The Importance of Data Visualisation in Natural Capital Conservation Scenario: Enhancing Decision-making Processes Through User Analysis, Personalisation and Co-design

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ABSTRACT

The conservation of Natural Capital emerges as a critical challenge for future generations, requiring the integration of nature and technology for effective monitoring and management. Leveraging tools like IT sensors, software, and AI, particularly evident in Agriculture 4.0, has yielded promising outcomes across various fields such as environmental conservation. However, to harness the full potential of the data collected, efficient presentation and comprehension mechanisms are essential, considering diverse stakeholders, especially end-users like scientists and policymakers. This necessitates the adoption of data visualisation and visual data analysis techniques, incorporating user participation through methods like personalisation and co-design. The exploration of data visualisation methods in the environmental sector, particularly within Italy's context where digitalisation in protected areas is low, is crucial. With upcoming investments in digitalisation and environmental sectors through strategic plans like PNRR, understanding how new technologies will be implemented becomes pivotal. Consequently, this research seeks to present and analyse optimal data visualisation methods in digital tools, aiming to enhance decision-makers comprehension and utilisation of data for strategic conservation decisions. The study proposes a novel approach to the design process, paving the way for further advancements in this domain.

Keywords: Decision-Support-System, Participatory Design, Natural Capital Conservation.

1 Introduction

Within the last two decades, extreme natural events connected with climate change are becoming more common. Scientific Academia widely recognises that our planet's climate is drastically changing at an unprecedent speed, and the consequences are affecting the natural equilibrium of ecosystems, biodiversity, and human life [1]. To fully understand how climate change and biodiversity loss affect human life on Earth, it is essential to highlight the interplay between these three elements. As it is possible to see in the graph Fig.1 produced by the International Panel for Climate Change [1] within the Summary for Policymakers, there is a strict interdependency between Climate Change, Human Society and Ecosystems, including biodiversity. These three elements are a clear risk for humanity and must be taken into consideration within the planning and policymaking in the forthcoming years. Indeed, each change in one area strongly affects the other variables, so it is pivotal to consider each of them [1].

As the natural ecosystem and biodiversity play a crucial factor in the planet and human well-being, it is essential to develop policies that take into consideration the protection and conservation of Natural Capital.

As it is possible to see from Fig.2. to stage a Climate Resilient Development, which ensures human health & well-being, equity and justice, it is essential to limit global warming through human and ecosystem transitions [1]. The paper will focus mainly on the latter, as the object of the research is to focus on the management and conservation of natural ecosystems. Indeed, to start an effective ecosystem transition, it

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is fundamental to focus on the conservation and restoration of the planet's ecosystems and their biodiversity, both on land and water.

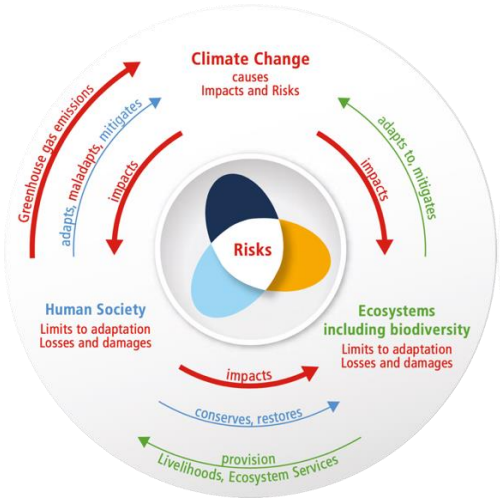

Figure 1: Climate Risks Interdependencies [1]

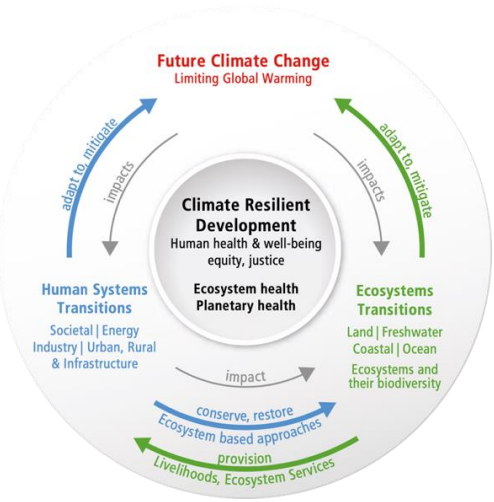

Figure 2: Climate Resilient Development Interdependencies [1]

2 Natural Capital and new technologies

2.1 Natural Capital

Defining what Natural Capital is crucial before moving forward with the analysis. The first definition of Natural Capital was given by Schumacher in 1973; he describes the Natural Capital as the exhaustible resources of nature [2]. Schumacher considers the whole stock of the planet's natural resources, including geology, soil, air, water, vegetation and all living organisms. Even if environmental issues affect countries and policymakers worldwide, the paper will focus on the Italian context, home to a wide range of different natural ecosystems. Indeed, the 5° report of Natural Capital in Italy from the Natural Capital Committee states that action is needed to protect this heritage and mitigate threatening events, such as soil erosion or forest fires [3]. The interest of the Italian government to take action towards the protection of the Natural Capital is confirmed by the PNRR plan. Indeed, the PNRR is the most critical environmental policy implementation plan of the next decade, which will invest more than 190 billion euros in new policies: the ecology transition and digital innovation count for more than half the budget [3].

2.2 Role of technology

Before starting the critical analysis, it is necessary to highlight the role of technology within this process. Indeed, cutting-edge technologies are being developed within natural resources management to produce more commodities and services with less raw materials. The interplay between nature and technology has become pivotal in monitoring, managing and protecting the natural ecosystem, a phenomenon that has already given excellent results in different fields, such as Agriculture 4.0 [4]. These new implementations do not only apply to the production and manufacturing sector but also to the observation and data collection related to biodiversity and ecosystems. Indeed, new tools, such as IT sensors, software and AI, are being implemented in the Environmental Sciences to understand better climate change and how to defend delicate ecosystems [5]. Meanwhile, managers of protected areas have widely recognized the value and need for credible, scientific information and data as a basis for making conservation and management decisions [6].

2.3 State of the art

Even if the development of these new technologies is progressing at unprecedent speed, the implementation of these tools within natural capital conservation is still underdeveloped. This phenomenon is in contrast with the thoughts of environmental managers, who recognise the need for reliable data and information on the status and trends of the key resources they manage as a basis for conservation planning and determining if the management practices have the desired effects. [6]. There are several reasons why these tools are not effectively implemented yet within conservation and management bodies.

Firstly, within the environmental sector, there is a somewhat chaotic and fractured data ecosystem as major corporations, government bodies, and universities [5]. Secondly, throughout the natural parks and protected areas, there is a low level of digitalisation and innovative tools used for the management and conservation of natural capital. Additionally, there is a lack of ability to aggregate and interpret data in such a way that it results in inefficient decision-support tools [5]. The scenario is worse within the Italian environmental conservation sector. Here, conservation bodies do not rely on innovative tools and the human capital is characterised by a low level of digital skills. Furthermore, some natural reserves have insufficient staff to implement complex planning policies. This situation needs to change as data are fundamental to take scientific and objective decisions [7], a process that has already begun focusing new policies and investments towards the environmental conservation and digital innovation sector with PNRR programme [8].

3 The importance of data communication

In fact, as stated by Grainger et al. [7], applying scientific knowledge coming from reliable data sources within environmental decision-making requires further consideration and investments. This statement highlights the importance of the reliability of information collected to improve the decision-making processes and the need to gather and process more data to make more informed decisions. This issue introduces the reader to another criticism: the communication and dissemination processes of the information gathered. If the data collected are not efficiently presented, read and understood by policymakers, they can lead to uninformed or wrong decisions [7]. Therefore, it is necessary that data not only are efficiently collected and processed but also correctly presented to the final user, whether a scientist or a manager [7].

3.1 Data visualisation

Thanks to new technologies, there is a vast amount of near real-time environment data available, which means there is great potential in environmental data visualisation. However, there is an urge for an effective communication process because if the transmission of information is not accurate, it can lead to a distorted sense of certainty, leading to poorly informed decisions and diminished trust in science [7]. Accordingly, there is an urgency to create effective ways to engage with data, mainly because the graphical feature of information visualisation affects the readability of data and the decision support system itself [5]. The National Park Service, the body that manages the natural capital in the United States, recognised worldwide as a pioneer in environmental management, monitoring and data collection, asserts that one of the most important characteristics of data should be Reliability. Reliability could be explained as the procedures that ensure that data are correctly managed, routinely analyzed, and readily available to key audiences in a usable and timely manner [6]. Within this context, it is becoming crucial to employ the proper data visualisation technique to use data correctly to allow the final users, whether a scientist or a manager, to rely on such information to make informed decisions.

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3.2 Environmental data visualisation challenges and techniques

Before presenting some data visualisation techniques and how to involve the final user to understand better the data collected, it is important to highlight an additional criticism that environmental managers must face. In fact, presenting data within the environmental area carries a more significant challenge because it usually takes into consideration several variables, particularly temporal data and maps. These two variables are critical factors for environmental data visualisation; however, using high-dimensionality, they create unique visual communication challenges [5]. Opportunely, visual applications within applied environmental research are beginning to emerge, particularly within geological, climate change, sustainability and landscape planning contexts, ecological decision-making and management [7]. However, as the process has begun recently, it is necessary to investigate this topic further to give the manager the best tools to improve decision-making processes in environmental planning. These elements suggest that it is even more important to focus on how data are presented and the process of choosing the best visualisation techniques for different types of users. Within this challenging scenario, it becomes fundamental to employ the proper data visualisation technique. Depending on which correlation between data and what type of variance the scientists want to highlight, there are different visual graphics models to adopt.

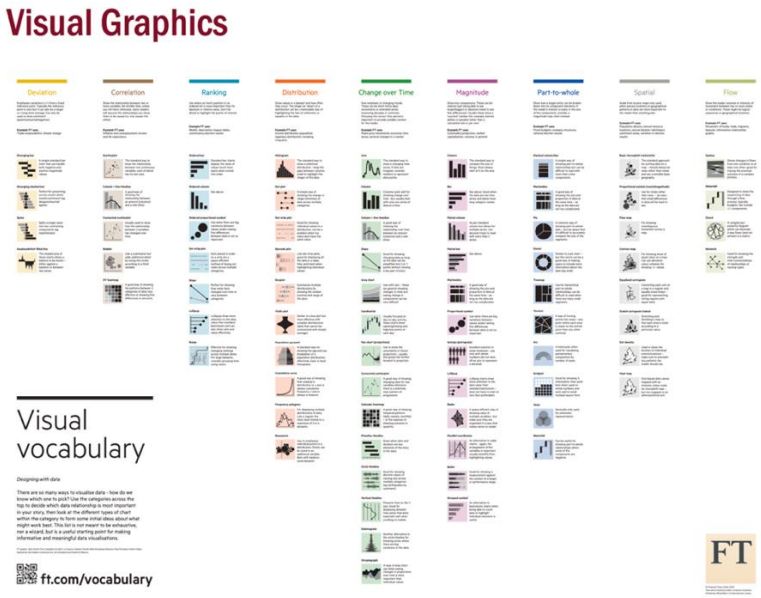

Figure 3: Visual Techniques, Visual vocabulary (2022)

As can be observed in Fig.3, there are several data visualization techniques that the designer could employ to highlight the characteristics of the data. Indeed, there are nine categories in which it is possible to operate depending on the story that should be highlighted: Deviation, Correlation, Ranking, Distribution, Change over time, Magnitude, Part to the whole, and Spatial Flow. Each category has several subgroups with specific techniques for different goals that could be particularly interesting for the environmental conservation scenario. As spatial and temporal data are significant within the environmental decision-makers, Spatial and Change over time techniques are widely employed.

3.3 Choosing the proper model

Once highlighted the importance of selecting the correct technique depending on the goals the scientist wants to reach, it is crucial to explore how to choose one method rather than another. Indeed, there are several techniques that could be used to draw a user's attention to the most salient aspect of a data story by presenting or arranging graphical elements [9]. An effective process is combining different techniques from different areas to find new solutions to solve the visualisation issue of complex and multivariable data [10].

Hence, the focus should be on the goal to achieve and the type of user that will read and use the data presented. Indeed, as stated by Cairo [9], when deciding on the type of visualisation, designers should always consider their objectives and audience needs (i.e. overall functionality) [9]. This statement highlights the importance of the final user in the design process, which will be analysed in the next chapter.

4 Not only data but people

The following chapter will explore the importance of shifting the focus to the final user while designing the most efficient way to present data, to take informed decisions within the environmental sciences. Additionally, some techniques that are employed to allow the final user to better understand and accept the data through involvement and participation, will be presented.

4.1 The focus on the user

As McIntosh et al. [11] suggested, focusing on the final user is fundamental to finding the best solution to present data effectively. In fact, within the environmental visualisation science scenario, the importance of the data user is getting recognised by designers and scientists, and some studies are beginning to integrate stakeholder-oriented approaches. This trend is in opposition to many designers who fail to fully engage with the user perspective because they mainly focus on the technical aspects instead of the final user's viewpoint [11]. This approach could be described as User-Centered Design (UCD), namely the involvement of the final user during the process of creation [12]. Indeed, data-driven decisions should meet user needs and expectations [13]. The reasons according to which it is crucial to involve end users within the design process are digital metabolization, acceptance and effective usage of data.

4.2 Acceptance and user involvement

The central role of the user is also highlighted by Roberto Verganti [14] in his book "Design Drive Innovation" states that when presenting innovative ways to provide information, it is fundamental to consider different stakeholders, particularly the final user, who will exploit and read such data to make strategic decisions [14]. As has been demonstrated in Agriculture 4.0, the involvement of the final user becomes instrumental for the purpose of technological metabolization and acceptance [15].

Here, the final user has been placed as an active participant instead of a passive spectator. In fact, the end user's involvement when defining, developing and testing a visualisation system, helps the designer learn about the domain expert's background, expertise, behaviour, and goals, as well as their work environment and familiarity with technology [16].

This approach could help people with lower IT skills, as it happens for national parks in Italy, or ease the technological transfer from analogical and improve the acceptance and metabolization of the new technologies [13]. There are several ways to involve users in the design process of new technologies. In the following paragraph, two of the most effective practices will be presented: personalisation and co-design. The visualisation designers should attempt to collaborate with potential end users throughout the whole

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design process to reach one of the main goals of this practice: to improve the likelihood of long-term adoption of the new technology [7].

This new scenario brings with it the need to make the user a "designer" in all project phases from a Co-Design perspective. Particularly the involvement during the collaborative creation process as co-creators from the first stages of the project until the end [12]. The correct involvement of several end users is crucial because it allows the efficient use and acceptance of new tools for everyday work processes. A fundamental practice within the Italian context, where the employees of protected areas are usually aged 50 or older, as it happens for Parco Nazionale d'Abruzzo, Lazio e Molise, the oldest National Park in Italy, which has more than 72% of the staff over 50 years of age [17]. As older generations are unwilling to employ new working methods and technologies, involving them throughout the design process is pivotal. That is why co-design has become an essential tool for designing new technologies. Additionally, visualisation design studies are particularly successful when researchers try to become familiar with the end user's real-world environment [12].

Another effective tool to improve the readability and acceptance of data is the personalisation of the data visualisation tools. In fact, within visualisation research, tailored and customised tools within decision-making environments are increasingly considered beneficial [7]. Additionally, the knowledge of the user characteristics and contexts of use is also important. Indeed, as Lorenz et al. [18] stated, visual communication tools within professional contexts should be customised based on an understanding of user characteristics and the potential context of use. When talking about user characteristics, it is essential to guarantee a deep knowledge of user features (user cognitive abilities, personality) to create tailored decision-making environments that are advantageous [7]. Creating the proper environment is important because, if the audience is unfamiliar with the graphical form or medium of the device, they may feel overwhelmed by the new technology. To avoid this effect, it could be helpful to introduce a switch option, allowing users to select scales, locations and scenarios that best match their expertise and context [19]. Additionally, adding customized elements can help avoiding a default design of software, which could be unhelpful [7].

5 Produce effective support to Decision-making

Section 4 gave an overview of the best practices that designers could employ to allow the final user to read, understand and accept the data. Indeed, being the environmental science sector characterised by digital underdevelopment and aged staff members, it is pivotal for the designer to employ some UCD techniques when creating new innovative data visualisation tools. Additionally, to improve the digital metabolization of new tools and the readability and acceptance of data, the designer should involve the end user in the whole design process to know his characteristics better and implement personalisation elements to allow him to trust the data for decision-making.

5.1 Supporting decision making taking informed decisions

Through the involvement of visual methods and technological tools in data presentation, park managers have more scientific and objective data available, which will help them to make informed decisions about the natural resources entrusted to their care [6]. Currently, this practice is even more critical because the Italian government is investing billions of euros in environmental projects for the Natural Capital with the PNRR campaign. Consequently, taking good, informed planning decisions in the next few years could lead to a long-term advantage in terms of biodiversity loss mitigation and ecosystem protection.

5.2 Understand and accept data to improve conservation

As stated by the US National Park Service, managers of protected areas have increasingly recognized the value and need for credible, scientific information as a basis for making management decisions and working with partners and the public to conserve natural resources. [6]. The availability of long-term data could effectively support policy planning through temporal analysis and simulation. Within this context, once again, it becomes pivotal for an effective application of data visualisation techniques because it could allow the decision-maker to better understand and accept the data for strategic decision-making in natural capital conservation [7]. If the designer does not put the manager in a condition of trust towards the data, the decision maker won't use the information collected for decision-making purposes. Collecting data from natural resource science activities is the first step to understanding the ecosystems within and around natural parks [6]. Therefore, thanks to a better knowledge and understanding of the complex natural ecosystems, it is possible to take better management decisions to improve Natural Capital conservation. This will result in an effective conservation of biodiversity and delicate ecosystems, ensuring a sustainable development for the human species and a climate crisis mitigation.

6 Conclusions

In conclusion, the critical interdependence between climate change, ecosystem protection, and human activity, emphasises the importance of effectively managing Natural Capital for sustainable development and the well-being of both the planet and its inhabitants. New technologies in environmental science, oriented towards data gathering and visualisation for decision-making support, play a pivotal role within this framework. However, due to the complexity of environmental data, selecting appropriate visualisation techniques tailored to specific goals becomes crucial, alongside ensuring trust and acceptance of the data collected for informed decision-making. This goal could be reached by focusing on employing user-centred design techniques such as co-design and personalisation of innovative data visualisation tools.

While there is limited empirically-based practical guidance in this field [7], particularly considering diverse cultural, institutional, and disciplinary backgrounds, a flexible approach to data visualisation techniques, co-design, and personalisation processes is advocated [20]. This flexible approach, coupled with a solution combining a fixed structure with customisable features tailored to end-users, can enhance trust in data and facilitate long-term policy-making decisions. These statements hold true for the Italian context as well, where the use of digital tools within conservation bodies is low. These environmental DSS are necessary as the government is investing billions of euros in environmental conservation and innovative tools through the PNRR project. The paper suggests further research to address existing limitations in the field, emphasising the need for structured and empirically tested theories to refine data visualisation tools for decision support systems in environmental sciences. A hybrid and flexible solution, adaptable to various contexts and different end users, could be a valuable key for similar yet different scenarios and a valuable starting point for further research and empirical testing.

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