Integrating the 17 SDGs into the European Green Deal, through Strategic and Financial Approaches

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Article

Keywords: European Green Deal, SDGs, Sustainability, Policy alignment, Text-mining, Machine Learning

Posted Date: March 21st, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2697240/v1

Abstract

The European Green Deal (EGD) is the growth strategy for Europe, covering multiple domains, and aiming to an equitable, carbon neutral European Union by 2050. The UN Agenda 2030, with its 17 Sustainable Development Goals (SDGs) set the bases for a global sustainability transition. However, the integration of the SDGs into the EGD is an overlooked issue in the literature, although it is particularly important, given Europe's slow progress to achieve the sustainability targets. In this paper, 22 central policies and strategies published during 2020–21 to support the EGD's implementation are assessed on how they align with Agenda's 2030 aspirations, using novel text-mining methodologies: one human-based and one machine-learning-based. The results outline an alignment of EGD policies to the main SDGs themes relevant to Food, Land, Oceans, Energy, but also a strong indication that the progress towards sustainability passes through "Peace, Justice, and Strong Institutions" (SDG16) and international "Partnerships for the Goals" (SDG17). We further explain the underlying policy mechanisms of the established 'necessary transformations' to build a sustainable Europe, along with the relevance of valuing the natural capital and integrating it into future investment and financial decisions.

1 Introduction

The European Green Deal (EGD) is the growth plan for a carbon neutral Europe by 2050. It covers a wide range of areas, including climate action, energy, agriculture, industry, and infrastructure, environment and biodiversity, transportation, finance and development, and research and innovation (European Commission, 2019). The UN Agenda 2030, signed by 193 countries, is the global agenda towards the "future we want", focused on poverty eradication and sustainable development on a global scale by 2030 (United Nations, 2015). Its 17 Sustainable Development Goals (SDGs) are our plan for building national, continental, and global investment programs for sustainable development. Since the introduction of the EGD in December 2019, the European Commission has launched a plethora of policies, regulations, recommendations, and other policy and strategy documents to support the actions required by the EU Member States to achieve the goals set within each of the aforementioned areas. The Commission President, Ursula von der Leyen, is committed to integrating the SDGs into European Semester, the EU's budgeting processes (von der Leyen, 2019), while the Annual Growth Strategy outlines that "this economic agenda must transform the Union into a sustainable economy, helping the EU and its Member States to achieve the United Nations Sustainable Development Goals" (European Commission, 2020). Arguably, achieving the sustainability agenda is a difficult and ambitious task. Several challenges such as the pandemic and the war in Ukraine have further slowed down its successful implementation in Europe. So, urgent action is required, and improved understanding of the underlying policy mechanisms is key to implement successful measures (Siddi, 2020; Dzebo, 2022).

Although researchers have studied the progress of the SDGs in EU (Kostetckaia, & Hametner, 2022; Hametner & Kostetckaia, 2020), as well as the impact of the EGD on multiple sectors (e.g., Von Homeyer, et al., 2022; Pietzcker et al., 2021; Leonard et al. 2021), the interlinkages between the EGD and the SDGs are an overlooked issue. Despite research on specific countries (Shevchenko et al., 2021) and the exploration of specific SDGs under certain policies, or methodological contributions aiming to improve their monitoring (Sachs et al. 2021; Borchardt et al. 2022), an overview of all SDGs into the EGD policies and how these are consequently integrated into six broad transformations is missing.

In this paper, we try to fill that gap by presenting an integrated mapping of the EGD policies and their joint implementation with the 17 SDGs. A novel methodology was developed by our group, the SDSN Europe Senior Working Group (SWG), based on human text-mining and Machine Learning (ML) techniques to provide a thorough and complete assessment of the relevant policy documents, illustrating the interaction among EGD and each SDG. The outcome is the mapping of the EGD policies and an assessment of the degree that these policies addressing particular SDGs. Moreover, we assess and explain the relationship of the EGD policies with the six necessary transformations for sustainability and the operationalization of the 17 SDGs, proposed in 2019 by Sachs et al. (2019).

Last, we connect the implementation of EGD/SDGs with the value of natural capital and argue towards integrating natural capital into investment processes. Natural capital provides 'ecosystem' services to the economy and the literature suggests that it is crucial for investors and policymakers to consider it in their financial and investment decisions (Dasgupta, 2021). To ensure long-term prosperity for all, greater amounts of public and private capital must be channeled into investment areas to achieve the SDGs and help create an environment of sustainable and inclusive economic growth. Hence, to switch from traditional financial models to more sustainable ones the value of natural capital must be integrated into financial decisions. We explain how an ecosystem-based benefits-transfer valuation approach can be developed to assign economic values to natural capital, by using 14 different biogeographical areas of Europe as an example. We perform meta-regression analysis on values extracted from existing empirical studies using a value transfer function and highlight the importance of bringing them into investment and financial decisions.

The results of this work are expected to be useful for researchers and policymakers, as they contribute to an improved understanding of the hidden elements and interconnections among the different policies and SDGs, and outline paradigms and areas for further improvement, facilitating the prioritization of actions that will keep countries on track towards achieving sustainability. To further enhance our work's policy implications, we reflect on our findings and provide strategic recommendations for addressing the significant issues that are likely to arise through the implementation of the ambitious sustainability agenda.

2 Methods

2.1 Cross-mapping of the 17 SDGs to the European Green Deal Policies

The mapping of the 17 SDGs to the EGD was done by reading all the policy documents selected (Table 1) and highlighting phrases that were semantically linked to the objectives of one or more SDGs. The sample of policies selected was based on expert judgement aiming to cover all relevant thematic policy areas: policy and strategy documents published after the EGD launch in December 2019 were retrieved, from the official website of European Union law (EURlex). For the search we using keywords covering the thematic areas of the EGD, namely Biodiversity, Building and renovating, Clean Energy, etc., as summarized in Table 1.

To decide whether there is a meaningful connection or not, we referred to the description of the 169 individual objectives defining the 17 SDGs (United Nations, 2017), and looked for keywords or synonyms. A similar matching approach was followed by Sachs et al. 2021, at a higher level though, as the 17 SDGs were mapped to the EDG's nine broad thematic policy areas, rather than specific policy documents, as herein. However, apart from the overall characterization of the degree of connection, we also assign a score, in a proportional way, that refers to the level of connection of each Policy to the SDGs, using a 4-point scale:

- 0: The Policy document does not interact with the specific SDG,
- 1: The Policy document enables the SDG outcomes,
- 2: The Policy document reinforces the SDG outcomes,
- 3: The Policy document directly affects the SDG outcomes.

The criterion for score assignment was the number of excerpts of a policy document that were linked to each SDG. Specifically, we assign a score of 3 to the SDGs with the maximum number of relevant phrases from the policy document, a score of 1 to the SDG with the least number of such phrases, and a score of 2 to those in between. Score 0 was received by the SDGs without connection to Policies.

Table 1
Mapping of Policies/Strategies to The European Green Deal Policy Areas. These 22 significant policy and strategy documents were published in 2020-21 in support of the implementation of the EGD.

EGD Policy Area	Name of Policy/Strategy
Biodiversity	· Biodiversity Strategy for 2030
	· Circular economy action plan
	· Blue economy strategy
Building and renovating	· A Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives
Clean energy	· Hydrogen Strategy
	· Offshore Renewable Energy Strategy
	· Methane Strategy
	· Energy poverty recommendation
Climate action	· European Climate Law
	· European Climate Pact
	· Adaptation Strategy
	· Stepping up Europe's 2030 climate Ambition
Eliminating pollution	· Chemicals strategy for Sustainability
From Farm to Fork	· Farm to Fork' strategy
Sustainable industry	· Industrial strategy
	· Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery
Sustainable mobility	· Smart Mobility Strategy
Overarching	· Fit-for-55
	· Strategy for Financing the Transition to a Sustainable Economy
	· Annual Sustainable Growth Strategy (ASGS) 2021–7 flagship areas
	· The European economic and financial system: fostering openness, strength, and resilience
	· Directing finance towards the European Green Deal

2.2 Cross-mapping through a Machine Learning (ML) Method

In parallel with the above method, a Deep Learning Model was developed. Its added value is the capability of capturing the semantic similarity between policies and SDGs. The main advantage of using ML, is the speed and preciseness of the process. It is a smart and accurate tool that could reveal hidden connections between texts, that are not easily noticed by the human eye. Moreover, the findings of the "human" approach could be validated. Such ML algorithms have been extensively used in the literature for accurate sentiment analysis (Maulud et al., 2021; Trappey et al., 2020).

Deep learning refers to extensive neural networks with many layers (deep) that "allow computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction" (LeCun et al., 2015). In 2017, Google Research introduced The Transformer, a deep learning model based on attention mechanisms, dispensing with recurrence and convolutions entirely (Vaswani et al., 2017). This innovation led to the development of a wide range of models based on transformers, allowing the processing of entire sequences without the need for labelled data in pre-training.

In this work, we fine-tuned a pre-trained transformer-based model to find the similarity score of each policy document with each SDG. This is called BERT (standing for "Bidirectional Encoder Representations from Transformers") and was introduced by Google Research in 2018 (Devlin et al., 2018). BERT is a bidirectional transformer pre-trained by using masked language modelling objective and next sentence prediction. Therefore, they are more advanced than Standard Language Models which are unidirectional, thus limiting the architectures that can be used for pre-training.

A pre-trained model supports the effort of defining the similarity score between each one policy document and SDG's – Targets - Indicators definitions, trying to compensate for the ambiguity of Natural Language. Data used for BERT pretraining come from the Toronto Book Corpus (c.800 million words) and Wikipedia (c.2,500 million words). For the purposes of the study, the "bert-base-uncased" (12-layer, 768-hidden, 12-heads, 110M parameters) model was used.

To fine-tune the pretrained BERT model, the latest available OSDG Community Dataset was used, along with the description of the targets and indicators of each Goal[1]. The OSDG Community Dataset is the result of the work of more than 1,000 volunteers from all over the world using the OSDG Community Platform, who label sentences and paragraphs according to their relation with each SDG. Each labelling exercise is a binary decision problem, in which volunteers decide whether specific text excerpts relate to a proposed SDG or not. A ratio is then calculated as follows:

$$agreement = \frac{|Labels_{positive} - Labels_{negative}|}{Labels_{positive} + Labels_{negative}}$$

The dataset is formed after text excerpts of paragraphs deriving from public documents, such as reports, policies, and publication abstracts. Furthermore, some documents originate from UN-related sources (e.g. SDG-Pathfinder and SDG Library). The released dataset (OSDG, 2021) constitutes of 32,115 labelled document excerpts and it contains the referred SDG, the number of volunteers that classified the connection to the SDG as negative, the number of volunteers that classified the connection to the SDG as positive and the agreement score based on the formula:

For the purposes of the presented research, data used were pre-selected using the following criteria:

- $Labels_{positive} > Labels_{negative}$, as we needed only to use data related to an SDG.
- $agreement > 0.6$, as we needed to be sure that the volunteers agreed to the labelling.

This pre-selection process produced 14,280 excerpts, in which minor corrections were made, such as separation of combined words and replacements of wrong letter. In the final set of excerpts, we added the indicators and the descriptions for each of the 169 targets of the SDGs, retrieved from Ritchie et al. (2018). This process led to a total of 15,083 text excerpts for model fine-tuning.

The number of text excerpts used for each SDG are shown in Table 2:

Table 2
Text excerpts used for each SDG

SDG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Number of extracts used for fine-tuning	970	726	1639	1993	1948	1132	1391	759	605	385	1081	232	991	613	480	66	72

The model was developed in Python, using PyTorch and Scikit-Learn. 80% of the text excerpts were used as training data and 20% as testing data. Adam Optimizer was used as an optimizer, while the Cross-Entropy Loss was chosen as the optimization criterion. Adam (short for Adaptive Moment Estimation) is a popular optimization algorithm used in machine learning for optimizing the parameters of a model during training. Entropy Loss is a term used in machine learning and specifically in the context of training neural networks for classification tasks. Next, the model was trained for 10 Epochs with a learning rate of 10^{-5}, resulting in an accuracy score of 0.889. Considering that the training data used for each SDG are not of the same size and that a text excerpt is most probably linked to more than one SDG, the accuracy score is acceptable.

Our objective is to get an answer to this question: "What is the probability that *X* policy document is linked to the *Y* SDG?". Scores are calculated by the model described above. The higher the score the bigger the probability for a scanned policy to be linked to a given SDG.

After getting our first results, we noticed that some scores are extremely high due to the high relevance of the policy to an SDG. Of course, this is not wrong, but the dominance of some SDGs over the others makes the interpretation of the results more difficult. So, we took another step and for each policy, we excluded the highest value. Then, we re-ran the process and obtained the scores distributed in a more uniform manner.

2.3 Mapping EGD Policies to the 6 SDGs Transformations

The SDGs and the Paris Agreement on Climate Change (2015) require governments to implement major transformations with the input of civil society, the scientific community, and business. Governments need to engage in robust multi-sector collaboration to meet their commitments and adequately prioritize the 17 SDGs in their national policies.

Sachs et al. (2019) proposed Six Transformations necessary to achieve the 17 SDGs, and calculated each one's relationship with the SDGs using scores for 0 to 3. These transformations refer to: 1. Education, Gender, and Inequality; 2. Health, Wellbeing, and Demography; 3. Energy Decarbonization and Sustainable Industry; 4. Sustainable Food, Land, Water, and Oceans; 5. Sustainable Cities and Communities; and 6. Digital

Revolution for Sustainable Development. They are all interconnected and mutually reinforcing and achieving them will require collaboration and action across sectors and at all levels of society.

Based on the mapping of policy documents to the SDGs, and the mapping of the SDGs to the six transformations, it is possible to estimate the linkage of Policies directly to the Transformations, by following three steps:

- **Step 1**: For each Transformation, calculate the simple average of the contribution of SDG in each transformative category (Table 3), as given by Sachs et al. (2019).
- **Step 2**: Multiplying the Table derived from step 1 with the scores of mapping policies to the SDGs with the human approach. A 22x6 matrix is obtained (Table 4), showing the extent that each policy contributes to each Transformation.
- **Step 3**: Using the data from Table 4, a Sankey diagram is produced, using SankeyMATIC, to visualize the influence of EGD Policies on the six Transformations (Fig. 1).

Table 3
Average SDG contribution to the 6 Transformations.

	1. Education, Gender, and Inequality	2. Health, Wellbeing and Demography	3. Energy Decarbonisation and Sustainable Industry	4. Sustainable Food, Land, Water, and Oceans	5. Sustainable Cities and Communities	6. Digital Revolution for Sustainable Development
SDG 1-No poverty	2,00	2,00	1,33	2,00	1,50	2,00
SDG 2-Zero hunger	2,00	3,00	1,33	3,00	1,50	2,00
SDG 3-Good health and well-being	1,67	3,00	2,33	3,00	1,50	2,00
SDG 4-Quality education	1,67	2,00	1,00	1,00	1,50	2,00
SDG 5-Gender equality	2,00	3,00	1,33	2,00	1,50	1,00
SDG 6-Clean water and sanitation	1,00	0,00	2,00	3,00	2,50	1,00
SDG 7-Affordable and clean energy	1,67	0,00	2,33	1,00	1,00	2,00
SDG 8-Decent work and economic growth	2,33	2,00	2,00	2,00	1,50	2,00
SDG 9-Industry, innovation, and infrastructure	2,00	1,00	2,00	1,00	2,50	3,00
SDG 10-Reduced inequalities	2,00	2,00	1,67	2,00	2,00	2,00
SDG 11-Sustainable cities and communities	1,00	1,00	2,67	2,00	3,00	2,00
SDG 12-Responsible consumption and production	1,33	1,00	2,67	3,00	2,00	2,00
SDG 13-Climate action	1,67	0,00	2,67	3,00	2,50	2,00
SDG 14-Life below water	1,33	0,00	2,00	3,00	1,00	1,00
SDG 15-Life on land	1,33	0,00	2,33	3,00	1,00	1,00
SDG 16-Peace, justice, and strong institutions	1,00	1,00	1,33	1,00	0,50	1,00
SDG 17-Partnerships for the goals	1,00	0,00	0,67	1,00	0,00	2,00

Table 4
Link between Policies and the Six Transformations.

	1. Education, Gender, and Inequality	2. Health, Wellbeing and Demography	3. Energy Decarbonisation and Sustainable Industry	4. Sustainable Food, Land, Water, and Oceans	5. Sustainable Cities and Communities	6. Digital Revolution for Sustainable Development
European Climate Pact	34	26	43	50	39	39
Directing finance towards the European Green Deal	19	10	25	29	21	20
European Climate Law	40	24	51	59	41	46
Fit for 55	43	24	57	55	50	54
A New Industrial Strategy for Europe	42	27	49	50	39	50
EU Hydrogen Strategy	36	21	44	38	39	45
7 technology flagship Areas, ASGS for 2021	43	33	53	50	46	51
Chemicals strategy for Sustainability	32	19	47	52	36	38
EU Strategy to reduce methane emissions	31	24	36	40	30	37
A Renovation Wave for Europe	30	14	43	39	36	39
EU Commission Recommendation on Energy Poverty	26	18	28	29	26	28
EU Strategy to harness the potential of offshore renewable energy for a climate neutral future	32	14	42	37	34	41
Smart Mobility Strategy	34	20	46	45	39	43
Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery	42	27	49	50	39	50
EU Biodiversity Strategy for 2030	39	26	47	56	34	42
Stepping up Europe's 2030 climate Ambition	42	26	56	54	47	50
EU Strategy on Adaptation to Climate Change	57	40	70	77	61	65
Circular Economy Action Plan	38	23	49	55	41	43
Farm to Fork Strategy	41	31	48	58	37	45
The European economic and financial system: fostering openness, strength, and resilience	26	15	30	28	21	32
The EU's Blue Economy for a Sustainable Future	30	18	40	46	35	35
Strategy for Financing the Transition to a Sustainable Economy	36	20	44	44	36	42

2.4 The value of Natural Capital in Europe and its link with the SDGs achievement

The 17 SDGs represent a baseline framework of sustainable development for future generations. The goals are deeply interconnected, which means that failure to any one of them hinders progress on others. According to the OECD, there is a huge funding gap in the implementation of the SDGs, estimated at USD 4.2 trillion per year, which was further amplified by the COVID-19 recession (OECD, 2020).

Another estimation, that included the cost of meeting growing commitments under the Paris Agreement and the cost of creating financial inclusion and prosperity for large parts of the world, found that the actual financing gap is likely to double or more, estimating it to be between USD 8.4 trillion and USD 10.1 trillion, which equates to almost 9–11% of global GDP in 2021 (Patel et al., 2020). This means that it is increasingly urgent for governments to develop comprehensive, sustainable, and inclusive approaches to finance the SDGs.

Money should not come solely from public finances, but from private sector, too. The motivation of private companies to adopt a holistic environmental strategy and invest seriously in SDGs, will come when they realize that a sound sustainability performance, generally implies a good financial performance as well (Koundouri et al., 2022).

Natural Capital provides a wide range of services called ecosystem services, which make the economy functional, therefore companies must realize the interaction among all types of Capital (Natural, Human, Produced), and how much dependent they are on each of them. This involves quantifying their impact on Natural Capital, Human Capital and Produced Capital to help them develop an appropriate strategy to address their business risks and opportunities.

Recognizing the importance of natural capital in the transition to sustainability and the need to help all stakeholders understand the value of nature and its contribution to society, we provide a valuation of the European Ecosystem Services in order to shed light on the full cost associated with the transition from the status quo to the complete achievement of the 17 SDGs, focusing on three main types of ecosystems: terrestrial, marine, and freshwater. The empirical analysis is aimed at first deriving the economic value of EU ecosystems, and then, building on the results, the study integrated the unit value of ecosystems with the SDG index. This enables the study's second goal, which is to quantify the social-economic value derived from shifting from the status quo of ecosystems to full SDG achievement.

The valuation of Ecosystem Services was done with the method of Benefit Transfer, using meta-regression analysis. Benefit transfer is a widely used approach for the estimation of economic values for ecosystem services by transferring available information from studies already completed in another location and/or context (Johnston, 2015).

Empirical valuation studies were used to obtain measures such as public's willingness to pay (WtP) to enjoy ecosystemic services in specific biogeographical regions. The primary literature was retrieved from the publicly accessible database EVRI (Environmental Valuation Reference Inventory), using Europe, and publication dates between 2012–2022, as selection criteria. The search initially returned 212 studies, which after screening resulted in 165 studies to be used for data extraction (more details in the Supplementary Material).

The studies were separated by ecosystem typology: Terrestrial, Marine, and Freshwater and each one was used to extract specific parts information. An excel file filled-in with the following data:

- **Study details**: Title, authors year of publication etc.
- **Willingness to Pay (WtP) or Willingness to Accept (WtA)**: Continuous variable expresses the average WtP in EUR in an annual basis.
- **Ecosystem**: Categorical variable for the typology of ecosystem considered in the study. The categorization of the Mapping and Assessment of Ecosystems and their Services (MAES) Typology for ecosystem classification (Zhongming, 2015) was followed: **Terrestrial** [Forest (42 studies), Cropland (18), Heathland and Shrub (1), Sparsed vegetated land (1), Urban (15), Grassland (6), and Inland and Wetlands (3)], **Freshwater** [Rivers and Lakes (14)], and **Marine** [Marine and Coastal (65)].
- **Type of Ecosystem Service**: Dummy variables referring to Cultural, Provisioning, Regulating, Supporting services.
- **Survey design**: Categorical variable describing the different methods for data collection, e.g., Computer-aided individual interviews, focus groups, in-person interview, etc.
- **Data year**: Year of data collection
- **Valuation method**: Categorical variable indicating the method used to develop the analysis, i.e., Contingent valuation, Choice experiment, Actual Expenditure/Market price, Count data model, Hedonic Price Method, Hedonic Property, Meta-analysis, Replacement costs, Travel cost method. In our final dataset, we have 76 Choice Experiment (CE) studies and 67 CVM studies and 22 studies from studies using revealed preferences.
- **Location**: Categorical variable for the geographical area in which the analysis has been developed
- **Country**: Categorical variable for the European country in which the analysis has been developed
- **Biogeographical and marine regions**: Dummy variables indicating the specific biogeographical and marine regions of European Union in which the study has been developed, namely Alpine, Atlantic, Black Sea, Boreal, Continental, Macaronesian, Mediterranean, Pannonian, Steppic. The categories are those used for reporting under Article 17 of the Habitats Directive (92/43/EEC).
- **Value elicitation method**: Categorical variable indicating the typology of elicitation used in the study
- **Age**: Continuous variable indicating the average value of age of the sample population (in years). In case of missing values, we used the mean age per country in the reference year was used, as derived from EUROSTAT database

- **Income**: Continuous variable indicating the average annual income of the sample population (in EUR). In case of missing values, the average income per country in the reference year was used, as derive from EUROSTAT database, or from EU-SILC and ECHP surveys.
- **Gender**: Percentage of males and females in the sample population.
- **Education**: Percentage of people in the sample, with high education level. In case of missing values, we used the percentage of population attended tertiary education in the country and the year of reference, as provided by EUROSTAT.

After gathering and cleaning up the dataset, we estimated the WtP, using the meta-regression model given by the formula:

$Yi = \gamma + \beta' Xi + \varepsilon i$ (1)

Where Y, is dependent variable (in our case, WtP), i refers to observations gathered from the studies, γ is the intercept of regression, $\beta\prime$ is the vector of parameters to be estimated as slopes of the matrix of the explanatory variables X_i; ϵ is the error term. For further details on the results of the regression, please refer to the supplementary material.

Finding a balance between socioeconomic development and ecosystem services is a crucial challenge for sustainable development (McCartney, 2014). To gain a high-level understanding of how WtP for ecosystem services relates to the achievement of 17 SDGs, for the 27 countries of the European Union, we calculated the correlation of the SDG scores per country, as provided by the UNSDSN Sustainable Development Report Europe 2021, and the Marginal WtP per country, calculated previously.

[1] For SDG16 and SDG17 we used expressions linked to these goals from the human approach, as the OSDG Community Dataset does not include texts for these goals, yet.

3 Results

3.1 Cross-mapping of the 17 SDGs to the European Green Deal Policies: Human approach

By applying the human approach described in the Method's section 2.1, we obtained the results of Table 5. The main message from this, is that the European policies, mostly affect SDGs 7, 8, 9, 12, and 13.

SDG 7 refers to ensuring access to affordable, reliable, sustainable, and modern energy for all. Energy consumption is responsible for a substantial share of Greenhouse Gas Emissions (GHG) globally (Nejat et al. 2015), and the EGD policies call for interventions that promote the use of renewable energy, resilient energy grids and uninterrupted supply of green energy carriers to all European citizens.

SDG 8 is about decent work and economic growth, which must be inclusive and sustainable. Tackling issues such as unemployment, safety at work, elimination of child labor, closing of the salary gap between genders, access to high quality jobs and advancement of labor force skills, seems to be high priorities in the European political agenda.

SDG9 promotes industrial innovation and infrastructure. As derived from our analysis, several European policies help in building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. European Commission is highly interested in adopting scientific research results and innovation, to increase the resilience of European countries and shield communities against the effects of climate crisis. In this line, approximately €100bn are available through Horizon Europe program, to finance research and innovation that fosters industrial competitiveness and assists the production and dissemination of advanced knowledge and technologies.

SDG 12 concerns the responsible consumption and production. It is derived that the European Commission, promotes policies for the establishment of responsible production and consumption habits and the implementation of a circular model of economy. It encourages European companies to do business in partner countries with reliable supply chains and business practices. Further, it tries to ensure that global value chains are managed sustainably so that the choices of the European consumers do not jeopardize environmental protection or workers' rights and opportunities in the partner countries.

SDG 13 urges for actions to combat climate change and its impacts. The European Commission has decisively shown its intention to reduce GHG to support limiting global warming by below + 1.5°C, according to the Paris Agreement. The launch "Fit-for-55" package in 2021 was a significant moment in support of SDG 13, as it suggests the revision of thirteen policies covering a wide range of activities, ranging from the operation of the Emissions Trading System to the creation of a Social Climate Fund that will support the most vulnerable parts of society in the sustainable transition.

3.2 Cross-mapping of the 17 SDGs to the European Green Deal Policies: Machine Learning (ML) Approach

The Deep Learning approach uncovered more detailed insights about the relationship between EGD policies and the SDGs, which can be beneficial to policy makers in understanding which policies to implement to achieve their SDG goals.

A close look into Table 6 reveals that most of the EGD policies demonstrate a high relevance with SDG 17 "Partnership for the Goals", SDG 12 "Responsible Consumption and Production", and SDG 16 "Peace, Justice, and Strong Institutions", SDG 13 "Climate Action", SDG 7 "Affordable and Clean Energy", and SDG 9 "Industry, Innovation, and Infrastructure". These results, confirm those from “Human Approach.”

Further, it is quite interesting that the "New Industrial Strategy" and the "Updating the 2020 Industrial Strategy", which are by subject related to energy, seem to be less linked to SDG 7 "affordable and clean energy" than they are to SDG 8 "Decent Work and Economic Growth" and to SDG 12 "Responsible Consumption and Production". This implies that, even though these documents are closely related to the energy sector, their focus is on stimulating economic growth and promoting responsible consumption and production. This finding is particularly intriguing because it implies that the semantic content of energy policies is related not only to their direct subject matter but also to broader implications and impacts of the policy on society, such as economic growth and responsible consumption.

3.3 Mapping EGD Policies to the 6 SDGs Transformations

Figure 1 show that the transformations most related to the European Green Deal are: *4-Sustainable Food, Land, Water, and Oceans;* and *3-Energy Decarbonization and Sustainable Industry*. This is not surprising, given that the primary objective of the EGD is to make the EU climate neutral, and these two transformations are intricately linked to this objective and the actions required to achieve it. The first category of transformations includes all the actions required to move to a model of circular economy and conservation of biodiversity, while the second category concerns the taking of measures to reduce dependence and finally disconnect production from fossil fuels and replace them with renewable energy sources.

Regarding transformation No4, Europe faces significant challenges in achieving SDG 2-Zero Hunger, due to problems of malnutrition and obesity (Lafortune et al., 2021). In addition, climate change and the collapse of biodiversity threaten the efficiency of the food supply chain. An integrated approach is therefore required to ensure the sustainability and health of systems, land use, and oceans, which the European Commission has recognized and has already integrated into its strategy. This priority concerns ministries responsible for agriculture and forestry, the environment, water, and natural resources, including marine, and health. So, national governments must adopt policies that will ensure the conservation of resources, protect, and restore ecosystems, reduce food loss, and waste, and ensure better nutrition while still meeting the needs of all stakeholders.

Regarding transformation No3, Fig. 1 confirms that one of the main priorities of EGD is to encourage the decoupling of Energy from carbon and the promotion of renewable sources. Also, to support the development of carbon capturing and of storage technologies, to increase grid flexibility through digitalization, and to make a smarter use of existing capacity.

The EU has already taken decisive steps to promote sustainable and efficient energy systems, such as introducing legislation and setting ambitious targets for renewable energy sources. These steps are meant to make sure that the switch from fossil fuels to cleaner energy sources happens in a way that is beneficial for both the economy and society. For example, it has implemented various policies and initiatives to promote the development of renewable energy sources, such as wind, solar, hydropower and bioenergy, and increased the target share of renewable energy in its energy mix to at least 32% by 2030 (European Environment Agency, 2022).

A study of the SDSN jointly with the Enel Foundation, published in November 2021 (Papa, 2021), analyzed the EU's energy and climate policies and put forward concrete proposals for the implementation of the EGD, in line with the SDGs. The study also highlighted the unique opportunities offered by the Recovery and Resilience Facility to address the socio-economic challenges arising from the COVID-19 pandemic. Using the case study of the Italian National Recovery and Resilience Plan, they demonstrated how European recovery could successfully operationalize climate action alongside the framework of the six transformations.

3.4 The value of Natural Capital in Europe and its link with the SDGs achievement

The results of the study showed that the value of ecosystem services in terms of citizens' WTP varies by ecosystem service and biogeographic region for all ecosystems (terrestrial, marine, and freshwater), and structural changes are needed to address biodiversity loss. More specifically, in seventeen of the 27 EU countries, i.e., almost 63%, citizens' WtP for the improvement of aquatic ecosystems (marine and freshwater) is greater than for terrestrial ecosystems (Fig. 2). This implies that citizens perceive the role of aquatic ecosystems as greater compared to terrestrial ecosystems. One explanation is that the citizens anticipate that marine and aquatic ecosystems are at greater risk of collapse than terrestrial ecosystems, so they are willing to spend part of their income to maintain or restore aquatic ecosystems. Or, marine/aquatic ecosystems are more valuable for the public well-being and their income, e.g., due to fishing activity, tourism, etc., than the terrestrial ones, therefore people are willing to bear the cost of maintaining these ecosystems in good condition. Whatever the exact cause of this phenomenon, aquatic ecosystems are more highly valued by citizens than terrestrial ones and it is up to policy makers to recognize this fact and use it as a guide when formulating or reforming environmental policies.

Finding a balance between socio-economic development and ecosystem services is a critical challenge for sustainable development. For this reason, the report further examined the correlation between WTP and the level of achievement of 17 SDGs in total, for the twenty-seven countries of the European Union. To calculate the correlation, each country's SDG scores from the UNSDSN Europe 2021 Sustainable Development Report (Lafortune et al., 2021), and the WTP per country mentioned above, were used. The “SDG Index Score” in Fig. 3 refers to the aggregated score for all 17 SDGs per ecosystem type, and then the correlations of WTP with each SDG are given.

A positive correlation means that an important level of WTP is associated with an elevated level of achievement of a particular SDG, and the closer the correlation is to the value 1, the stronger the correlation. Conversely, a negative correlation means that a high (or low) level of WtP is associated with a low (or high) level of achievement of a particular SDG. Again, the closer the correlation is to the value − 1, the stronger the (negative) correlation.

It is important to note that a correlation does not always indicate a cause-and-effect relationship, but only that two variables tend to move together. This means that two variables may share a relationship, and that one could influence the other, but it cannot be proven beyond a reasonable doubt without further analysis to understand the cause and effect of a relationship.

Figure 4 illustrates the cross-sectional correlation coefficients between national MWTP estimates and SDG Index Scores and the Scores for all the 17 Underlying goals for all ecosystems and the three ecosystem services categories, respectively. Data for the SDG Scores were obtained from SDSN.

4 Discussion

The 17 SDGs is a globally accepted framework for the eradication of poverty and the achievement of sustainability at a global scale by 2030, considering three pillars of sustainable development: economic, social, and environmental. The European Leadership explicitly adopts the SDGs and integrates them into various policy areas. In June 2021, the European Climate Law was adopted, making both a revised 2030 Agenda (55% reduction in GHG emissions compared to 1990) and the aim of climate neutrality by 2050 legally binding. In July 2021, the European Commission released its "Fit for 55" policy recommendations to reach the new 2030 goal.

In this work, the interconnections and the alignment of the two policy frameworks were assessed, identifying gaps, areas to prioritize and suggestions on how to facilitate their mutual achievement. The approach presented, combining “human-eye” and ML text-mining methods was successful for mapping the EGD policies to the 17SGDs, and can be a helpful tool for policymakers to understand the underlying interactions between the SDGs and various policies. The “human-eye” approach shows a pervasive connection between the EGD policies and the SDGs, with a greater link with SDG13, SDG9, SDG7, SDG12 and SDG8. This means that sustainable production, consumption, and growth must drive economic activity in Europe. The results of the ML approach validate these findings, and give two additional benefits: First, enabled a much faster and accurate assessment and mapping of the SDGs' impacts on EGD policy, ad second, it revealed hidden connections, that were not easily observable by the human eye.

Thus, the results can majorly support decision-makers in establishing priorities for action and/or further strengthening, in order to achieve sustainability goals. The importance of "Peace, Justice, and Strong Institutions" (SDG16) and international "Partnerships for the Goals" (SDG17), is a novel finding, indicating that the SDGs can only be achieved as a whole: If greater emphasis is put just on economic, environmental and climate goals/policies, then other social, justice, equity and cooperation aspects will hinder the progress of any goal.

Sustainable finance is critical to achieving the policy goals set out in the European Green Deal and the EU's international climate and sustainability commitments. As the world's economies become increasingly reliant on natural capital, sustainable finance and investing must be prioritized to ensure the preservation of natural resources for future generations. The need to ensure the sustainability of natural capital is more pressing than ever and there is an urgent need for the financial sector to support investments in projects that protect and restore it. The valuation of the services that ecosystems and natural capital provide to other types of capital, in terms of monetary value, should be considered in policymaking, assessing the costs and benefits associated with alternative decisions. Also, the valuation of biodiversity and ecosystem services could serve to link economic policy with environmental protection through appropriate financial tools. This approach is also in line with the SDGs in the broader context of environmental protection and preservation. Substantial investments must be channeled through private funds for the transition to a climate-neutral, climate-resilient, resource-efficient, and fair European economy as a supplement to public funds.

The findings of this work are expected to support a holistic climate action, along with broader sustainability implications for more efficient policies. Currently, Europe and the world are recovering from the pandemic. Europe is experiencing an ongoing war with escalating consequences affecting multiple domains. Thus, the messages of the paper are timely, emphasizing on the urgent need to exploit the opportunities we have for a more sustainable recovery from the pandemic, promoting peace and international partnerships, justice, and strong institutions considering the value of the environment.

Declarations

Conflict of interest statement: No conflict of interest.

Author contributions: All authors contributed equally to the Conceptualization; Methodology; Investigation; Results; Writing—original draft preparation; Writing—review and editing.

Data Availability: The data used are available at https://drive.google.com/drive/folders/1O2Wx-VhqckP119frb1MRwgw9t84-_ocl?usp=share_link

Code Availability: The codes used for this work will be publicly available.

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Tables

Table 5 and 6 are available in the Supplementary Files section.

Figures

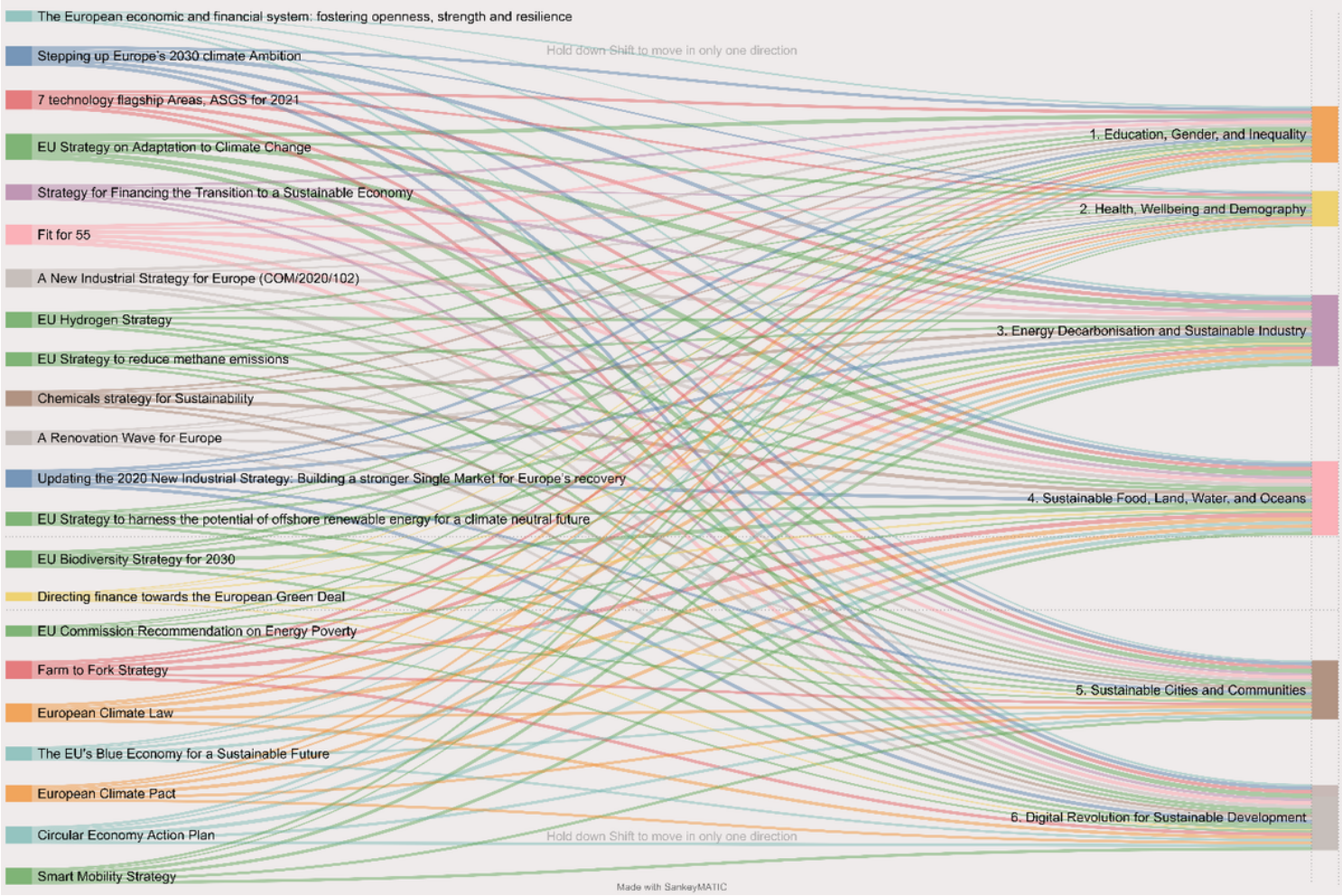

Figure 1

Sankey diagram for the contribution of the Policies to the 6 Transformations

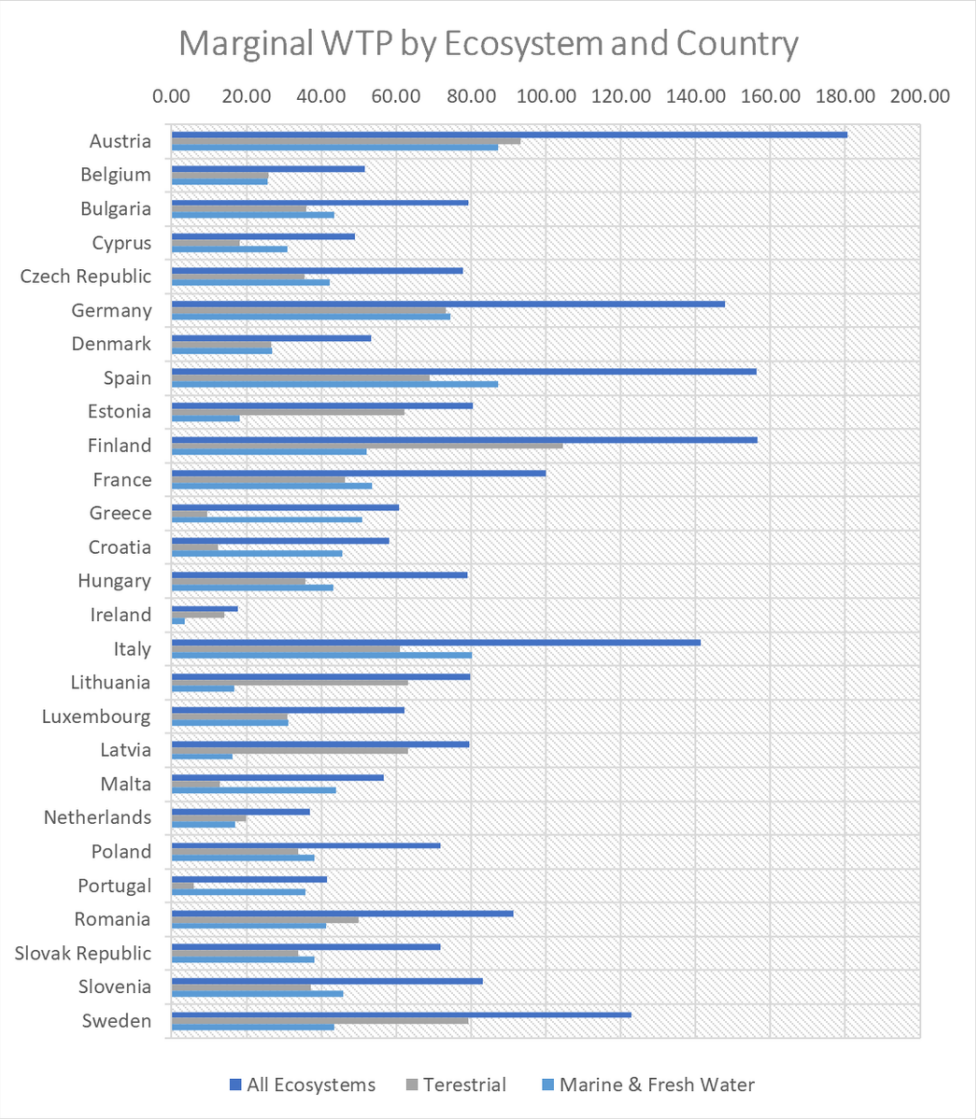

Figure 2

Marginal WTP by Ecosystem and Country

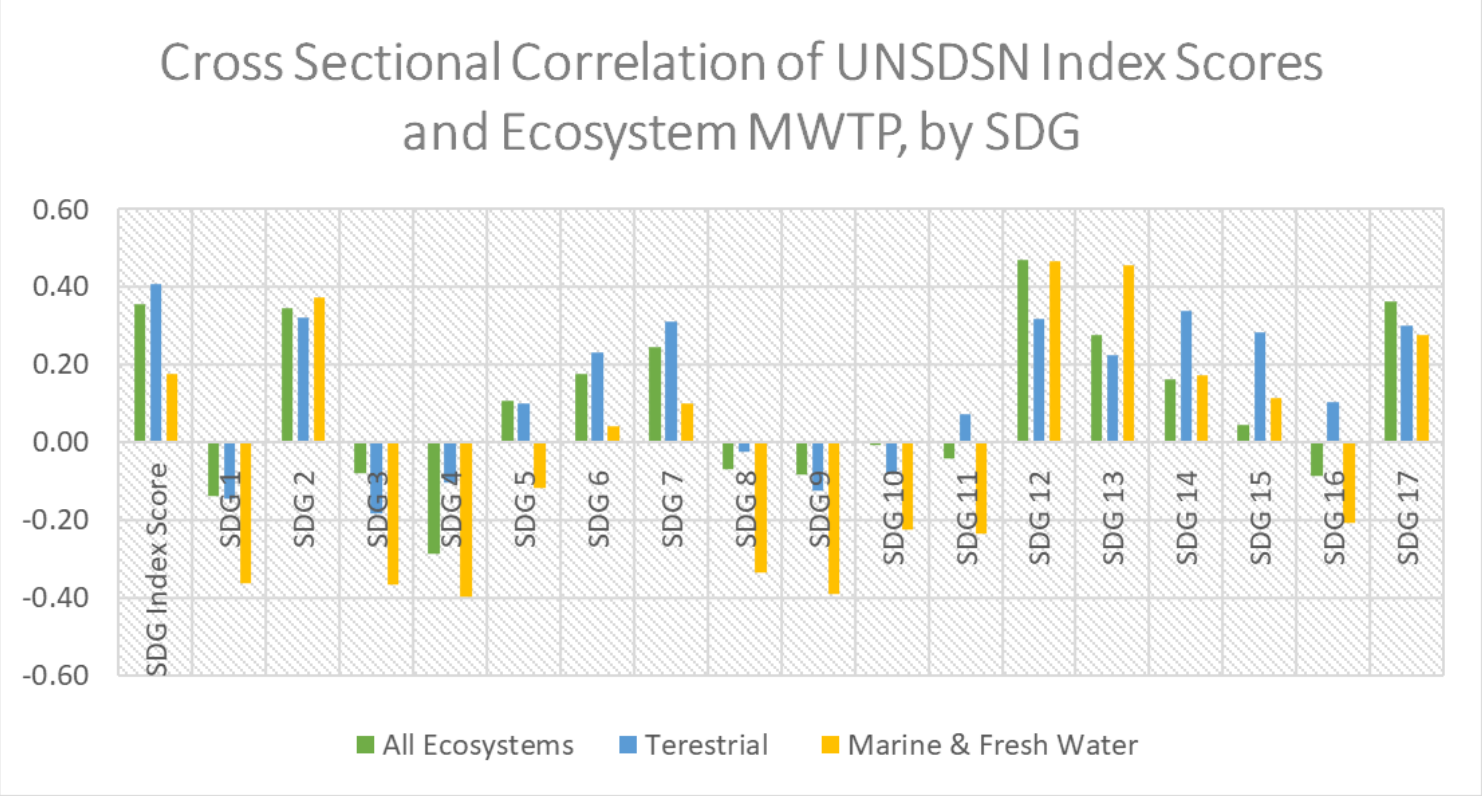

Figure 3

Correlation of SDG achievement scores and WTP

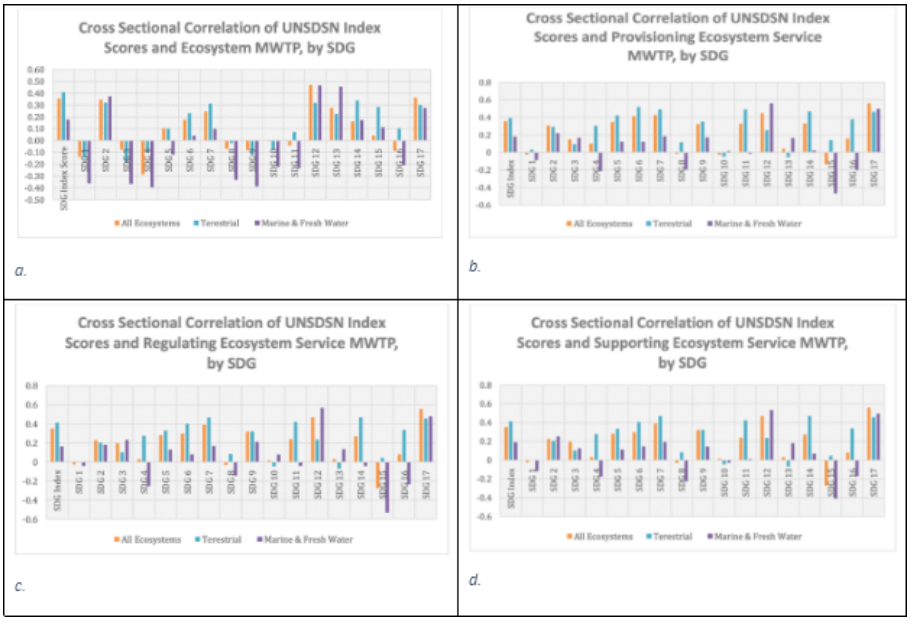

Figure 4

a) Cross Sectional Correlation of UNSDSN Index Scores and Ecosystem MWTP, by SDG. b) Cross-Sectional Correlation of UNSDSN Index Scores and Provisioning Ecosystem Service MWTP, by SDG. c) Cross-Sectional Correlation of UNSDSN Index Scores and Regulating Ecosystem Service. d) Cross-Sectional Correlation of UNSDSN Index Scores and Supporting Ecosystem Service

Supplementary Files

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- floatimage1.png
- Table6.docx