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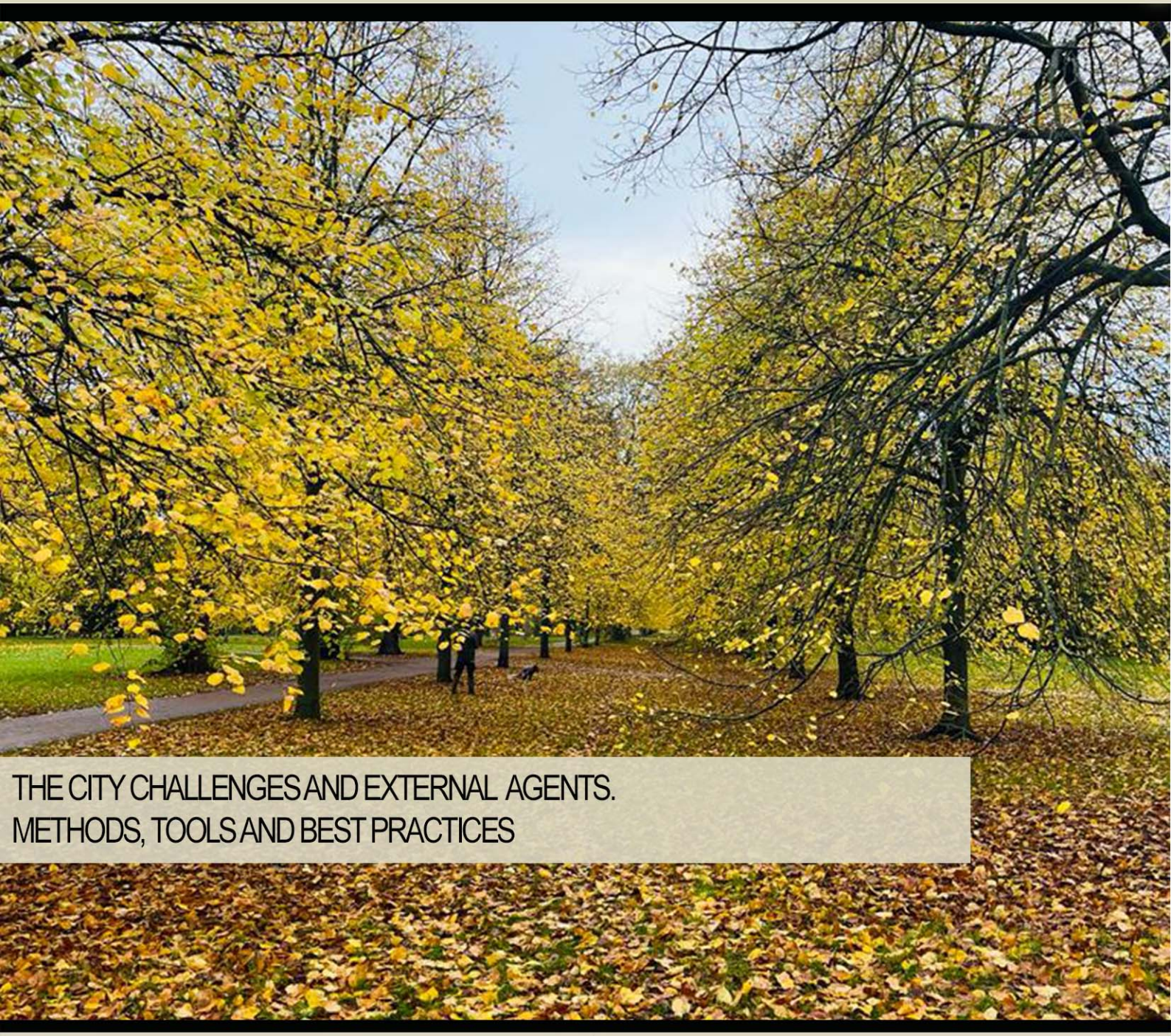

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

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The cover image shows a view of Hyde Park in London (United Kingdom) during the autumn season.
The photo was taken by Enrica Papa in November 2023.

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Digitalisation process and sustainable development of vulnerable territories

Assessment of equity potentials of major Mediterranean islands

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Abstract

The "Path to the Digital Decade" features the digital transformation goals that the member states of the European Union must reach by 2030. It also highlights the need to align the digital strategy with the 17 Sustainable Development Goals (SDGs) by use of relevant indicators for assessing progress in each single SDG. The Digital Economy and Society Index (DESI), published in 2022, demonstrates how new advances in the digitalisation process have filled several gaps in digital skills and infrastructures; while the DESI Country Profiles witness the lower levels of digital performance of insular territories, compared to the states' mainland. This paper explores the way digitalisation progress might improve islands' sustainability performance and equity concerns in the EU. Relevant achievements are assessed by the proposed Index of Islands' Potential Equity (I_{IPE}), i.e. a composite index, combining an Islands' Sustainability Index (I_{IS}) for grasping socio-economic and environmental aspects; and an Islands' Digitalisation Index (I_{DI}), for identifying the level of public/private digital transformation. The results obtained through the I_{IPE} index demonstrate how powerful the strategies of island governments in digitalisation progress can prove in achieving SDGs and rendering island contexts less vulnerable and more competitive in the European scenery.

Keywords

Path to the digital decade; Digital europe programme; Insularity; Islands' digital and developmental shortfall; Mediterranean islands.

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1. Introduction

In March 2021, the European Union (EU) presented the strategic program "Path to the Digital Decade" (COM 574 final, 2021; Digital Compass, 2022), i.e., a ten-years path, aiming to establish: common digitalisation trajectories and equity of digital rights across Europe (European Union, 2022a; Europe's Digital Decade, 2022); and joint governance for multi-country projects that monitor progress and address existing shortcomings (EU4Digital, 2021; Europe's Digital Decade, 2022; EU Monitor, 2021). The program is based on a digital compass, consisting of four key pillars, namely: i) skills, ii) digital transformation of businesses, iii) secure and sustainable digital infrastructures, and iv) digitalisation of public services. The mechanism for monitoring and controlling the path's progress of EU member states is based on the Digital Economy and Society Index (DESI), which specifies digital performance at the national level (DESI by components, 2022). In addition, DESI emphasises the central role that digital technology plays in featuring a sustainable future, by defining relevant indicators for assessing progress towards the 2030 SDGs (SDG Indicators, 2022). Thus sustainability and digitalisation are perceived as two key drivers for the equitable global transformation of the European communities, rendering them economically, socially, and ecologically competitive (European Union, 2022b). Such an inextricable tie between sustainability and technological advances in the EU is already articulated in 2010 by the EU's Eco-innovation Action Plan. Moreover, it is in alignment with the scientific discussion, claiming that sustainability and digitalisation are intertwined and provide promising potential in tackling "global challenges and creating a more just and sustainable society, laying the groundwork for achieving the Sustainable Development Goals" (Irajifar et al., 2022; Franco, 2022). The linkage between sustainability and digitalisation is also stressed by Van der Velden (2018), who underlines the role of new technologies and digital skills and their transforming power, claiming that sustainable development is intimately connected to digitalisation. Also, Seele et al. (2017 p.183) state that "digitalisation has (positively as well as negatively) incalculable potential to help achieve sustainability of the planetary and human system, or at least help reduce the negative impact of people"; illuminating also the adaptive nature of sustainability to new possible scenarios and challenges presented by the digital age; or, stated differently, the power of digitalisation as a force, capable of modifying sustainability.

Over the years, scientific research efforts have extensively, though in a piecemeal way, analysed the contribution of digitalisation to sustainability, e.g. by reducing resource consumption and environmental impacts (Gensch et al., 2017; Liu et al., 2019; Chen et al., 2020; Pellicelli et al., 2022; Valentini et al., 2023) or increasing gains in economic efficiency, associated with the penetration of innovative technologies in the industrial and commercial sectors (Ahmad et al., 2018; Kunkel et al., 2021; Niehoff, 2022; Burinskienė et al., 2022 Sgambati et al., 2023). However, a noticeable gap exists in the literature as to the assessment of the impacts of digitalisation on sustainability objectives overall (Ringenson et al., 2018; Carnerud et al., 2020). In fact, by partially analysing the role of digitalisation in specific aspects of sustainability, its potential contribution to sustainability as a whole is reduced (Silvestri, 2015). Even more pronounced is the lack of published research that explores the impacts of digitalisation on sustainable spatial development from an urban planner's perspective, linked to governance strategies and urban processes (Barreto et al., 2018; Creutzig et al., 2019a, 2019b; Seele et al., 2017; Talia, 2021). In addition, despite that the EU encourages member states to implement a digitalisation policy that, at the same time, promotes territorial equity, digitalisation per se in the EU is today still spatially unbalanced. In fact, in DESI (2022), digitalisation inequalities and a diversifying digital pace across the EU is evident, discriminating between the "frontrunners" or "fastest" countries that adopt policies and achieve a high digitalisation level (DESI by components, 2022); and the "slower" ones, namely those countries that, due to their geographic and other peculiarities, are confronted with severe obstacles to join the digitalisation upsurge. A distinct example of the latter – the "slower" ones – is insular territories (European Parliament Resolution, 2003; Analysis of the island regions and outermost regions of the European Union, 2003; Atlas of the Islands, 2013; Euroislands, 2013; European Parliament Resolution, 2016).

Geographical isolation and related structural weaknesses of these territories are key factors that prevent them from keeping pace with mainland regions in terms of sustainability achievements, including also digitalisation progress and gains (Chatziefstathiou et al., 2005; The Development of the Islands, 2013; Muthamilselvan et al., 2016; Stratigea et al., 2017; Garau et al., 2018; Garau et al., 2019; Garau et al., 2020a; Garau et al., 2020b; Garau et al., 2022). Bridging the aforementioned digitalisation gap requires much more effort and a deeper insight into the basic geographical and structural attributes of each single island context as well as those factors that increase islands' own digitalisation disparities.

Taking into consideration the particular disadvantages of islands, and the persisting developmental weaknesses with a significant impact on the overall well-being of these territories (C268/8, 2015), the Digital Decade can eventually further exaggerate inequalities between insular and mainland territories.

Following the above discussion, the aim of this work is to identify this gap in order for more informed and dedicated policies to be articulated for handling it. Towards this end, six major islands in the Mediterranean are explored in terms of equity potential in comparison to non-island countries through the development of an Islands Potential Equity Index (I_{IPE}). I_{IPE} Index aims at evaluating the islands' capacity to attain levels of Sustainable Development (SD) that are equivalent to those of non-island countries.

In this respect, the concept of equity is perceived as synonymous to vulnerability (i.e., weaker islands' position due to structural problems) or competitiveness (i.e., lower islands' performance compared to non-island states). Key research questions in this respect, characterizing the originality of this work, are: (i) Can a high degree of digitalisation resolve problems related to insularity? Or does the strengthening of digital skills contribute to the resolution of the islands' sustainability problems? (ii) Is the strengthening of technological infrastructure capable of making islands more competitive, and hence less vulnerable, from the standpoint of regional equity? (iii) Is the achievement of the 17 SDGs and the goals of the Digital Decade, drafted by the EU, directly proportionate to the geographical and socio-economic factors of a territory, in this instance islands?

The structure of this work has as follows: section 2 provides an overview of the main structural inefficiencies of six major islands in the Mediterranean and a comprehensive study of the programmes for digitalisation advancements and implementation; while concludes with the theoretical and practical gaps of the digitalisation and sustainability status of these islands. Section 3 describes the steps undertaken for establishing the I_{IPE}, used for both analysing islands' performance in the binomial sustainability/ digitalisation; and studying competitiveness performance between islands and non-island Member States, with a view to achieving EU equity. Section 4 applies these steps to the six case study islands; while Section 5 discusses the results obtained. Finally, in Section 6 conclusions are drawn.

2. Digitalisation policy and SDGs' achievements - State of the art of the Major Mediterranean Islands

Achievement of the 2030 SDGs constitutes a highly-rated political priority in the EU. This is implemented by the SD Strategy, unfolding through a number of legislative acts (SD in the European Union, 2009; COM 640 final, 2019; EUROPE 2020, 2019; Food Safety, 2022). These acts aim at the integration of European policies and commitment towards equity achievements and digital transformation of member states.

Speaking of the insular territories, performance of EU policies as to the aforementioned goals are rather poor, since these territories fall short of becoming part of the EU's envisioned SD trajectories or develop a governance framework that properly addresses structural problems for facilitating achievement of the European goals (European Union, 2022b). In fact, the EU objectives linked to the territorial dimension, such as the: (i) achievement of a spatially balanced SD pattern, (ii) protection and improvement of environmental quality, and (iii) strengthening of the economic, social, and territorial cohesion among EU countries, are more difficult to be attained in insular contexts (European Union, 2022b). This is due to geographical peculiarities and natural barriers that frame islands' developmental potential and result in various forms of inequalities.

Thus, a significant sustainability gap (social, economic and environmental) appears between island and non-island territories (Garau et al., 2022); and is explicitly displayed in various sustainability dimensions.
Critical, in this respect, are insular policies that can establish tight linkages between innovation/digitalisation and sustainability concerns, by clearly illuminating the structural inefficiencies of island regions; and identifying concrete digitalisation targets in support of islands' efforts to align with the 17 SDGs and keep pace with non-insular contexts. Figure 1 shows the interrelationships between island-specific structural issues, as these are demarcated by the Economic and Social Committee (C268/8, 2015) as well as pertinent literature (Analysis of the island regions and outermost regions of the European Union, 2003; Herrera et al., 2018; Garau et al., 2018; Smart Island World Congress, 2018) on the one hand; and the actual problems that insular territories need to address on the other, as these are demonstrated in the case of Sardinia, Italy.
These problems, as shown in Figure 1, address the: (i) environmental dimension (e.g., limited energy sources); (ii) socio-economic dimension (e.g., population decline, an economic environment that discourages the flourishing of entrepreneurship); and (iii) digitalisation dimension (e.g., activating technology in the cultural and creative industry - CCI). Speaking of the digitalisation dimension in particular, this is perceived as an additional structural problem of insular territories, further reinforcing inequalities of island regions both within their territories as well as between them and non-island contexts.

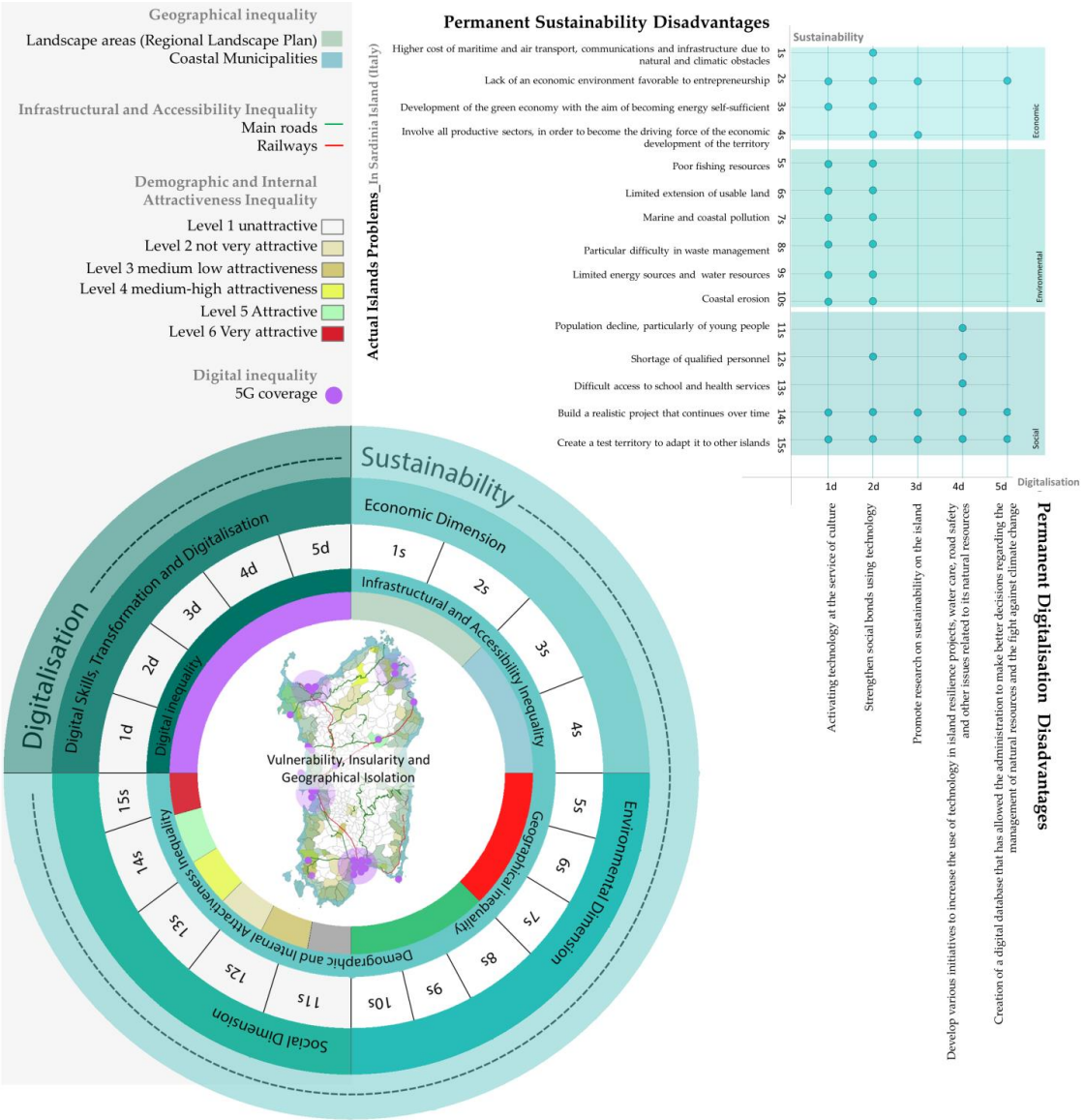

Fig.1 Relationship of digitalisation and sustainability dimensions in island territories and their spatial repercussions in terms of internal island inequalities in the case of Sardinia, Italy

Worth noting is also that the disparities noticed in Sardinia are assessed in the time span 2019-2022, despite the fact that EU islands' policies date back to 2000 (C268/8, 2015). This, in a way, reflects the limited potential of the EU SD policies to fully grasp peculiarities of island territories; and cope with the specific, and of permanent nature, geographical barriers that island regions are confronted with.

Indeed, despite the quite early dedicated endeavours to work out the specific islands' structural problems (e.g., work led by Vincenzo Viola since 1998 on the "Problems of the Island Regions of the European Union" in the context of the "Commission for Regional Policy"), no considerable progress is yet in place; and disparities between island and non-island territories are widened (A4-0118, 1998).

In the light of the Digital Decade in this respect, island territories, in their way to strengthen digitalisation for achieving sustainability gains, need to place efforts in both reaching the EU goals and coping with insularity drawbacks.

This struggle can eventually further deepen the gap between insular and non-island regions in terms of equity and sustainability gains.

In seeking to explore aspects of equity potential of islands regions compared to non-island ones, six main islands in the Mediterranean, namely Sardinia, Sicily, Corsica, and Crete (regions belonging to Italy, France, and Greece, respectively), Malta, and Cyprus (EU Insular Member States) are used as a case study in this work (Figure 2). These islands are emblematic since they: (i) are major islands falling into the same Sea Basin, thus geographically comparable as to the territorial, economic, and environmental strategies for sustainable development; (ii) suffer from similar structural problems as well as vulnerability and barriers to 2030 SDGs' achievement, and (iii) display, through time, similar trends in public and private digitalisation trajectory (Table 1) and related performance in SDGs.

Fig.2 The case study area – The Mediterranean Islands of Sardinia, Sicily, Corsica, Crete, Malta, and Cyprus

Tab.1 summarises the:

i) regulations, protocols and strategies that the case study islands have already implemented with respect to the key DESI topics, e.g., diffusion of digital technologies, digitalisation of Recovery and Resilience Plan (RRP), human capital, connectivity, integration of digital technology, digital public services;

ii) structural problems in common, as displayed in the Sardinia example (Fig.1);

iii) progress in the 17 SDGs (rated as SDGs Achieved, Challenges remain, Significant challenges remain, Major challenges remain and Information unavailable).

In the islands of the study region that are parts of mainland states (Sardinia, Sicily, Corsica, and Crete), the regulations identified apply across the whole country, i.e., at a supra-regional policy level, including islands.

	Regulations, Protocols and Strategies	**Digital Economy and Society Index (DESI) 2022**	**Structural problems common to island regions (Fig. 1)**	**SDGs' Progress (Europe Sustainable Development Report, 2021)** **SDG achieved** **Challenges remain** **Significant challenges remain** **Major challenges remain** **Information unavailable**
Italy (Sicily and Sardinia)	– Cloud Italy. The Cloud of the Public Administration – Minister of Innovation: technological innovation and digital transition – Strategic Programme on Artificial Intelligence 2022-2024 – National Cybersecurity Agency heard the Cybersecurity Nucleus	Diffusion of digital technologies	Digitalisation and Innovation	No Poverty Zero Hunger Good Health and Well-Being Quality Education Gender Equality Clean Water and Sanitation Affordable and Clean Energy Decent work and Economic Growth Industry, innovation and Infrastructure Reduced Inequalities Sustainable cities and communities Responsible consumption and production Climate Action Life below Water Life and Land Pace, Justice and Strong Institution Partnership for the Goals
	– The National Recovery and Resilience Plan (PNRR)	Digital in Recovery and Resilience Plan (RRP)	Digitalisation and Innovation + Environmental, economic transition and social inclusion	
Greece (Crete)	– Operational Programme for the digital transformation 2021-2027 – Digital Transformation Bible 2020-2025	Diffusion of digital technologies	Digitalisation and Innovation	No Poverty Zero Hunger Good Health and Well-Being Quality Education Gender Equality Clean Water and Sanitation Affordable and Clean Energy Decent work and Economic Growth Industry, innovation and Infrastructure Reduced Inequalities Sustainable cities and communities Responsible consumption and production Climate Action Life below Water Life and Land Pace, Justice and Strong Institution Partnership for the Goals
	– Greece's Recovery and Resilience Plan	Digital in Recovery and Resilience Plan (RRP)	Digitalisation and Innovation + Environmental, economic transition and social inclusion	
	– Greek National Coalition for digital skills – Develop your digital skills online!	Human capital	Digitalisation and Innovation + Social inclusion	
	– Ultrafast broadband for internet users throughout Greece	Connectivity	Digitalisation and Innovation	
	– Cyber security – Connect with the Greek start-up ecosystem	Integration of digital technology	Digitalisation and Innovation	
	– Highlight 2021-2022: rapid progress in digital public	Digital public services	Digitalisation and Innovation	

	Regulations, Protocols and Strategies	Digital Economy and Society Index (DESI) 2022	Structural problems common to island regions (Fig. 1)	SDGs' Progress (Europe Sustainable Development Report, 2021) SDG achieved Challenges remain Significant challenges remain Major challenges remain Information unavailable
	services available for citizens and businesses at national level			
France (Corsica)	– France 2030 plan	Diffusion of digital technologies	Digitalisation and Innovation	No Poverty Zero Hunger Good Health and Well-Being Quality Education Gender Equality Clean Water and Sanitation Affordable and Clean Energy Decent work and Economic Growth Industry, innovation and Infrastructure Reduced Inequalities Sustainable cities and communities Responsible consumption and production Climate Action Life below Water Life and Land Pace, Justice and Strong Institution Partnership for the Goals
	– France's Recovery and Resilience Plan	Digital in Recovery and Resilience Plan (RRP)	Digitalisation and Innovation + Environmental, economic transition and social inclusion	
	– Education and digital – The France Very High-Speed Plan (PFTHD) – The Edu-up device – Skills Investment Plan	Human capital	Digitalisation and Innovation + Social inclusion	
	– Stratégie nationale pour l'intelligence Artificielle	Connectivity	Digitalisation and Innovation	
	– Acceleration strategies for innovation – National Cloud Strategy: launch of the industrial support plan for the sector	Integration of digital technology	Digitalisation and Innovation	
	– Perform an administrative procedure on line – The cloud for administrations	Digital public services	Digitalisation and Innovation	
Cyprus	– Digital Strategy 2020-2025 – Digital Skills - National Action Plan 2021-2025 – Cyprus National Broadband Plan 2021-2025 – Cyprus Industrial Strategy Policy – National strategy on Artificial Intelligence – Cybersecurity Strategy of the Republic of Cyprus 2020	Diffusion of digital technologies	Digitalisation and Innovation	No Poverty Zero Hunger Good Health and Well-Being Quality Education Gender Equality Clean Water and Sanitation Affordable and Clean Energy Decent work and Economic Growth Industry, innovation and Infrastructure Reduced Inequalities Sustainable cities and communities Responsible consumption and production Climate Action Life below Water Life and Land Pace, Justice and Strong Institution Partnership for the Goals
	– Cyprus' Recovery and Resilience Plan	Digital in Recovery and Resilience Plan (RRP)	Digitalisation and Innovation + Economic transition and social inclusion	
	– Innovative schools and Educational cores – e-Safe Schools	Human capital	Digitalisation and Innovation + Social inclusion	

	Regulations, Protocols and Strategies	Digital Economy and Society Index (DESI) 2022	Structural problems common to island regions (Fig. 1)	SDGs' Progress (Europe Sustainable Development Report, 2021) SDG achieved Challenges remain Significant challenges remain Major challenges remain Information unavailable
	– National e-Health Authority (NeHA – Cypriot National Contact Point for e-Health (NCPeH)	Digital public services	Digitalisation and Innovation	
Malta	– Strategy and Vision for Artificial Intelligence in Malta 2030 – Supporting the Technology Industry in Malta – Malta's Smart Specialisation Strategy 2021 – 2027 – Digital Malta	Diffusion of digital technologies	Digitalisation and Innovation	No Poverty Zero Hunger Good Health and Well-Being Quality Education Gender Equality Clean Water and Sanitation Affordable and Clean Energy Decent work and Economic Growth Industry, innovation and Infrastructure Reduced Inequalities Sustainable cities and communities Responsible consumption and production Climate Action Life below Water Life and Land Pace, Justice and Strong Institution Partnership for the Goals
	– Pathfinder MDIA Digital Scholarship	Digitalization of Recovery and Resilience Plan (RRP)	Digitalisation and Innovation + Environmental, economic transition and social inclusion	
	– National e-Skills Strategy – Women4IT – EU Code Week – ICT Skills Demand and Supply Monitor – The national employment policy 2021-2030	Human capita	Digitalisation and Innovation + Social inclusion	
	– EPIC Malta mobile and fixed network evolution	Connectivity	Digitalisation and Innovation	
	– Business Re-Engineering and Transformation Scheme	Integration of digital technology	Digitalisation and Innovation	
	– Online guide to government services – MyHealth – MALTA DATA PORTAL – [open.data.gov.mt]	Digital public services	Digitalisation and Innovation + Environmental, economic transition and social inclusion	

Tab.1 Comparison of case study islands in terms of digital regulations, protocols and strategies, DESI key topics, common structural problems and SDGs' progress

Indulging into the information presented in Tab.1 unveils that in case of islands belonging to a state, namely Sardinia, Sicily, Corsica, and Crete, digitalisation processes and infrastructure deployment have a strong national connotation, thus leaving aside the islands' structural problems and barriers to sustainability.

In case of Greece, however, country's RRP seems to better address insularity weaknesses, thus achieving outstanding results in terms of the SDGs "Affordable and Clean Energy", "Decent work and Economic Growth", "Industry, Innovation and Infrastructure" and "Reduced Inequalities".

Similar seems to be the situation in island states. Malta, for example, despite the early implementation of technological transition strategies tightly linked to sustainability has, at first, rather failed to address the EU directions in relation to SDGs.

These early efforts, however, are followed by more dedicated ones, leading in 2018 to "A Strategy and Vision for Artificial Intelligence (AI) in Malta 2030", which forms the ground for digital infrastructure projects that are more promising as to SDGs' achievement by use of AI.

Finally, policies in Cyprus are more focused on international standards than on the island's actual challenges and problems. According to the Cyprus RRP, emphasis is placed on measures that can lead to "rapid, strong and inclusive recovery and an accelerated GDP growth on a sustainable basis through real output growth" (Cyprus RRP, 2021 19-20); while progress is made in the majority of the SDGs (Tab.1).

The above discussion highlights that a successful implementation of digitalisation policies in support of SDGs in insular territories is not yet in place. Efforts carried out so far in the case study islands fail to fully grasp and incorporate inherent disadvantages of insularity in respective digitalisation policies.

This gap needs to be resolved for ensuring equity in digitalisation and sustainability achievements in both islands and mainland states/regions.

An attempt to handle equity concerns, in this respect, is made by the Islands' Potential Equity Index (I_{IPE}) presented in the following, which represents a composite of the digitalisation and sustainability dimensions in island regions, taking into account the structural insularity drawbacks.

3. The Methodological Approach

The Islands' Potential Equity Index (I_{IPE}) is a composite index, emanating from a systematic approach (Abis et al., 2013; Garau et al., 2016, 2018, 2019, 2020).

It attempts to assess the equity dimension with respect to the digitalisation and sustainability processes in island contexts. Particularly in this work, assessment of I_{IPE} follows a two-step approach that serves comparison at the:

(i) Case study level, displaying the diversifying case study islands' equity performance in terms of sustainability and digitalisation (Section 3.1);

(ii) EU level, demonstrating discrepancies in equity performance between island territories and non-island EU states, as well as the EU average I_{IPE} performance, for comprehending the rating of islands' digital and sustainable achievements in the European scenery (Section 3.2).

The I_{IPE} is calculated by use of Formula 1, being the outcome of two core indexes:

(i) Core Index of Islands' Sustainability (I_{IS}), which reflects the level of sustainability achievements of existing strategies, attained in islands' territorial context; including social and economic equity, environmental and infrastructural impacts;

(ii) Core Index of Islands' Digitalisation (I_{ID}), which demonstrates the impacts digital technologies currently have on islands and their future implementation capabilities in the public and private sectors; and highlights the islands' digitalisation potential to resolve current inadequacies.

$$I_{IPE} = I_{IS} + I_{ID} \quad (1)$$

I_{IPE} displays how sustainability and digitalisation aspects are interconnected. It is calculated by a normalisation of factors that fall into each sub-index I_{IS} and I_{ID}; and is the outcome of their arithmetic mean (Momeni & Antipova, 2022; Wang et al., 2022).

More specifically, the two core sub-indexes I_{IS} and I_{ID} are specified through six dimensions, namely the:

- social, environmental and economic for the IIS, and
- skills, digitalisation of public/private domains and digital infrastructure for IID,

which are further specified by use of the state of the art of literature-based indicators (Ciccarelli, 2003; Gismondi & Russo, 2004; Abis et al., 2013; Mazziotta et al., 2010; González et al., 2015).

In particular, the above first three dimensions, incorporated in I_{IS} index, highlight the island's state of sustainability as the outcome of already implemented programs, actions, and strategies for improving internal well-being. The value of the I_{IS} core index (Formula 2) is the sum of three main constituents (sub-indexes), namely the: I_{SOS} for the social factor, I_{ENS} for the environmental and I_{ECS} for the economic one; divided by 14, which represents the number of indicators used to describe I_{IS}.

$$I_{IS} = (I_{SOS} + I_{ENS} + I_{ECS})\ (1/14) \quad (2)$$

The next three dimensions, falling into I_{ID}, represent the digital penetration by means of digital infrastructure, digitalisation of public/private sectors and digital skills. The value of the I_{ID} core index (Formula 3) is the sum of three main constituents (sub-indexes), namely the: I_{DS} for digital personal skills; I_{DTD} for digitalisation of processes in companies, research institutions and administrative bodies of public/private sectors; and I_{DI} for digital infrastructure. The sum of the three variables is divided by 14 (number of indicators used to describe I_{ID}).

$$I_{ID} = (I_{DS} + I_{DTD} + I_{DI})\ (1/14) \quad (3)$$

In Table 2, the values of 28 literature-based indicators (Column 3) (Bohme, et al., 2011; The Development of the Islands, 2013; Garau et al., 2020b), used for calculating the six sub-indexes of Formula 2 and 3 (Column 2) and thus I_{IS} and I_{ID}, are presented.

With regard to the selection of the aforementioned indicators, the following can be noticed:

- core index IIS: selection of indicators for assessing the sub-indexes ISOS, IENS and IECS that are summed to provide the IIS value is justified by a large number of recent literatures on well-being and sustainability topics at the regional level (indicative literature examples are IAEG-SDGs, 2020; EU 2030 Agenda, 2020);
- core index IID: indicators used for assessing the sub-indexes IDS, IDTD, and IDI summing up to the IID value represent both the cornerstones of the EU "Path to the Digital Decade" and the islands' attitude towards innovation.

Data on indicators of Tab.2 are collected from the Eurostat Regional Yearbook (2022) and the Eurostat Data Browser (2022a, 2022b, 2022c); and refer to regional data (NUTS II) for Sardinia, Sicily, Crete and Corsica and national data (NUTS I) for Malta and Cyprus, thus providing an island-centric perspective in I_{IPE} assessment.

Dimensions (Variables) of core indexes I_{IS} and I_{ID}	**Sub-indexes for assessing the core indexes I_{IS} and I_{ID}**	**Indicators used for assessing sub-indexes**	**Sicily**	**Crete**	**Corsica**	**Cyprus**	**Malta**	**Sardinia**	**Luxembourg**	**Finland**	**European average**
Core Index of Islands' Sustainability (I_{IS})											
Social State	I_{SOS}	*Material and social deprivation rate*	20	34.7	13.1	13.3	9.9	20	3.4	4.90	12.4
		Tertiary educational attainment	19.5	37.5	28.9	57.8	40.2	24.8	60.6	34.08	40.2
		Employment rate of recent graduates from vocational programmes	24.8	45.3	DnA	59	89.5	42.2	100	57.97	79.1

Dimensions (Variables) of core indexes I_{IS} and I_{ID}	Sub-indexes for assessing the core indexes I_{IS} and I_{ID}	Indicators used for assessing sub-indexes	Sicily	Crete	Corsica	Cyprus	Malta	Sardinia	Luxembourg	Finland	European average
		Reduction in the at-risk-of-poverty rate after social transfers	6.1	6.5	9.9	8	6.1	4.8	9	13.56	7.9
		Life expectancy at birth	82.1	82.1	84	82.5	82.6	83.5	82.4	49.14	81.1
Environmental State	I_{ENS}	Share of organic farming in utilised agricultural area	26.1	2.3	4.4	3.1	0.2	8.5	3.5	82.22	7.1
		Exposure to air pollution by fine particulate matter	11.54	14.08	8.45	14.50	12.50	9.71	10	5.19	14.5
		Soil loss by water erosion	11.58	7.98	9.35	3.00	4.30	4.71	2.1	0	2.5
		Railway density	53	0	27	0	0	18	105	27.75	100
		Number of passengers carried per 1 000 inhabitants	3.729	16.899	12.285	12.681	14.222	5.645	6973	3.293	2 312
Economic State	I_{ECS}	GDP per inhabitant	58	57	86	90	100	69	260	110	100
		Average annual rate of change of gross value added	-0.4	2.1	3	4.2	5.2	0.6	2.5	0.48	1.8
		Nights spent in tourist accommodation by origin	50.5	96	29.4	94.2	95.2	51	87.8	33.12	47.3
		Primary income per inhabitant	12.1	11.4	17.5	16.7	DnA	13.9	30.4	73.4	19.5
Core Index of Islands' Digitalisation (I_{ID})											
Digital Skills	I_{DS}	Daily internet users	68	71	76	88	83	72	92	73.4	80
		People participating in social networks	44	64	34	78	72	47	60	59.8	57
		People using internet banking	26	38	63	52	60	36	71	73.6	58
		Individuals who used the internet for interaction with public authorities	27	51	83	57	63	35	78	70.8	100
		Individuals who have never used a computer	42	DnA	11	21	18	32	**2**	**3.6**	100
		People ordering goods or services over the internet for private use	33	46	56	47	63	44	79	60.4	65
Digitalisation of public / private sectors	I_{DTD}	Human resources in science and technology	29.8	31.8	49.9	51.2	45.9	32	62.5	54.48	47.2
		R&D personnel	0.7	1.6	1.7	0.5	0.7	0.7	2	1.6	1.5
		Employment in technology and knowledge-intensive sectors	45.5	3	DnA	8.6	10.2	21.8	7,5	33,42	100
		R&D personnel and researchers by	10,90	3,959	DnA	2,121	1,588	4,121	5,790	10,299	2,964,580

Dimensions (Variables) of core indexes I_{IS} and I_{ID}	Sub-indexes for assessing the core indexes I_{IS} and I_{ID}	Indicators used for assessing sub-indexes	Sicily	Crete	Corsica	Cyprus	Malta	Sardinia	Luxembourg	Finland	European average
		sector of performance									
		R&D researchers in the business enterprise sector	30.5	10.2	61.9	33.4	56.2	19.5	39,6	60,08	54.8
Digital Infrastructures	I_{DI}	R&D expenditure per inhabitant	146.2	210.6	773.4	154	156.9	170.1	1170,3	926,42	660.9
		Annual change in the share of persons usually working from home	6.2	3.7	DnA	3.2	8.7	7.5	11,6	8,44	6.9
		Percentage of households with broadband access in relation to households with internet access	98	DnA	87	100	100	97	98	99	100

* In italics = indicator expresses an inefficiency (the value of the indicator takes a negative sign in calculations)
In bold = indicator values taken from the Eurostat Data Browser (indicators not in bold were taken from the Eurostat Regional Yearbook)
DnA = data not available

Tab.2 Dimensions of core indexes, sub-indexes and indicators in the studied insular contexts – Comparison with Luxembourg, Finland and the EU average*

Tab.2 contains, additionally, respective indicators' values for Finland and Luxembourg in order for a direct comparison between islands and non-island European states to be served. Finland is selected as the state rated first in the DESI ranking; while Luxembourg as the one disposing the highest DESI index among the purely continental EU states (no insular part or sea border). This allows for a better insight when comparing equity performance among islands, nations with no islands or sea boundaries as well as nations disposing insular parts.

For assessing equity aspects of islands with respect to the EU member states, Formula 4 is applied to each indicator value relating to the case study islands (Tab.2, values in Columns 4 to 9), and the European average (Tab.2, values in Column 12).

$$\textit{European average: } 100 = \textit{Island Sub-indicators: } X \tag{4}$$

Assessments of islands' equity perspective in terms of sustainability and digitalisation in the aforementioned two-step approach – case study and EU level – are presented in the following.

3.1 Case study level – Analysis of current sustainability and digitalisation performance of studied islands

To simplify the analysis/comparison at the case study level, the values of each core index I_{IS} and I_{ID} (derived by Formulas 2 and 3 respectively) are converted to a percentage. Fig.3 depicts the I_{IPE} as an interpretative circular diagram (Adenle et al., 2020) with a maximum value of 100%.

This is divided into two parts, each reflecting respectively the contribution of sustainability I_{IS} and digitalisation I_{ID} to I_{IPE}; and being assigned a share from 0% to 50% (Fig.3a). This choice is supported by the DESI indicators (DESI Key Indicators, 2022); and the SDG global indicators (SDG Indicators, 2022); and is implemented by Formulas 5 and 6, used to calculate the aforementioned share, i.e., the contribution of sustainability I_{IS} (%) and digitalisation I_{ID} (%) achievements to the value of I_{IPE}.

Formula 7 calculates I_{IPE} as a percentage, allowing for a graphical analysis of each island's sustainability and digitalisation state.

$$I_{IS}\ (\%) \quad 100 : I_{IS} = 50 : X \tag{5}$$
$$I_{ID}\ (\%) \quad 100 : I_{ID} = 50 : X \tag{6}$$
$$I_{IPE}\ (\%) = [I_{IS}\ (\%) + I_{ID}\ (\%)] \tag{7}$$

Fig.3b demonstrates the way the different performance of core indexes I_{IS} and I_{ID} is interpreted, namely:

- A performance range from 0% to 12.5% indicates insufficient sustainability (I_{IS}) and digitalisation (I_{ID}) strategies; and a need for a thorough revision in order for more robust policies to be established in these fields;
- A performance range from 12.5% to 25% manifests that despite potential for improvement, islands are currently falling short to achieve the EU sustainability and digitalisation objectives;
- A performance range from 25% to 37.5% demonstrates a promising current combination of sustainability and digitalisation policies, capable of delivering fruitful outcomes. However, islands' structural problems impede further improvements;
- Finally, a performance ranges from 37.5% to 50% demonstrates that current strategies, referring to the 2030 Agenda (in case of I_{IS}) and the Digital Decade (for I_{ID}) are producing satisfactory results and that islands are taking important steps towards the achievement of relevant objectives.

The central blue arrow in Fig.3b represents the overall view delivered by the Islands' Potential Equity Index (I_{IPE}), summing up the performance of core indexes I_{IS} and I_{ID}, and is interpreted as follows:

- A value from 0% to 25% denotes a quite low performance of current sustainability and digitalisation policies and a need for their complete redesign;
- A value from 25% to 50% and 50% to 75% denotes a low and a medium performance respectively. These performance ranges identify islands that have active regulatory tools on sustainability and digitalisation, but lack successful linkages of digitalisation strategies to structural drawbacks of islands;
- Finally, a value from 70% to 100% implies a governance structure and related policies that can successfully perform in sustainability and digitalisation domains, thus leading to a high level of islands' equity potential.

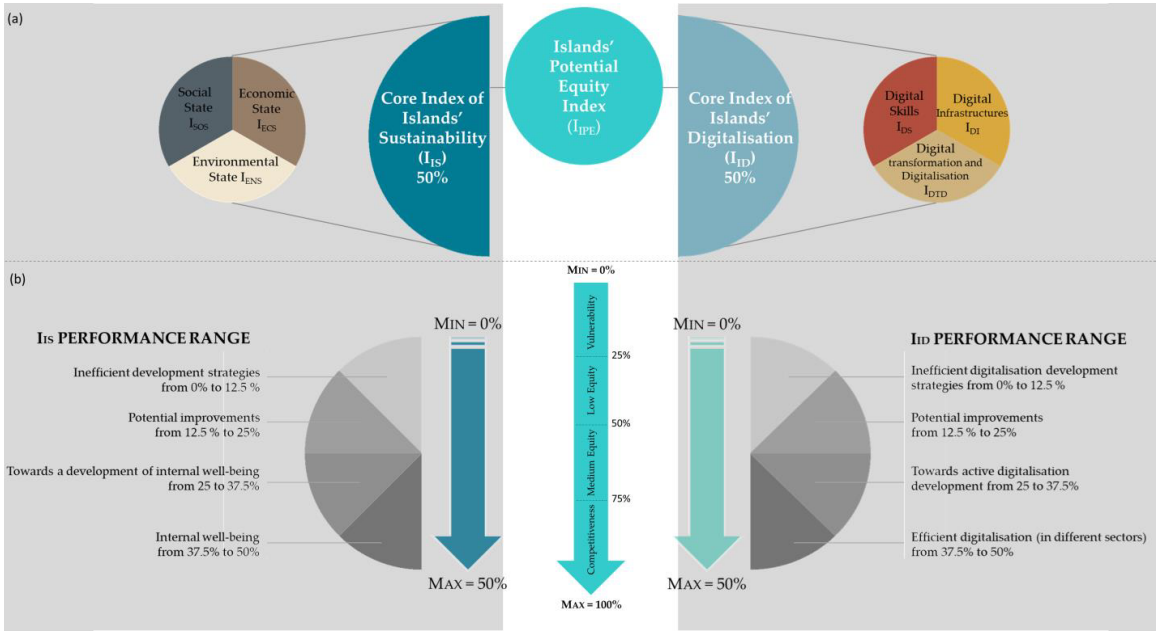

Fig.3 Schematic representation of the Islands' Potential Equity Index (IIPE) and thresholds of its two core sub-indexes IIS and IID.

3.2 EU level - Comparative analysis of island and non-island EU states: vulnerability or competitiveness?

This section presents the methodology used for assessing competitiveness or vulnerability of island territories in comparison to the European average. Values of indicators are calculated by use of Formula 4 and are subsequently classified in 9 classes (Tab.3, Column 1).

Column 2 of Tab.3 shows the classes obtained from the Eurostat Regional Yearbook (2022). The nine classes are used for all indicators. In case that an indicator expresses a certain inefficiency, e.g., the "material and social deprivation rate" (in italics in Tab.2), the value of the class is reversed, i.e., if the value is 9 it becomes 1, if it is 8 it becomes 2, etc., so that the indicator's value remains always positive (Atlas of the Islands, 2013).

Classes	Classes defined by the Eurostat Yearbook =9	
0	Data not available	0
1	< 65	1
2	65 - < 75	2
3	75 - < 85	3
4	85 - < 95	4
5	95 - < 105	5
6	105 - < 115	6
7	115 - < 125	7
8	125 - < 135	8
9	> 135	9

Tab.3 Classes adopted for the construction of the Islands' Potential Equity Index (I_{IPE}), in alignment with classes used in the Eurostat Regional Yearbook, 2022

After calculating the classes of each variable, Fig.4 depicts an interpretative positioning matrix (Abis et al., 2013; Garau et al., 2016; Pinna et al., 2017; Garau et al., 2020), constructed by use of indicators.

The classes obtained are converted into a pair of coordinates, useful for positioning each island within a grid (Fig.4a), where the Core Index of Islands' Sustainability (I_{IS}) is measured on the ordinate axis and the Core Index of Islands' Digitalisation (I_{ID}) is reflected on the abscissa axis.

In particular, each indicator that falls into the different variables has the same weight during its normalisation.

The intersection between the abscissa and the ordinate axis generates four quadrants, each of which provides a concrete description of the situation of the European islands in terms of their equity potential I_{IPE} as a consequence of I_{IS} and I_{ID}.

In particular, in terms of equity performance, the most vulnerable islands are located in the Quadrant 1 (Fig.4b) and display relatively low values for both core indexes I_{IS} and I_{ID}, i.e., sustainability and digitalisation.

Islands falling in this quadrant need to put in place more effective policies in order to achieve results equivalent to the EU average.

Quadrant II incorporates islands that despite well-performing in terms of digitalisation and related infrastructure, they fail to utilise them for developing strategies that promote sustainability objectives. Quadrant III contains islands that perform pretty well in terms of sustainability but poorly in terms of the digitalisation in regard to the EU average.

In this quadrant fall islands that may improve their equity performance by using digitalisation consolidation strategies. Finally, Quadrant IV contains islands that are highly competitive by means of their outstanding sustainability and digitalisation performance, compared to the non-island nations of the European Union.

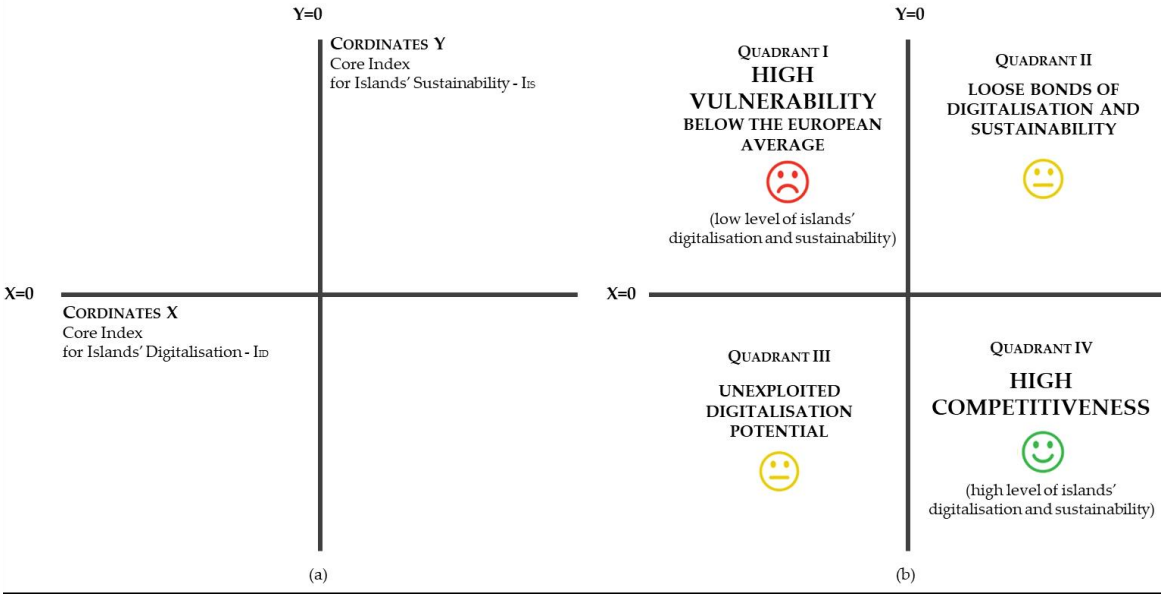

Fig.4 Positioning matrix of core indexes I_{IS} and I_{ID}: (a) interpretative matrix; (b) quadrants' matrix values

4. Results

The above-described methodology provides an explanatory framework for assessing effectiveness of policies and strategies of insular contexts towards harmonization with the current inspiring EU sustainability and digitalisation objectives.

In fact, the dimensions of core indexes I_{IS} and I_{ID}, the sub-indexes for estimating these dimensions and the indicators used for assessing sub-indexes and, through them, the core indexes I_{IS} and I_{ID} (see Tab.2) are in alignment with the directions of both the DESI Key Indicators (2022) and the Agenda 2030 SDGs.

The values obtained for each case study island and the two non-island nations are compared to the EU average (Tab.4).

Dimensions (Variables) of core indexes I_{IS} and I_{ID}	**Sub-indexes for assessing the core indexes I_{IS} and I_{ID}**	**Indicators used for assessing sub-indexes**	**Sicily**	**Crete**	**Corsica**	**Cyprus**	**Malta**	**Sardinia**	**Luxembourg**	**Finland**
Core Index of Islands' Sustainability (I_{IS})										
Social State	I_{SOS}	*Material and social deprivation rate*	-161.29	-279.84	-105.65	107.26	-79.84	-161.29	-27.42	-39.52
		Tertiary educational attainment	48.51	93.28	71.89	143.78	100.0	61.69	150.75	84.78
		Employment rate of recent graduates from vocational programmes	31.35	57.27	0.00	74.59	113.15	53.35	126.42	73.28
		Reduction in the at-risk-of-poverty rate after social transfers	77.22	82.28	125.32	101.27	77.22	60.76	113.92	171.65
		Life expectancy at birth	101.23	101.23	103.58	101.73	101.85	102.96	101.60	60.59

Dimensions (Variables) of core indexes I_{IS} and I_{ID}	Sub-indexes for assessing the core indexes I_{IS} and I_{ID}	Indicators used for assessing sub-indexes	Sicily	Crete	Corsica	Cyprus	Malta	Sardinia	Luxembourg	Finland
Environmental State	I_{ENS}	Share of organic farming in utilised agricultural area	367.61	32.39	61.97	43.66	2.82	119.72	49.30	1158.03
		Exposure to air pollution by fine particulate matter	-79.59	-97.10	-58.28	-100.00	-86.21	-66.97	68.97	35.76
		Soil loss by water erosion	-463.20	-319.20	-374.00	-120.00	-172.00	-188.40	84.00	0.00
		Railway density	53.00	0.00	27.00	0.00	0.00	18.00	105.00	27.75
		Number of passengers carried per 1 000 inhabitants	161.29	730.93	531.36	548.49	615.14	244.16	301.60	142.42
Economic State	I_{ECS}	GDP per inhabitant	58.00	57.00	86.00	90.00	100.00	69.00	260.00	110.00
		Average annual rate of change of gross value added	-22.22	116.67	166.67	233.33	288.89	33.33	138.89	26.67
		Nights spent in tourist accommodation by origin	106.77	202.96	62.16	199.15	201.27	107.82	185.62	70.02
		Primary income per inhabitant	62.05	58.46	89.74	85.64	0.00	71.28	155.90	376.41
Core Index of Islands' Digitalisation (I_{ID})										
Digital Skills	I_{DS}	Daily internet users	85.00	88.75	95.00	110.00	103.75	90.00	115.00	91.75
		People participating in social networks	77.19	112.28	59.65	136.84	126.32	82.46	105.26	104.91
		People using internet banking	44.83	65.52	108.62	89.66	103.45	62.07	122.41	126.90
		Individuals who used the internet for interaction with public authorities	27.00	51.00	83.00	57.00	63.00	35.00	78.00	70.80
		Individuals who have never used a computer	-42.00	0.00	-11.00	-21.00	-18.00	-32.00	-2.00	-3.60
		People ordering goods or services over the internet for private use	50.77	70.77	86.15	72.31	96.92	67.69	121.54	92.92
Digitalisation of public / private sectors	I_{DTD}	Human resources in science and technology	63.14	67.37	105.72	108.47	97.25	67.80	132.42	115.42
		R&D personnel	46.67	106.67	113.33	33.33	46.67	46.67	133.33	106.67
		Employment in technology and knowledge-intensive sectors	45.50	3.00	0.00	8.60	10.20	21.80	7.50	33.42

Dimensions (Variables) of core indexes I_{IS} and I_{ID}	Sub-indexes for assessing the core indexes I_{IS} and I_{ID}	Indicators used for assessing sub-indexes	Sicily	Crete	Corsica	Cyprus	Malta	Sardinia	Luxembourg	Finland
		R&D personnel and researchers by sector of performance	0.37	0.13	0.00	0.07	0.05	0.14	0.20	0.35
		R&D researchers in the business enterprise sector	55.66	18.61	112.96	60.95	102.55	35.58	72.26	109.64
Digital Infrastructures	I_{DI}	R&D expenditure per inhabitant	22.12	31.87	117.02	23.30	23.74	25.74	177.08	140.18
		Annual change in the share of persons usually working from home	89.86	53.62	0.00	46.38	126.09	108.70	168.12	122.32
		Percentage of households with broadband access in relation to households with internet access	98.00	0.00	87.00	100.00	100.00	97.00	98.00	99.00

Tab.4. Normalized average values of islands and non-island member states compared to the European average (calculated by Formula 4)

Tab.5 shows the sum of the values of each indicator shown in Tab.2, calculated using: Formula 2 for the Core Index I_{IS}, Formula 3 for the Core Index I_{ID} and finally Formula 1 for the Equity Index I_{IPE}.

The I_{IPE} values are rounded up. In case an indicator expresses a certain island's inefficiency (marked in italics in Tab.4), the respective class value is subtracted and not added in the overall calculation.

The I_{IPE} (Tab.5, row 4) serves for: analysing equity performance among the case study islands and comparing their individual performance to the EU average as well as the non-island member states. Such comparisons are presented in the following Sections 4.1 and 4.2 respectively.

	Sicily	Crete	Corsica	Cyprus	Malta	Sardinia	Luxembourg	Finland
Formula 2 Core Index of Islands' Sustainability (I_{IS})	24.34	59.74	56.27	92.46	90.16	37.53	64.67	138.68
Formula 3 Core Index of Islands' Digitalisation (I_{ID})	47.44	47.83	68.39	58.99	70.14	50.62	94.94	86.48
Formula 1 Islands' Potential Equity Index (I_{IPE})	71.77	107.57	124.66	151.45	160.30	88.15	159.61	225.15

Tab.5 Partial (I_{IS} and I_{ID}) and overall (I_{IPE}) equity performance of case study islands and the two non-island states

4.1 Vulnerability and competitiveness of case study islands

In order to illustrate the core indexes I_{IS} and I_{ID} and the I_{IPE} in an interpretive circular diagram, the percentages of their previously displayed values are determined, using Formulas 5 (I_{IS}), 6 (I_{ID}) and 7 (I_{IPE}) (Tab.6).

Each value of the two core indexes (I_{IS} and I_{ID}) (Tab.6, rows 2 and 3) represents % performance in sustainability and digitalisation fields respectively, ranging from 0% to 50% (maximum value for each core index).

	Sicily	Crete	Corsica	Cyprus	Malta	Sardinia	Luxembourg	Finland
Formula 5 (I_{IS} in %) – Core Index of Islands' Sustainability	12	30	28	46	45	19	32	69
Formula 3 (I_{ID} in %) – Core Index of Islands' Digitalisation	24	24	34	29	35	25	47	43
Formula 1 (I_{IPE} in %) – Islands' Potential Equity Index	36	54	62	75	80	44	80	113

Tab.6. Partial (I_{IS} and I_{ID}) and overall (I_{IPE}) equity performance of major Mediterranean case study islands, Luxembourg and Finland in percentages

Row 4 of Table 6 shows the overall islands' performance (I_{IPE}) in terms of territorial equity potential. The performance of the two non-island nations – Luxembourg and Finland – is also calculated. In Figure 5, a visualization of outputs of Table 6 is provided.

I_{IPE} assessments (Tab.6 and Fig.5) reveal a certain grouping of case study islands. Islands of the first group (Crete - 54%, Corsica - 62% and especially Cyprus - 75% and Malta – 80%) seem to perform well in terms of I_{IPE} achievement; while islands of the second one (Sicily – 36% and Sardinia – 44%) are rather left behind and need to strengthen policy efforts in order for a higher level of equity and competitive development to be attained.

Additionally, Cyprus and Crete have the lowest I_{ID} (29% and 24% respectively) in comparison with their I_{IS} (46% and 30%), highlighting a certain deficit in digitalisation policies in their territories. Corsica (I_{ID} 28% and I_{IS} 34%) implements the national (French) strategies for coping with the sustainability/digitalisation dichotomy.

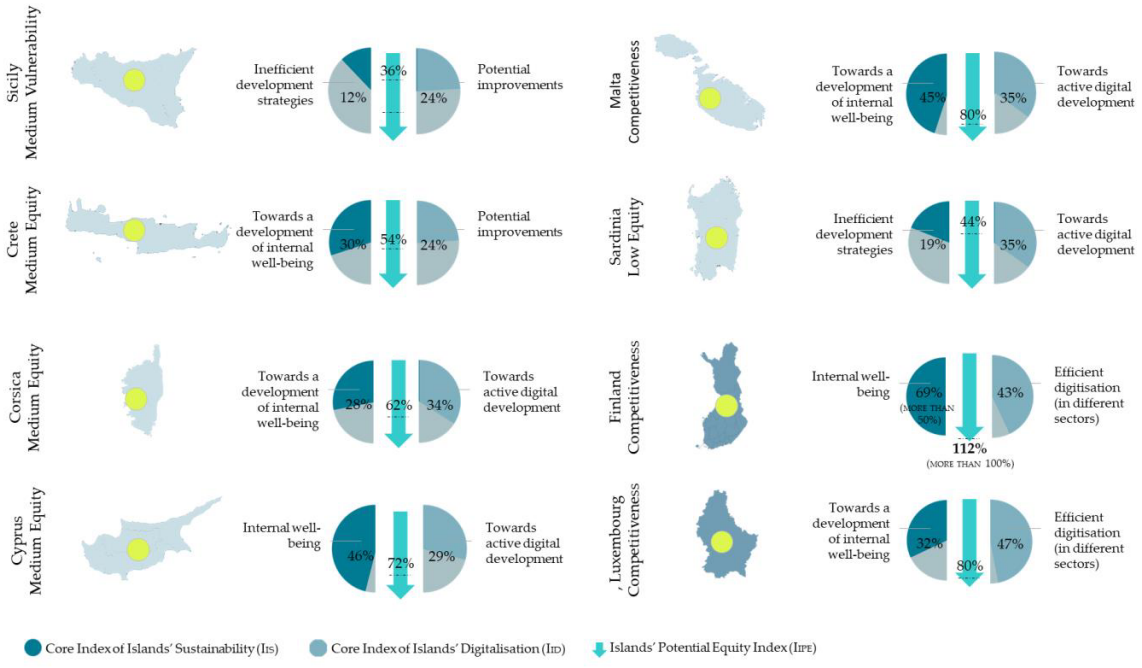

Fig.5 Potential equity performance of case study islands and the non-island EU states of Luxembourg and Finland.

French legislation however, influenced by the strategies for Overseas Departments, contains certain barriers to sustainability policies at the national level, including Corsica.

Low I_{IPE} performance of Sardinia and Sicily (44% and 36% respectively) is attributed to various inadequacies that severely impede high sustainability gains (I_{IS} in Sardinia 19%, Sicily 12%); while the great attention in digitalisation at a national level has positively affected performance in this field as shown by I_{ID} (Sardinia 35%, Sicily 24%).

Based on the structural similarities of case study island areas, certain good practices of those better performing can be replicated by the rest of them.

As such can be considered those e.g., of Malta Island, which, with an equity potential of 80%, seems to be comparable with the EU non-island members.

In fact, the Maltese government has a more than a decade-long history of integrating sustainability objectives and digitalisation policies, further strengthened over the past five years (Strategy and Vision for Artificial Intelligence in Malta 2030, 2019).

This is supported by the values of I_{IS} (45%), witnessing that persisted political action copes effectively with insularity problems, resulting in considerable gains in sustainability; and I_{ID} (35%) unveiling adoption of digitalisation policies that are capable of achieving an outstanding level of performance in terms of the Island's "Digital Decade" goals.

Good practices can also be drawn from non-island states that include islands in their territorial jurisdiction and reach a high level of sustainability and digitalisation performance.

Finland, for example, shows excellent achievements in I_{IS} (50%), exceeding the EU average; and a challenging I_{ID} (43%).

Since 1981, Finnish islands are under the Island Development Act (Finland Island Policy, 2022), ensuring accessibility to transport, services etc. and safeguarding the social, economic and geographic integrity of island areas (Finland Rural and Island Policy, 2022). Furthermore, appointment of the Island Committee in 2008 has upgraded priorities towards a fair development of island areas.

4.2 Comparison between EU non-island states and case study islands

Variables and indicators selected for calculating each core index I_{IS} and I_{ID} set the ground for comparing sustainability and digitalisation performance of islands and analysing their vulnerability and competitiveness in relation to the two selected EU non-island countries.

These assessments can shed light on the structural drawbacks of island territories and related barriers to sustainability and digitalisation performance; and the strategies/actions needed for accelerating sustainable and digital transition as well as joining efforts of the European Commission towards an equitable well-being across the EU (Reform Support, 2022).

Such a comparison is based on results of Tab.4. Classes for each sub-indicator in relation to the European situation for all islands are displayed in Tab.7; while in Tab.8 coordinates for each case study island are displayed.

In Fig.6, results of each single case study Mediterranean island and the two non-island EU countries are located in a methodological grid, using I_{IPE}.

Considering digitalisation advances (I_{ID} performance in X axis) and sustainability achievements (I_{IS} performance in Y axis) of EU average and non-island member states (Fig.6), case study islands seem generally to fall, more or less, short, especially when compared with the two – highly-performing – non-island countries. This unveils the islands' fragility to efficiently address EU sustainability and digitalisation objectives. In addition, it implies a certain failure of the EU policies to properly handle structural deficits of insularity; while, despite the efforts of island regions to keep pace with EU sustainability and digitalisation objectives, insularity barriers condemn them to be in the "tail" of the European territory in terms of performance outcomes.

Dimensions (Variables) of core indexes I_{IS} and I_{ID}	Sub-indexes for assessing the core indexes I_{IS} and I_{ID}	Indicators used for assessing sub-indexes	Sicily	Crete	Corsica	Cyprus	Malta	Sardinia	Luxembourg	Finland
Core Index of Islands' Sustainability (I_{IS})										
Social State	I_{SOS}	*Material and social deprivation rate*	1	1	1	1	1	1	3	9
		Tertiary educational attainment	1	4	2	9	5	1	9	3
		Employment rate of recent graduates from vocational programmes	1	1	0	2	6	1	8	2
		Reduction in the at-risk-of-poverty rate after social transfers	3	3	8	5	3	1	6	9
		Life expectancy at birth	5	5	5	5	5	5	5	1
Environmental Stateì	I_{ENS}	Share of organic farming in utilised agricultural area	9	1	1	1	1	7	1	9
		Exposure to air pollution by fine particulate matter	1	1	1	1	1	1	8	9
		Soil loss by water erosion	1	1	1	1	1	1	7	9
		Railway density	1	0	1	0	0	1	6	1
		Number of passengers carried per 1 000 inhabitants	9	9	9	9	9	9	9	9
Economic State	I_{ECS}	GDP per inhabitant	1	1	4	4	5	2	9	6
		Average annual rate of change of gross value added	1	7	9	9	9	1	9	1
		Nights spent in tourist accommodation by origin	6	9	1	9	9	6	9	2
		Primary income per inhabitant	1	1	4	4	0	2	9	9
Core Index of Islands' Digitalisation (I_{ID})										
Digital Skills	I_{DS}	Daily internet users	4	4	5	6	5	4	7	4
		People participating in social networks	3	6	1	9	8	3	6	5
		People using internet banking	1	2	6	4	5	1	7	8
		Individuals who used the internet for interaction with public authorities	1	1	3	1	1	1	3	2
		Individuals who have never used a computer	1	1	1	1	1	1	1	1
		People ordering goods or services over the internet for private use	1	2	4	2	5	2	7	4
Digitalisation of public / private sectors	I_{DTD}	Human resources in science and technology	1	2	6	6	5	2	8	7
		R&D personnel	1	6	6	1	1	1	8	6

Dimensions (Variables) of core indexes I_{IS} and I_{ID}	Sub-indexes for assessing the core indexes I_{IS} and I_{ID}	Indicators used for assessing sub-indexes	Sicily	Crete	Corsica	Cyprus	Malta	Sardinia	Luxembourg	Finland
		Employment in technology and knowledge-intensive sectors	1	1	0	1	1	1	1	1
		R&D personnel and researchers by sector of performance	1	1	1	1	1	1	1	1
		R&D researchers in the business enterprise sector	1	1	6	1	5	1	2	6
Digital Infrastructures	I_{DI}	R&D expenditure per inhabitant	1	1	7	1	1	1	9	9
		Annual change in the share of persons usually working from home	4	1	0	1	8	6	9	8
		Percentage of households with broadband access in relation to households with internet access	5	0	4	5	5	5	5	5

Tab.7 Classes and coordinates of indicators described in Tab.3

	Coordinates (X) Core Index of Islands' Sustainability (I_{IS})		Coordinates (Y) Core Index of Islands' Digitalisation (I_{ID})	
		values rounded up		values rounded up
Sicily	2.93	3	1.86	2
Crete	3.14	3.5	2.07	2.5
Corsica	3.36	3.5	3.57	4
Cyprus	4.29	4.5	2.86	3
Malta	3.93	4	3.71	4
Sardinia	2.79	3	2.14	2.5
Luxembourg	7	7	5.29	5.5
Finland	5.64	6	4.79	5

Tab.8 Coordinates X and Y for each case study island and the non-island EU states

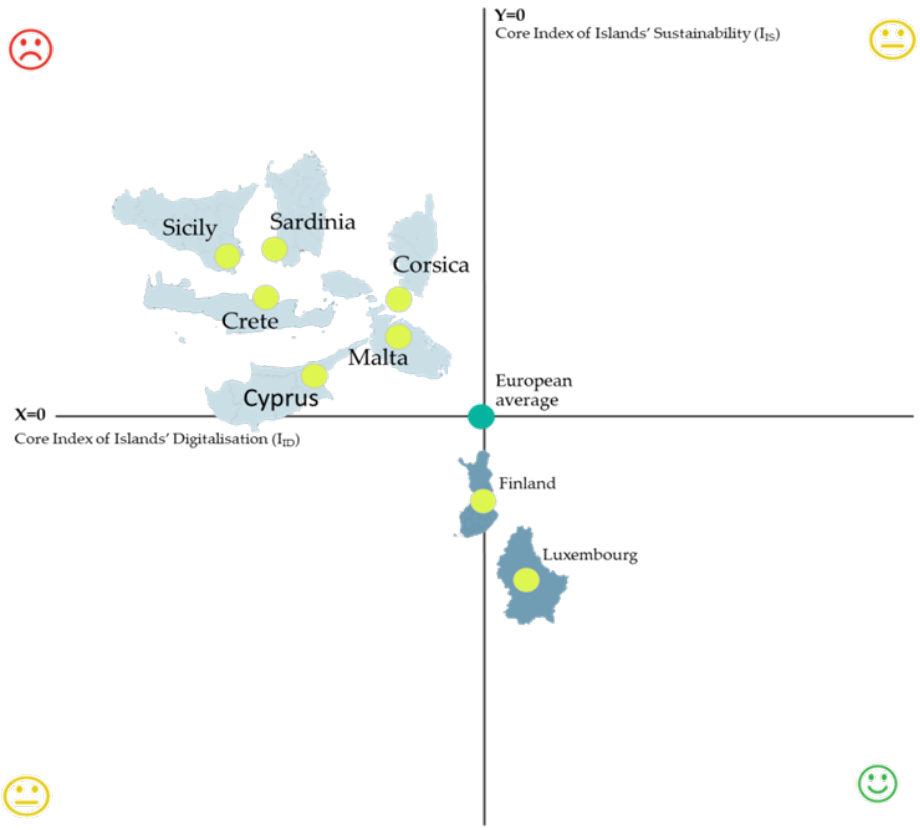

Fig.6 Position of islands and the two non-island EU countries in the methodological grid – Relationship between Core Index of Islands' Sustainability (I_{IS}) and Core Index of Islands' Digitalisation (I_{ID}).

5. Discussion

In the previous sections are analysed the digitalisation and sustainability performance of major Mediterranean islands that enables the comprehension of the islands' current achievements and their comparison to the EU average and non-island states. The key findings are summarized as follows:

- Integration of digitalisation and sustainability policies. Taking into account the role of digitalisation in achieving sustainability gains, strengthening their bonds in the policy realm and related interventions can enrich efforts of island regions towards a more efficient handling of insularity barriers for achieving higher rates of equity potential. This implies the need for a joint study of digitalisation processes, sustainability objectives and insularity disadvantages. An insularity-driven and strongly interwoven sustainability and digitalisation policy framework, in this respect, can add value to handling insularity constraints and aligning with EU directions, as shown by the Malta example;
- The need for insularity-focused policy interventions – Island-states vs islands belonging to a state. Comparison of case study islands' achievements highlights the higher performance of island-states, i.e., Malta and Cyprus. This is mainly due to the more focussed and nation-wide policies that take into account structural problems, and are tightly linked to insularity connotations of island territories. Such a focussed policy seems to be a precondition for achieving the EU sustainability and digitalisation objectives. In contrast, island non-state regions are subject to nation-wide policies that largely ignore peculiarities and structural disadvantages of island territories, a fact that is largely reflected in related performance of these islands (Section 4.1);
- Ability of digital innovation to impact sustainability of island contexts over the long-term. The digital transformation process and related efforts differ between island contexts and non-island countries, as shown by comparative analyses of equity potential between the case study islands on the one hand, and Luxembourg, Finland and the European average on the other (Section 4.2). In fact, insular regions are

confronted with greater challenges as to the: development/promotion of services in line with structural and geographical peculiarities; benefits reaped from projects that have a nation-wide focus and engage a range of administrative bodies, which often lack adequate knowledge on islands' territorial peculiarities (the supra-regional policy context, as in island regions such as Sardinia, Sicily, Corsica and Crete); and resource availability – financial and human – for the development/maintenance of digital infrastructure and services. Establishment of long-term strategies, in this respect, presupposes proper adjustments of digitalisation processes to the distinct territorial features of islands and their limitations.

Furthermore, results of Section 4 demonstrate that digitalisation policy in island contexts – from enhancing connectivity and the relationship between citizens and public administrations to the promotion of innovative actions in the business ecosystem and digital skills' enhancement – still needs to fill several gaps in terms of alignment with the 17 SDGs. In fact, the 17 SDGs in Europe are increasingly pursued through various digitalisation pathways, bringing on board benefits on data accessibility/dissemination, and communication/interaction among different stakes and stakeholders (citizens, administrators, politicians, planners, etc.), issues in which island regions are generally lagging behind due to the (geographical) isolation. The latter has severe socioeconomic effects, hence reducing the equity potential and competitiveness of island territories; while raising difficulties for these regions to keep pace with the EU developments. The analysis conducted demonstrates that resolving these issues in insular territories calls for higher resource and time allocation with respect to non-island states. Additionally, it presupposes a deep insight and understanding of local structural inefficiencies and the articulation of ad hoc sustainability and digitalisation strategies.

6. Conclusions

The digital transformation goals, proposed by the EU in line with the Digital Decade, highlight the need to align the 17 SDGs with the digitalisation process and respective infrastructure deployment in the Member States. The island territories are now confronted with an additional challenge, i.e., alignment with the European directions not only in the sphere of sustainability but also digitalisation.

In support of this new challenge and in order to grasp the new opportunities emerging in the Digital Decade, this study provides an operational methodology for assessing current islands' sustainability and digitalisation performance as a starting point for articulating more robust and insularity-driven policies. This methodology attempts to establish links among: the digitalisation regulations that are already in place in the six case study islands; the 17 SDGs, prescribed by the UN Agenda; and the actual problems of the island territories.

At the heart of the proposed methodology lies the articulation of two core indexes – I_{IS} and I_{ID} –, addressing achievements in sustainability and digitalisation in island territories respectively; while also underlining the importance of the theoretical and practical linkages of the DESI objectives and the SDGs. The two core indexes sum up to establish the Islands' Potential Equity Index (I_{IPE}), unveiling that progress in digitalisation can favour sustainability achievements, provided that regulations implemented are in line with real insularity drawbacks. This, in turn, implies the need for shifting from a nation-wide to a place-based, islands in this case, policy making approach.

Elaboration of data and results in six major Mediterranean islands demonstrates that, despite the implementation of relevant national digitalisation strategies, an evident delay in the achievement of SDGs is in place in island contexts, when compared to EU average or other non-island member states. In addition, comparative work across islands stresses the importance of more dedicated, island-driven digitalisation policies in order for sustainability performance to be improved.

More specifically, further deployment of technological infrastructure and strengthening of digital skills can positively affect islands' competitiveness and decrease vulnerability at a European level. Relevant implications of this research include:

- Replicability of the methodology in other spatial contexts with structural handicaps in support of identifying adjustments in objectives, policies and strategies at the European level that can ensure equity in competitiveness and wealth across the diversifying territories of EU. Examples of such spatial contexts are mountainous areas, ultra-peripheral areas, small islands etc., allowing also the generation of timely and evidence-based data;
- Applicability and scalability of this methodology is associated with both spatially-handicapped territories and other types of regions, e.g., metropolitan areas, provinces or a union of different municipalities;
- Outcomes produced can feed policy improvements at various spatial levels, e.g., the European one by establishing more region-specific legislative actions; the national, by properly embedding insularity peculiarities in nation-wide policy; and the local level, with insular administrative bodies elaborating strategies that are capable of resolving current digitalisation and sustainability gaps;
- Linkages established between digitalisation and sustainability endeavours in less privileged regions, as the insular ones, shed light on the contribution of digital advances in peripheral areas for attaining a more promising future developmental trajectory. Thus, the ground of such advances is broadened, expanding from the urban context (e.g., smart city) to the regional one (insular, rural etc.) in support of a more equitable share of the benefits of the Digital Decade Path for community as a whole.

Comparison of islands' sustainability and digitalisation performance with the two non-island countries and the European average clearly illuminates the challenges faced by the island communities; and paves the way for establishing a set of optimal policies in promoting/coupling digitalisation and sustainability in these regions. Such policies can: strengthen efforts of island territories to conform to the strategic objectives of the EU; support islands to gain a higher degree of autonomy and competitiveness; and work out inequalities between various types of regions. However, worth noticing is the inadequacy of data availability that is necessary for properly feeding the proposed methodological approach, allowing thus for more freedom in the selection of indicators and offering the chance to study a larger islands' sample. This will enable the methodology to be expanded for use in similar settings within countries neighboring the islands, and the comparative analysis to be broadened by encompassing more general topics before delving into specific areas, such as the digitalization aspects related to sustainability.

Author Contributions

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Image Sources

Fig.1: Relationship of digitalisation and sustainability dimensions in island territories and their spatial repercussions in terms of internal island inequalities in the case of Sardinia, Italy. Source: own elaboration;

Fig.2: The case study area – The Mediterranean Islands of Sardinia, Sicily, Corsica, Crete, Malta, and Cyprus ;

Fig.3: Schematic representation of the Islands' Potential Equity Index (I_{IPE}) and thresholds of its two core sub-indexes I_{IS} and I_{ID}. Source: own elaboration;

Fig.4: Positioning matrix of core indexes I_{IS} and I_{ID}: (a) interpretative matrix; (b) quadrants' matrix values. Source: own elaboration;

Fig.5: Potential equity performance of case study islands and the non-island EU states of Luxembourg and Finland. Source: own elaboration;

Fig.6: Position of islands and the two non-island EU countries in the methodological grid – Relationship between Core Index of Islands' Sustainability (I_{IS}) and Core Index of Islands' Digitalisation (I_{ID}). Source: own elaboration

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