similarly, adaptation aims and approaches are likely to differ from one place to another due to current and historical socio-economic and environmental contexts, and the trend of implementation of adaptation measures. Rural areas are the site of some of the key environmental goods and services that can help mitigate the impact of climate change. These are mainly related to biodiversity, soil, water, renewable energy and climate action (OECD, 2018; OECD, 2019). Adaptation capacity is fostered by the preservation of natural resources, development of green infrastructure and creation of environmental services. As a consequence, environmental policies and innovation can foster job creation in Europe

(European Environment Agency, 2020c). This also means that the resources managed primarily by rural people become more essential. For example, the forestry sector is essential to mitigation of, and adaptation to, climate change. However, a major barrier to the implementation of emergency responses and adaptation measures may be a lack of trained personnel in rural areas (European Environment Agency, 2013).

Nature-based solutions are being adopted as one policy response that delivers multiple benefits of mitigation and adaptation of climate change. The European Commission defines nature-based solutions as "actions which are inspired by, supported by or copied from nature … to turn environmental, social and economic challenges into innovation opportunities" (European Commission, 2015). Such solutions are designed to produce multi-benefits, such as promoting a green economy and addressing societal challenges of human health and well-being, reducing the degradation and loss of natural capital, disaster risk reduction, social cohesion and poverty alleviation (Pauleit *et al.*, 2017; European Commission, 2011).

The delivery of multiple benefits is one of the aims of "investment towards a productive and balanced portfolio of sustainable physical capital, human capital, social capital, intangible capital, and natural capital assets", articulated by Hepburn *et al.* (2020). The argument was developed for planning and implementing a green recovery from COVID-19, with transformational adaptation in support of achieving the Sustainable Development Goals and 'building back better' (United Nations, 2020). Examples of such transformational adaptation are large scale restoration and expansion of natural environments that deliver multiple benefits (e.g. carbon sequestration and storage, enhance biodiversity, landscapes for human health and well-being), and innovations in food production such as indoor farming. In light of the trajectories required to achieve climate neutrality by 2050, the rate of such transformations is likely to have to accelerate.

Maes *et al.* (2020) identify research challenge of interactions between climate and other pressures, the complex nature of the interactions and dynamic feedback which varies in space and time. They note that "adaptation and mitigation measures can also have negative impacts on ecosystems, creating new pressures or exacerbating existing ones". Amongst gaps in knowledge reported are the applicability and efficacy of certain adaptation and mitigation actions, and the associated trade-offs and synergies.

4.2 Land Use and water

Climate change is leading to changes in land management practices in Europe: i) crop suitability and productivity, changes in soil characteristics (e.g. moisture), change in time to access land, impacts of intense rainfall, changes in timing of crop development; ii) mixed livestock systems due to reductions in water availability, possible increases in feed costs, changes in animal appetite and health, increased risk of liver fluke (*Fasciola hepatica*) in livestock. Responding to these types of challenges is likely to lead to changes in products (i.e. it is not possible to grow some products, or raise livestock, in future), changes in regulations, and modifications to requirements on suppliers or supply chain, or changing mechanisms (e.g. transition to all-electric vehicles), and for marketing new products (H2020 UNISECO).

The Eurobarometer (European Commission, 2020c) reported 69% of respondents agreeing with the statement 'EU farmers need to change the way they work in order to fight climate change even if that means that EU agriculture will be less competitive'. From a review of 40 practices, Smith *et al.* (2019; H2020 CIRCASA) explain what land management practices can co-deliver food security, climate change mitigation and adaptation, and combat land degradation and desertification, and where competition may arise.

Agro-ecological approaches to land management, and the use of associated farm practices, can contribute to reducing greenhouse gas emissions, the loss of biodiversity, and increasing compliance with social rights. Findings from research projects (e.g. EU H2020 UNISECO) show that, at the level of farm enterprises, changes in farm practices such as the uptake of organic fertilisers in place of mineral fertilisers, no-till agriculture, can reduce GHG emissions, within the wider context of farming systems (e.g. mixed farming, general cropping). Evidence suggests that the level of reduction in GHG emissions is very context dependent (e.g. local climate, baseline emissions from existing practices). Under particular circumstances reductions of over 50% in GHG emissions can be achieved. Landert *et al.* (2020; H2020 UNISECO), from analysis of case studies across Europe, demonstrate how transitions to agro-ecological farming systems can increase the provision of public goods (e.g. biodiversity, climate stabilisation, soil quality). Such co-benefits from land may require trade-offs in other dimensions such as reductions in farm income, requirements for capital investment. Trade-offs between land as a provider of climate services and land for agriculture are likely to become increasingly relevant as climate impacts worsen.

The adaptation of land management practices offers considerable scope for delivering multiple benefits. Farmers and foresters are stewards of the environment and key actors in adapting to climate change, such as mitigating risks of flooding whilst also increasing biodiversity and habitat networks. However, alongside behavioural change by individuals, there is a need for coordinated behavioural change across sectors in communities of place, and joined-up through time. For example, responses to extreme events such as flooding using nature-based solutions that reduce flood risk, may require changes in attitude of land managers towards the functions of land, in turn reflecting the introduction of new ideas by innovators, encouraging new entrants to land management (farming, forestry, waters), or initiatives taken by communities to buy-out land ownership and take responsibility for measures to protect their properties. Bulkeley (2020) in their review of EU projects relating to nature-based solutions, identified a need to "develop transition pathways for affected sectors and regions that take account of concerns about the loss of livelihoods, employment, social cohesion and cultural ties that may arise through the widespread uptake of nature-based solutions."

In its final report in 2018, the EIP-AGRI Focus Group Grazing for Carbon notes the potential of grasslands as a significant carbon sink in Europe, and the challenge for sustainable grazing livestock systems is finding the "optimum management to combine animal production with the delivery of other ecosystem services like C sequestration." A key aim is to identify how to increase the soil C content in grazing systems. Amongst their recommendations are "Incorporate a holistic view of the grasslands and grazing systems, considering livestock, crops and soil

related issues, to align perceptions between farmers, scientists and policy makers"; and the benefits of recording farm activities or indirect indicators of farm activities that have potential to increase C storage.

Energy availability and pricing affects agriculture, directly through growth of crops for biofuels, and indirectly through requirements for greenhouse crops in northern latitudes. It also has implications for the balance of imported versus locally grown produce, due to the energy cost of transport. In a scenario of energy scarcity, more land would need to be dedicated to local food production, and cultivation of energy intensive greenhouse crops, such as soft fruits, could become inviable.

The European Environment Agency (2020) estimates that in 2018, land-use change and forestry (LULUCF) represented a net carbon sink of approximately 263 Mt CO2e. However, human activities of woodland felling, disturbing carbon rich soils, lead to reductions in this sink. For the period 2021 to 2030, the EU are incorporating land use and forestry into the EU's emission-reduction efforts (for the first time). Public policies, at EU and national levels, to increase forestry cover (e.g. new EU Forestry Strategy), guidelines to limit planting and land use change on peat and carbon rich soils, and the restoration of peatlands, all contribute to protecting and enhancing this carbon sink. These strategies require to be coherent, integrated with planning policies (e.g. spatial planning) at relevant levels of governance.

The planning and changes in land use can be designed to achieve multiple benefits. For example, the final report of the EIP Agri Focus Group Agroforestry (2017) notes the multi-functional nature of agro-forestry as part of a strategy to tackle climate change through both provision of sinks of greenhouse gases and adapting production to one that fits in the changed climate (also, Smith *et al.*, 2014). They note how the different agro-forestry systems contain multiple species that have to act symbiotically with each other and within the farm system. Their dependencies on local contexts enable the creation of place-based systems that contribute cultural and environmental benefits.

Results-based approaches to climate and environment objectives are being tested in various studies. Eichhorn *et al.* (2020; H2020 CONSOLE) report on examples of a Biodiversity Monitor for dairy farming, and an equivalent for arable farming. These use a result-based methodology to measure and reward performance for achieving biodiversity objectives (soil, landscape, environment and climate) on dairy and arable farms in The Netherlands. The results for each farm are expressed as biodiversity-stimulating key performance indicators for use as a basis for new revenue models.

Climate change is very likely to cause changes in habitats and species, with local extinctions and continental-scale shifts in species distributions in Europe (Intergovernmental Panel on Climate Change, 2014b; European Environment Agency, 2020c). It is leading to changes in the seasonality of biological events, such as flowering of plants or hatching of birds (European Environment Agency, 2020c). In Southern Europe, the provision of ecosystem services is projected to decline across all service categories (Intergovernmental Panel on Climate Change, 2014b), and in Alpine areas the habitats of plants will be pressurised and reduced significantly.

Fresh water is a critical ingredient for life, the management of which should be a key element in strategies for adapting to climate change. The resilience of fresh water quality and quantity is critical for rural communities, urban environments, farming, energy systems and industry. Fluctuations in the patterns of precipitation will place pressure on groundwater resources. The timing of the use of resources can exacerbate problems. For example, the timing of irrigation required to ensure the production of one crop can coincide with low water levels in conventional water resources (e.g. for irrigating corn, France). Changes in the requirements of consumers, use of land, or policy responses are required to address competing priorities. In relation to water, a prospectively valuable option for adaptation strategies is to increase its reclamation and reusing industrial effluent (e.g. treated wastewater) in agriculture (H2020 MAGIC, Policy Brief on reclaimed water for agriculture).

Land uses in Europe should not be the only consideration when making transitions to climate neutrality. Severe climate impacts elsewhere in the world are expected to result in increased population migration, which would be increasingly focused on temperate zones as other parts of the world become less habitable. The imports and exports of goods and services to and from the EU to other areas of the world mean that the environmental, economic and social influences are global.

4.3 Social innovation and partnerships

Social innovation enables citizen-led groups to get purposefully engaged in tackling societal challenges of climate change and reversing loss of biodiversity, filling a gap where markets or policy have failed. Polman *et al.* (2017; H2020 SIMRA) defined social innovation as "the reconfiguring of social practices, in response to societal challenges, which seeks to enhance outcomes on societal well-being and necessarily includes the engagement of civil society actors." So, community responses to climate change can lead to the emergence of new practices, new networks and new governance arrangements, some formal (e.g. Community Trusts) and others informal (e.g. local volunteer groups), for example in forest environments (Nijnik *et al.*, 2019; H2020 SIMRA).

A workshop run by ENRD on LEADER and Climate Action (Brussels, December 2019) profiled the example of the Suderbynis ecovillage on the island of Gotland Sweden, which refers to itself as a "social laboratory", with examples of implementation of climate mitigation, and low energy buildings. However, the complexity of applying for funding (e.g. LEADER) creates significant challenges for communities which have restricted access to relevant expertise (Slee *et al.*, 2020; H2020 SIMRA).

Tackling challenges as significant as climate change requires a breadth of perspectives and knowledge, to understand the issues (e.g. resources, threats, consequences), and the relevance of place and the evolution of environments, people and lifestyles. Transdisciplinary approaches, with support for developing of human capital and social capital, and with the strong civic engagement of local actors, can transform ideas into actions. Ravazzoli *et al.* (2021; H2020 SIMRA) provide evidence from 11 Social Innovations of triggers and reconfigurations of governance by civil society, and how socially motivated responses to failures of markets and State, led to social innovations, some explicitly aimed at environmental conservation and climate mitigation actions, and others with indirect environmental benefits (e.g. forest and land restoration, sustainable tourism, provision of social services, etc.). For change to have longevity it requires social support and acceptance. Community-centred decision-making is consistent with democratic governance, with the potential to bring together a multitude of experiences, creation of shared objectives and in due course more robust stewardship.

Economic changes arising due to climate change can be expected to influence the feasibility, and incentive to adapt and the nature of transitions to climate-neutrality. Changes in commodity prices due to climate change will affect the costs of raw materials. Farmers, for example, can benefit from diversifying the commodities they produce and their sources of income (e.g. through on-farm diversification activities). However, income stabilisation and risk management strategies are important components in planning diversification.

The transition to renewable or fossil free energy will be required to accelerate if the target of climate neutrality is to be achieved by 2050. EU production of hard coal in 2019 was 65 million tonnes, down by 77% from the figure in 1990 of 277 million tonnes. Transitions to a climate neutral continent will require move away from fossil fuels, leaving communities in some areas exposed to the loss of core sectors of employments. Such a transition requires engaging with communities of interest and place to understand of the potential impacts on rural areas, the opportunities which could be encouraged, and the barriers to overcome. In line with this, the H2020 TRACER project aims to support coal-intensive regions around Europe 'to design (or re-design) their Research and Innovation strategies' to facilitate transitions towards sustainable energy systems. They ran an event on challenges for a Just Transition to life after coal, in the Jiu Valley, Romania. Subject included visions of a carbon-neutral economy, labour and social issues, and green skills. Examples of approaches to transitions in coal-intensive regions are accessible from their best practice platform.

To encourage and support changes in behaviours is likely to require multiple channels of communication and action. All insights to understanding cultures offer benefits of understanding and insights to how climate change can be tackled. Observation and measurement provide formal records of change, contributing to the evidence base to inform actions. Peer-to-peer learning and on-the-ground demonstration of practices provides effective approaches to communicating knowledge to land managers (H2020 AGRIDEMO; H2020 PLAID). Scientific evidence and on-farm demonstration provide valuable sources of knowledge exchange, but other forms of documenting change and conveying knowledge and traditions through generations can lead to overcoming barriers of culture and mindset, such as towards land uses and practices (e.g. renewable energy, digital tools, land management practices). Such approaches can include insights from literature, music, performing art and humanities.

To plan and tackle transitions to climate-neutral and managing impacts on environmental services requires access to contemporary knowledge. Such knowledge must also be accessible to actors in managing assets of land and waters, and social and economic infrastructure in rural areas. Effective means of sharing knowledge and building capabilities through the development of green skills, is one element of creating new opportunities for economic development, and are priorities for enabling the modernisation of infrastructure, economic recovery and growth.

Transdisciplinary approaches appear to offer considerable benefits for facilitating action on the ground through deploying mechanisms for partnership working and co-learning. Evidence from FP7 SOLINSA (Moschitz *et al.*, 2014) shows approaches to improved access through Learning and Innovation Networks for Sustainable Agriculture (LINSA). They showed how LINSAs operate at the boundaries of policy, society, business and research in which networks of producers, consumers, experts, NGOs, SMEs, local administrations, researchers and extension services work towards identifying common goals (with this project focusing on sustainable agriculture and rural development). They identify the emergence of transition partners as new kind of actors, with particular roles and functions, and strengthening of roles of AKIS with LINSAs.

4.4 Food and diet

Tackling red meat production and consumption could make a meaningful contribution towards reducing greenhouse gas emissions. A multi-strand approach would be to reducing cattle numbers, decarbonising the beef and dairy industries, and changing consumer preferences and diets.

Theurl *et al.* (2019) (H2020 UNISECO) indicate that diets and the composition and quantity of livestock feed, not crop yields, are the strongest determinants of GHG emissions from food-systems when existing forests are to be protected. Approaches to decarbonising the beef industry include the development of a wearable device (a nose ring for cattle) to capture and convert up to 90% of methane from animals and oxidises it into CO2, in the H2020 ZELP project. Initial assessments of the approach show 53% reductions in methane, and that economically the service could generate £3.56m cumulated revenue, more than £2.9m gross profit and more than £2.1m net income by 2029.

Innovation in products shows promising results for alternatives to red meat in human diets. For example, an analysis of environmental footprints of cooked protein balls made from peas (Pisum sativum), and Swedish-style beef meatballs made from Irish or Brazilian beef showed reductions in acidification (35%), climate change (38%), and land use (46%). When the density of nutrients is taken into account, the figure are acidification (89%), climate change (87%), and land use (93%) (Sageta *et al.* 2021; H2020 TRUE). When the carbon opportunity cost of land was considered, in a scenario of 5% of German beef consumption replaced by protein balls, a saving of approximately 8 million tonnes CO2e annually could be achieved, equal to 1% of Germany's annual GHG emissions.

H2020 TRUE project also studied options for transitions to increased sustainable legume cultivation and consumption across Europe, across pedo-climatic zones and farm network types. Lienhardt *et al.* (2019) report on benefits accruing from the use of a leguminous crop, pea (Pisum sativum L.), as a source of starch for alcohol (gin) production compared to wheat-gin. Co-products from the production of 1 litre of pea-gin could substitute up to 0.66 kg soybean animal feed and mitigating the associated greenhouse gas emissions (2.2 kg CO2 eq, for each litre of bottled pea gin). Their Life Cycle Analysis showed reduced footprints of global warming (12%), resource depletion (15%), human toxicity (15%), acidification (48%) and terrestrial eutrophication (68%), traded-off with 112% more land area required for crops for pea-gin versus wheat-gin.

Further innovation can come from developing the local provision of food and associated supply chains benefits from sharing knowledge. The GROW Observatory approach (H2020 GROW) provides mechanisms for 'empowering farmers and food-growing communities to improve the quality of soils using sensors, an app and satellite data.' It has provided guidance for communities to aid them in the cultivation of produce.

Such approaches can also motivate social integration, innovation and community resilience. For example, innovative approaches are also being taken to communicate messages about food and diet to public audiences. For example, the Creative Food Cycles project used digital technologies and creative performances to explore phases of Production to distribution, Distribution to consumption, and Consumption to disposition, in three areas of Europe. Consideration of local and regional food processes of food cycles explored a circular economy approach to considering urban-rural interfaces, food nodes, food networks and food structures, with a view to developing new ideas for stewardship of territories.

H2020 RURITAGE project reports how creative arts can contribute to revitalising rural territories, using participative projects and storytelling as means to 'understand the environment, foster awareness on the relation among landscape, hazards and man's interventions.'

4.5 Business and finance

Robins *et al.*, (2018) outline the challenges of transitions for workers, communities and countries, and for investors of understanding systemic risks from climate change, reinvigorating fiduciary duty, recognising material value drivers, uncovering investment opportunities, and contributing to societal goals.' Addressing these challenges requires the linking of strategic pathways that take account of food and land systems in rural areas, across and between business sectors, and between production and consumption.

Emerging opportunities of the multiple uses of land include the development of agri-renewables and the evolution of farming systems in line with the principles of a circular economy. Adaptive behaviours include new opportunities for businesses built around "Eco-design" and the circular economy focusing on new products designed with aims of remanufacturing, re-purposing or recycling. This would place a greater emphasis on the recovery of "critical raw materials". The transition is one trigger for innovation in products, such as the development of 100% biodegradable materials used in ways that can have multi-benefits (e.g. Spawnfoam, producing pots in which plants or trees are planted in the soil with the pot, used with natural fertilizers; Colmorgen and Khawaja, 2019; H2020 BE-Rural).

Innovation in land management can be realised through developing carbon positive businesses and multi-functional land use (e.g. demonstrated at Glensaugh Carbon Positive Farm, UK; H2020 UNISECO), at which innovative uses of resources to raise co-financing can be explored (Vivid Economics and Environmental Finance, 2018). Approaches to raising funds to finance or re-finance green projects or assets include debt instruments such as green bonds (International Capital Markets Association, 2018). In its study of green bonds, the H2020 MAGIC project report their value as of 2019 of $US 257.7bn, up from $US37bn in 2014. They conclude that such bonds can provide positive environmental impacts but require to be accompanied by complementary policies on either the demand or the supply side, with an effective governance regime that ensures the legitimacy of the allocation of the proceeds (MAGIC, 2020).

H2020 CONSOLE project (Eichhorn *et al.*, 2020) is testing the operation and uptake by consumers and businesses of offsetting their carbon footprint through donations for restoring ditched peatlands. The 'Carbon Market' (Hiilipörssi, Finland) is an online donation service, funds raised from which provide capital for restoration actions, in which the 'landowner commits to leave the peatland untouched and transform it into private protection before the restoration begins.'

Business of all sizes, micro- to multi-national, and private and public sector, have roles in achieving net-zero climate targets. In March 2020 the European Commission adopted a circular economy action plan (European Commission, 2020d). This sets out a plan for a sustainable product policy legislative initiative, to make products fit for a climate-neutral, resource-efficient and circular economy, establishing sustainability principles and appropriate means of regulation where appropriate. Noting that the purchasing power of public authorities represents 14% of EU GDP and as such public procurement is a 'powerful driver of the demand for sustainable products.' In line with this it proposes 'minimum mandatory green public procurement (GPP) criteria and targets in sectoral legislation and phase in compulsory reporting to monitor the uptake of Green Public Procurement.'

4.6 Open science

International responses to global shocks such as COVID-19 have benefited from Open Science through the free flow of research data and ideas accelerating research to combat the disease and in recovering from its impacts. As explained by OECD (2020) in its report on Why open science is critical to combatting COVID-19, Open Science requires sustainable infrastructures, human and institutional capabilities, and mechanisms sharing data across borders and between the public and private sectors, civil society, and researchers.

Encouraging the participation of citizens provides one option for democratising the tackling of climate change, and potentially broadening the uptake of climate actions and thus the prospects of achieving the targets of net-zero by mid-century. However, involving citizens in co-constructing agendas for tackling climate change requires understanding of the relevant institutions and processes of governance (e.g. Churski *et al.*, 2019; H2020 TERIFFICA).

The EU Climate Pact, with its emphasis on connecting and sharing knowledge, learning about climate change, and developing, implementing and scaling-up solutions, delivers on the principles of Open Science, of: i) maintaining and promoting good practice and scientific rigour, and maximising access to robustly described data and methods that underpin scientific conclusions; ii) maximising access to scientific knowledge and reuse and combination of data and software, to maximize common good from public investment in science and its infrastructures; and iii) maximising engagement and participation of all people and cultures in the scientific process to foster its democratisation and increase societal impact of scientific activities for common good.

The EU Open Science Cloud and Portal provides tools, evidence and data for use by practitioners in land management, business or rural development for creating operational and instrumental impacts, capacity building, and developing support and peer networks. In knowledge intensive arenas such as agro-ecology, the open science approach can contribute to motivating and empowering rural actors to develop shared visions for local areas, monitored and informed through citizen science (e.g. observation, interpretation, and informed and timely actions) (Schultz *et al.*, 2018; H2020 LANDSENSE).

Access to earth observation technologies provides another means of measurement and monitoring of changes in biodiversity and climate over time (e.g. Sentinel satellite missions). This has increasing potential for monitoring in near real time as an input to early warning and tackling environmental emergencies such as wildfires and flooding, by public, private and third sectors (Safar *et al.*, 2020; EO4AGRI.eu).

Transdisciplinary partnerships, using Open Science approaches, provide one means of fostering closer links between society, practice, policy and research, which can form part of the approaches to tackling societal challenges. The multi-actor approach (Slatmo *et al.*, 2020) provides one model of co-constructing solutions through knowledge exchange, operationalising Articles 2 of the 8th EU Environment Action Programme which seeks involvement of "citizens, social partners and other stakeholders, and encouraging cooperation in the development and implementation of strategies, policies or legislation related to the 8th Environment Action Programme amongst national, regional and local authorities, in urban and rural areas."

5. Conclusions

Approaches to agreeing pathways to achieving net-zero GHG emissions by mid-century have global support and commitments. Ambitious policy aims have been set to achieve climate neutrality of Europe by 2050. This would require alignment of the plans of Member States on their delivery to the Paris Agreement on climate change, and actions informed by the 5-yearly stocktakes. Evidence from modelling show the magnitude of changes in rates of emissions required to achieve those aims.

In turn that requires significant changes in use of resources, production, management of natural resources, ways of working and lifestyles, and the importance of ensuring transitions are consistent with principles of social rights. Contributions to all aspects of those changes will be made by rural areas. That reflects the significance of managing natural resources in strategies to sequester CO2, and the necessity of adapting to the effects of climate change.

The Horizon Europe Climate Mission calls for science to support communities in building their capacities to imagine and shape innovative future pathways. This is especially needed in rural areas across Europe, which face marginalisation, depopulation and increased vulnerability to climate change.

Research findings have identified opportunities, for new types of business, products, careers, roles of environmental features, and of understanding systems in which ways of life interact with wider environmental contexts. They also identify consequences of climate change, destroying, degrading or threatening the world's environmental assets, and the ecosystem services they deliver, and leading to change over short, medium and longer time periods. Recognition of the significance of these changes to society and the environment has become more widespread, with hierarchies of linked policies for mitigating or adapting to climate change at global, European, national, regional and local levels.

Climate change affects all aspects of life on earth. This Discussion paper does not cover all factors that could influence living, working or visiting rural areas, or the natural and cultural assets located therein. The SHERPA process provides opportunities to gather evidence from across Europe, at multiple levels, as to the: i) types of transitions required to achieve climate neutrality in the context of the MAPs; ii) how can policy interventions enable or facilitate these transitions, considering the solutions needed at local and national levels, and the related implications for the wider policy framework (EU and global), as well as the research needs and gaps.

6. Acknowledgements

SHERPA acknowledges the organisations, authors and projects which provide sources of data and information, cited below. SHERPA is funded from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 862448.

References

Black, R., Cullen, K., Fay, B., Hale, T., Lang, J., Mahmood, S. and Smith, S.M. 2021. Taking Stock: A global assessment of net zero targets, Energy & Climate Intelligence Unit and Oxford Net Zero. pp.30.

Bulkeley, H. 2020. Nature-based Solutions for climate mitigation: Analysis of EU-funded projects. Report to European Commission. pp.34.

Chartier, O., Salle, E., Irvine, K., Kull, M., Miller, D., Nieto, E., Vestergård, L.O., Potters, J. and Slätmo, E., Zomer, B., Iadecola, F. 2021. Long-Term Vision for Rural Areas: Contribution from SHERPA science-society-policy platforms. SHERPA Position Paper. DOI: 10.5281/zenodo.4557440

Churski, P., Fagiewicz, K., Herodowicz, T., Lupa, P., Mizgajski, A. and Morawska-Jancelewicz, J. 2019. Report on institutional framework conditions, relevant local and regional processes, instruments and co-creation factors related to or adaptable for climate action., D3.3 H2020 TERIFFICA, pp.60.

Colmorgen, F. and Khawaja, C. 2019. Small-scale technology options for regional bioeconomies, Bio-based strategies and roadmaps for enhanced rural and regional development in the EU. pp. 57. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c7d25750&appId=PPGMS

Council of Europe 2000. European Landscape Convention. pp7.

Convention on Biological Diversity 2020. Ecosystem Approach, accessed at www.cbd.int/ecosystem/

de Jong, R., Edens, B., van Leeuwen, N., Schenau, S., Remme, R. and Hein, L. 2016. Ecosystem Accounting Limburg Province, The Netherlands, Wageningen University and Statistics Netherlands (CBS). pp26.

Diamond, R. and Willan, J. 2020. Coronavirus disease 2019: Achieving good mental health during social isolation. *The British Journal of Psychiatry*, 217(2), 408-409. doi:10.1192/bjp.2020.91

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Hill, R., Chan, K.M.A., Baste, I.A., Brauman, K.A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P.W., van Oudenhoven, A.P.E. van der Plaat, F., Schröter, M., Lavorel, S., Aumeeruddy-Thomas, Y., Bukvareva, E., Davies, K., Demissew, S., Erpul, G., Failler, P., Guerra, C.A., Hewitt, C.L., Keune, H., Lindley, S. and Shirayama, Y. 2018. Assessing nature's contributions to people. Science 359 (6373), 270-272. DOI: 10.1126/science.aap8826

Eichhorn, T. *et al.*, 2020. Report on WP2 lessons learned, Deliverable D2.2, CONtract SOLutions for Effective and lasting delivery of agri-environmental-climate public goods by EU agriculture and forestry (CONSOLE), pp. 69.

EIP-AGRI Focus Group Agroforestry: introducing woody vegetation into specialised crop and livestock systems 2017. Final Report to European Commission, pp32.

EIP Agri Focus Group Grazing for Carbon 2018. Final Report to the European Commission, pp32.

EIP-AGRI Focus Group on Forest practices and climate change 2019. Final Report to the European Commission, pp36.

ESPON (2020). Sustainable development and climate change resilience: ESPON evidence. Topic Paper. Retrieved from: www.espon.eu/sites/default/files/attachments/Topic%20paper%20-%20Sustainable%20development%20and%20climate%20change%20resilience.pdf

Esparcia, J. 2014. Innovation and networks in rural areas. An analysis from European innovative projects. *Journal of Rural Studies*, 34, 1–14. https://doi.org/10.1016/J.JRURSTUD.2013.12.004

European Commission 2011. Our Natural Capital: An EU Biodiversity Strategy to 2020.

European Commission 2013. Communication from the Commission to The European Parliament, The Council, The Economic and Social Committee and The Committee of The Regions: Our Life Insurance, Our Natural Capital: An EU Biodiversity Strategy To 2020. European Commission, pp. 24.

European Commission 2015. Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities: Final Report of the Horizon 2020 Expert Group on Nature-based Solutions and Re-naturing Cities.

European Commission 2019a. The European Green Deal. Communication from The Commission to The European Parliament, The European Council, The Council, The European Economic and Social Committee and The Committee of The Regions. European Commission. pp24.

European Commission 2019b. Natural Capital Accounting: Overview and Progress in the European Union, 6th Report, Final. European Commission, pp80.

European Commission 2020a. Sustainable Europe Investment Plan and European Green Deal Investment Plan. Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions, pp. 25.

European Commission 2020b. Working with Parliament and Council to make the CAP reform fit for the European Green Deal. European Commission, November 2020, pp9.

European Commission 2020c. Attitudes of European citizens towards the Environment DG ENV. pp.164

European Commission 2020d. Circular Economy Action Plan: For a cleaner and more competitive Europe. European Commission, pp. 283.

European Environment Agency 2013. *Adaptation in Europe. Addressing risks and opportunities from climate change in the context of socio-economic developments*, EEA report n°3/2013

European Environment Agency 2020a. Climate Change: Driving Forces, European Environment Agency.

European Environment Agency 2020b. Climate change impacts in Europe. Retrieved from:www.eea.europa.eu/highlights/why-does-europe-need-to/climatechangeimpactineurope.pdf/view

European Environment Agency 2020c. State of the Environment Report (SOER) 2020. Retrieved from: www.eea.europa.eu/soer/2020

Ferreira, I., Kirova, M., Montanari, F., Montfort, C., Moroni, J., Neirynck, R., Pesce, Arcos Pujades, A., Lopez Montesinos, E, Pelayo, E., Diogo Albuquerque, J., Eldridge, J., Traon, D. 2019. Research for AGRI Committee – Megatrends in the agri-food sector, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels.

Górriz-Mifsud E, Burns M, Marini Govigli V. 2019. Civil society engaged in wildfires: Mediterranean forest fire volunteer groupings. *Forest Policy and Economics* 102:119-129.

Gunderson, L.H. and Holling, C.S. 2002. P*anarchy: understanding transformations in human and natural systems*. Island Press, Washington, D.C., USA

Guizzardi, D., Muntean, M., Schaaf, E., Lo Vullo, E., Solazzo, E., Monforti-Ferrario, F., Olivier, J. and Vignati, E. 2019. EDGAR v5.0 Greenhouse Gas Emissions. European Commission, Joint Research Centre (JRC). http://data.europa.eu/89h/488dc3de-f072-4810-ab83-47185158ce2a [Accessed September 1, 2020]

Hanna, R., Xu, Y. and Victor, D. 2020. After COVID-19, green investment must deliver jobs to get political traction. *Nature* 582, 178-180 (2020) doi: 10.1038/d41586-020-01682-1

Hepburn, C., O'Callaghan, B., Stern, N., Stiglitz, J., and Zenghelis, D. 2020. 'Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change?', Smith School Working Paper 20-02.

Hagyo, A., Barredo, J.I., Czúcz, B., Caudullo, G., Ceglar, A., Spinoni, J., Cammalleri, C. and Paracchini, M.L. (2020), Climate Change. In: Maes *et al.*, Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment, Chapter 4.1. EUR 30161 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17833-0 (online), 978-92-76-22954-4 (supplement), doi:10.2760/757183 (online),10.2760/519233 (supplement), JRC120383: 277-298.

International Capital Markets Association 2018. Green and Social Bonds: A High-Level Mapping to the Sustainable Development Goals (June), pp8.

Intergovernmental Panel on Climate Change 2014a. AR5 Climate Change 2014: Impacts, Adaptation, and Vulnerability. Region Aspects. Chapter 23: Europe. Retrieved from: www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap23_FINAL.pdf

Intergovernmental Panel on Climate Change 2014b. AR5 Climate Change 2014: Impacts, Adaptation, and Vulnerability. Human Settlements, Industry, and Infrastructure. Chapter 8: Urban Areas. Retrieved from: www.ipcc.ch/report/ar5/wg2/

Intergovernmental Panel on Climate Change 2018. Special Report: Global warming of 1.5C. Retrieved from www.ipcc.ch/sr15/

IPBES 2018. The IPBES assessment report on land degradation and restoration. Montanarella, L., Scholes, R. and Brainich, A. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. pp744. https://doi.org/10.5281/zenodo.3237392

IPBES 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. 56 pages. https://doi.org/10.5281/zenodo.3553579

Keramidas, K., Fosse, F., Diaz Vazquez, A., Schade, B., Tchung-Ming, S., Weitzel, M., Vandyck, T. and Wojtowicz, K. 2021. Global Energy and Climate Outlook 2020. A New Normal Beyond Covid-19, EUR 30558 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-28417-8 (online), doi:10.2760/608429 (online), JRC123203.

Landert, J., Pfeifer, C., Carolus, J., Schwarz, G., Albanito, F., Muller, A., Smith, P., Sanders, J., Schader, C., Vanni, F., Prazan, J., Baumgart,L., Blockeel, J., Weisshaidinger, R., Bartel-Kratochvil, R., Hollaus, A., Mayer, A., Hrabalova, A., Helin, J., Aakkula, J., Svels, K., Guisepelli, E., Smyrniotopoulou, A., Vlahos, G., Iordanidis, Y., Szilagyi, A., Podmaniczky, L., Balazs, K., Galioto, F., Longhitano, D., Rossignolo, L., Povellato, A., Zilans, A., Jegelevicius, G., Fratila, M., Yoldi, U.I., Massa, C., Adrian, J.B., Sahlin, K.R., Roos, E., Frick, R., Bircher, R., Aalders, I.H., Irvine, K.N., Kyle, C. and Miller, D.R. 2020. Assessing agro-ecological practices using a combination of three sustainability assessment tools, *Landbauforschung Journal of Sustainable Organic Agricultural Systems*, 70, 129-144.

Lienhardt, T., Black, K., Saget, S., Porto Costa, M., Chadwick, D., Rees, R., Williams, M., Spillane, C., Iannetta, P., Walker, G. and Styles, D. 2019. Just the tonic! Legume biorefining for alcohol has the potential to reduce Europe's protein deficit and mitigate climate change, *Environment International,* 130, September 2019, 104870. https://doi.org/10.1016/j.envint.2019.05.064

Maes, J., Teller, A., Erhard, M., Conde, S., Vallecillo Rodriguez, S., Barredo Cano, J.I., Paracchini, M., Abdul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Marin, A., Ivits, E., Mauri, A., Rega, C., Czucz, B., Ceccherini, G., Pisoni, E., Ceglar, A., De Palma, P., Cerrani, I., Meroni, M., Caudullo, G., Lugato, E., Vogt, J., Spinoni, J., Cammalleri, C., Bastrup-Birk, A., San-Miguel-Ayanz, J., San Román, S., Kristensen, P., Christiansen, T., Zal, N., De Roo, A., De Jesus Cardoso, A., Pistocchi, A., Del Barrio Alvarellos, I., Tsiamis, K., Gervasini, E., Deriu, I., La Notte, A., Abad Viñas, R., Vizzarri, M., Camia, A., Robert, N., Kakoulaki, G., Garcia Bendito, E., Panagos, P., Ballabio, C., Scarpa, S., Montanarella, L., Orgiazzi, A., Fernandez Ugalde, O. and Santos-Martín, F. 2020. Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment, EUR 30161 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17833-0 (online),978-92-76-22954-4 (supplement), doi:10.2760/757183 (online),10.2760/519233 (supplement), JRC120383. pp. 452.

H2020 MAGIC 2018. Reclaimed Water for agriculture. The case of the Canary Islands. Is it possible to cover the demand for irrigation by water reuse? Policy Brief, July 2020. Moving Towards Adaptive Governance in Complexity: Informing Nexus Security H2020 MAGIC Project pp2.

H2020 MAGIC 2020. Green Bonds: A Sustainable Finance Silver Bullet? Policy Brief, July 2020. Moving Towards Adaptive Governance in Complexity: Informing Nexus Security H2020 MAGIC Project pp2.

Millennium Ecosystem Assessment 2005. A Framework for Assessment, pp25. (https://www.millenniumassessment.org/en/Framework.html)

Miller, D.R. 2018. Transformations in European landscapes: towards 2030 targets., In: Roth, M., Eiter, S., Rohner, S., Kruse, A., Schmitz, S., Frantal, B., Centeri, C., Frolova, M., Buchecker, M., Stober, D., Karan, I., van der Horst, D. (eds.). Renewable Energy and Landscape Quality, COST Action RELY TU 1401, JOVIS, Chapter 5.1, pp214-225.

Miller, D.R., Kruse, A. and Roth, M. 2018. Adaptive management strategies for renewable energy landscapes., In: Roth, M., Eiter, S., Rohner, S., Kruse, A., Schmitz, S., Frantal, B., Centeri, C., Frolova, M., Buchecker, M., Stober, D., Karan, I. and van der Horst, D. (eds.). Renewable Energy and Landscape Quality, COST Action RELY TU 1401, JOVIS, Chapter 5.2, pp226-235.

Miller, D.R., Thomson, J., Barron, S., Bate, B., Brooks, S., Campbell, G., Crofts, R., Dawson, L.A., Hawkins, M., Hearns, D., Hughes. R., McFarlane, A., Pretence, P., Rankine, D., Thomson, L., Wade, R., Younie, S. and Saunders, G. 2020. Position statement on landscape, land use and economy, September 2020., Scotland's Alliance - Working Group 3 Report, September 2020, 17pp.

Moschitz, H. *et al.*, 2014. Agricultural Knowledge Systems in Transition: Towards a more effective and efficient support of Learning and Innovation Networks for Sustainable Agriculture. Final Report. FP7 SOLINSA. pp.47.

Nijnik, M., Secco, L., Miller, D.R. and Melnykovych, M. 2019. Can social innovation make a difference to forest-dependent communities?, *Forest Policy and Economics*, 100, 207-213.

OECD, 2001. Glossary of Statistical Terms. https://stats.oecd.org/glossary/detail.asp?ID=843

OECD, 2018. Rural Policy 3.0. A framework for Rural Development. OECD. www.oecd.org/cfe/regional-policy/Rural-3.0-Policy-Note.pdf

OECD, 2019. Rural Policy 3.0. People-Centred Rural Policy. www.oecd.org/rural/rural-development-conference/documents/Rural-3.0-Policy-Highlights.pdf

OECD, 2020. Why open science is critical to combatting COVID-19, OECD, pp5.

Pauleit, S., Hansen, R., Lorance Rall, E., Zölch, T., Andersson, E., Catarina Luz, A., Szaraz, L., Tosics, I. And Vierikko, K. 2017. Urban landscapes and green infrastructure. In: Environment and Human Health, Management and Planning. Oxford Research Encyclopedia of Environmental Science DOI: 10.1093/acrefore/9780199389414.013.23

Plieninger, T., van der Horst, D., Schleyer, C. and Bieling, C. 2014. Sustaining ecosystem services in cultural landscapes. *Ecology and Society* 19(2): 59. http://dx.doi.org/10.5751/ES-06159-190259

Polman, N., Slee, B., Kluvánková, T., Dijkshoorn, M., Nijnik, M., Gezik, V. and Soma, K. 2017. Classification of Social Innovations for Marginalized Rural Areas, D2.1. Social Innovations in

Marginalized Rural Areas (SIMRA), Report to European Commission. pp32.

Poore, J. and Nemecek, T. 2018. Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), 987-992.

Ravazzoli, E., Dalla Torre, C., Da Re, R., Govigli, V.M., Secco, L., Gorriz-Mifsud, E., Pisani, E., Barlagne, C., Baselice, A., Bengoumi, M., Dijkshoorn-Dekker, M., Labidi, A., Lopolito, A., Melnykovych, M., Perlik, M., Polman, N., Sarkki, S., Perlik, M., Polman, N., Vassilopoulos, A., Koundouri, P., Miller, D.R., Streifeneder, T. and Nijnik, M. 2021 Can social innovation make a change in European and Mediterranean marginalized areas? Social innovation impact assessment in agriculture, fisheries, forestry and rural development., *Sustainability*, 13, Article No. 1823.

Robins, N., Brunsting, V. and Wood, D. 2018. Climate change and the just transition: A guide for investor action. Report by The Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science. pp. 32.

Roth, M. *et al.*, 2018. "Renewable Energy and Landscape Quality". EU COST ACTION RELY (Renewable Energy and Landscape Quality), pp96. ISBN 978-3-86859-524-6

Safar, V., Kubickova, H., Krivanek, A., Krivankova, K., Kvapil, J., Kozhukh, D., Kepka Vichrova, M., Cerbova, K., Charvat, K., Horakova, S., Druml, S., Mayer, W., Mayer, S., Mildorf, T., Lilja Bye, B., Ángel. M. 2020. D6.6 Strategic Research Agenda Report. EO4AGRI.eu https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5d5d627b5&appId=PPGMS

Sageta, S., Costa, M., Sancho Santos, C., Vasconcelos, M.W., Gibbons, J., Styles, D. and Williams, M., 2021. Substitution of beef with pea protein reduces the environmental footprint of meat balls whilst supporting health and climate stabilisation goals. Journal of Cleaner Production, 297, 126447. https://doi.org/10.1016/j.jclepro.2021.126447

Slatmo, E., Oliveira e Costa, S. and Qvist Eliasen, S. 2019. Methods for setting-up of MAPs. D5.1 SHERPA. Report to the European Commission. pp.28.

Slee, B., Miller, D., Weiß, G., Ludvig, A., Zivojinovic, I. and Lukesch, R. 2020. Practice Guide 1: Social Innovation for Policy Target Groups, Deliverable D6.3, Social Innovation in Marginalised Rural Areas. Report to the European Commission. pp. 26.

Smith, P., Gregory, P.J., van Vuuren, D. Obersteiner, M., Havlik, P., Rounsevell, M., Woods, J., Stehfest, E., and Bellarby, J. 2010. Competition for land. *Philosophical Transactions of the Royal Society B,* 365(1554), 2941-2957. Retrieved from: https://royalsocietypublishing.org/doi/10.1098/rstb.2010.0127

Smith, P., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E.A. Haberl, H., Harper, R., House, J., Jafari, M., Masera, O., Mbow, C., Ravindranath, N.H., Rice, C.W., Robledo Abad, C., Romanovskaya, A., Sperling, F., and Tubiello, eds. 2014. Agriculture, Forestry and Other Land Use (AFOLU). Edited by O. Edenhofer, R. Pichs-Madruga, E. Farahani Sokona, Y., S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx, Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA.: Cambridge University Press.

Theurl, M.C., Lauk, C., Kalt, G., Mayer, A., Kaltenegger, K., Morais, T.G., Teixeira, R. F. M., Domingos, T., Winiwarter, W., Erb, K.H. and Haberl, H. 2019. Food systems in a zero-deforestation world: Dietary change is more important than intensification for climate targets in 2050, Science of The Total Environment, Volume 735, 2020, 139353.

UNECE 1998. Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters. pp25.

United Kingdom National Ecosystem Assessment 2011. Glossary of Concepts, http://uknea.

unep-wcmc.org/EcosystemAssessmentConcepts/Glossary/tabid/104/Default.aspx

United Nations 1992a. Rio Declaration on Environment and Development. Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992, A/CONF.151/26 (Vol. 1).

United Nations 1992b. Convention on Biological Diversity. 5 June 1992, Rio de Janeiro www.biodiv.org/doc/legal/cbd-un-en.pdf

United Nations 2015. Paris Agreement, United Nations Framework Convention on Climate Change on Climate Change. pp 27. http://unfccc.int/paris_agreement/items/9485.php

Vivid Economics and Environmental Finance 2018. Natural capital finance model – Strategic Outline Case, report prepared for Defra, pp65.

Wild, B., Andersson, A., Bröder, L., Vonk, J., Hugelius, G., McClelland, J.W., Song, W., Raymond, P.A. and Gustafsson, O. 2019. Rivers across the Siberian Arctic unearth the patterns of carbon release from thawing permafrost. *Proceedings of the National Academy of Sciences*. May 2019, 116 (21) 10280-10285; DOI:10.1073/pnas.1811797116.

World Commission on Environment and Development (WCED) 1987. Our Common Future. (Brundtland Report) Report of United Nations Commission on Environment and Development. pp.300.

SHERPA
Rural Science-Society-Policy Interfaces

www.rural-interfaces.eu

SHERPA receives funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 862448