Transformation of Disused Railways Based on ES Assessment: Sassari Case

Bilge Kobak[1,2(✉)]

[1] IUSS Pavia, Pavia, Italy
bilge.kobak@iusspavia.it
[2] DICAAR Università degli Studi di Cagliari, Via Marengo 2 CA, 09123 Cagliari, Italy

Abstract. Ecosystem services (ES) knowledge leads to action and is essential for improving the relationship between humans and environment, as it provides crucial information for decision-makers. This paper showcases abandoned railway landscapes as valuable resources for Green Infrastructure strategies, focusing on their potential to enhance ES at the provincial level using Sassari Province as a case study. Employing an adapted ESTIMAP model, it evaluates cultural ES by mapping recreation potential in Sassari, using areas of interest and slow mobility network as parameters to emphasize the potential of disused railways as ES sources. The results underscore the importance to integrate ES assessment into decision-making process while demonstrating the potential of disused railways to improve nature-based recreation. By advocating for the reuse of existing structures, and particularly focusing on a single typology of brownfields such as railways, it allows for the identification of specific actions and provides municipalities with actionable insights to determine starting points for implementation.

Keywords: Ecosystem Services · Green Infrastructure · Disused Railways

1 Introduction

Landscape is a dynamic process between society and environment that constantly changes as a result of human activity and environmental influences. The territorial landscape has been significantly shaped by urbanization and industrial development, reflecting the dynamism and growth of cities. As cities expanded, the demand for mobility grew, leading to the emergence of transportation landscapes. Logistics networks, including extensive railway lines, began to integrate into vast industrial areas, shaping not only the urban landscape but also regions. While grey infrastructure continued to grow at an accelerated rate, environmental concerns arose due to unsustainable use of resources. A huge portion of industrial landscapes, including transportation landscapes has been abandoned due to various factors such as economic crisis, emergence of new technologies etc. These abandoned areas, which were formerly thriving centres of urban and industrial activity, present problems with regard to urban decay, unsustainable land use, and environmental degradation. This underscores precisely why they can serve as valuable assets and integral components of green infrastructures. Rather than seeking to

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024
O. Gervasi et al. (Eds.): ICCSA 2024 Workshops, LNCS 14818, pp. 370–386, 2024.
https://doi.org/10.1007/978-3-031-65273-8_24

compensate for adverse impacts on ecosystem services elsewhere, a more strategic approach entails the revitalization of these abandoned sites where environmental degradation was initially occurred through their integration to Green Infrastructure network.

Numerous studies have explored brownfields within the framework of green infrastructure (GI) strategies, recognizing their potential to provide ecosystem services (ES). However, there exists a gap in the literature regarding specific measures to harness this potential effectively. Hence, there is a need for research focusing on the distinctive typologies of brownfields, as comparing, for instance, a quarry to a railway is not feasible. Consequently, instead of treating brownfields as a singular typology, it is imperative to categorize them for more nuanced analysis and strategic planning. This paper, by focusing on railways as part of transportation category, provides a framework to address and mitigate this gap.

Typically, disused or abandoned railways are transformed into greenways. Making them a part of the slow mobility network is a common method in their transformation however their ES values are not highlighted in the literature. Although there many examples of railway regeneration and greenway projects, their relation and potential place in GI framework is not much studied. While studies started to adopt the idea of using brownfields for regeneration in the context of GI, research specifically focusing on railways within this topic remains limited. One notable example is the work of Gasparrini and Terracciano [1], who discuss "The disused railway as a greenway for urban regeneration" along the Messina Palermo railway line in their study for the Green and Blue Infrastructure Messina. However, there is currently a lack of in-depth studies exploring why each of these typologies of brownfields could serve as valuable assets for GI networks, particularly in terms of their potential to provide ES. Moreover, there is a need to elucidate the specific interventions that can be implemented on these areas to maximize their contribution to the GI network.

To provide specific actions, there is a need to improve the ES knowledge because in order to support new policies that specifically take into account the effects on ES, the most direct results are anticipated when ES knowledge is purposefully used to generate actions [2]. To do so, this paper proposes an adapted version of ESTIMAP-Recreation model to assess the recreation potential in abandoned railway landscapes through Cultural ES.

Cultural ES which are associated with intangible values and heritage becomes important in post-industrial areas as these areas reflect the past activities of society. Cultural ES is described as "non-material" benefits that society gets from ecosystems [3]. These services include recreational, educational, cultural, spiritual values, knowledge systems, social relationships, sense of belonging, tourism/ecotourism etc. [4]. Hence, out of the 4 groups of ES, Cultural ES are considered and found the most useful since certain characteristics of railways allow for recreation, promote culture and heritage, and connect different communities.

2 Case Study

2.1 Location

Sassari is one of the four provinces of Sardinia region in the south of Italy, as seen in Fig. 1. The province has 491.571 habitants as of 1 January 2019. Its capital is the city of Sassari, and it is characterized by industrial activities, historic centres, and tourism thanks to its coastal characteristics. It is selected for the application of the methodology because it is characterized by industrial activities and hosts several railway lines on the provincial scale, including abandoned lines and partially operating lines.

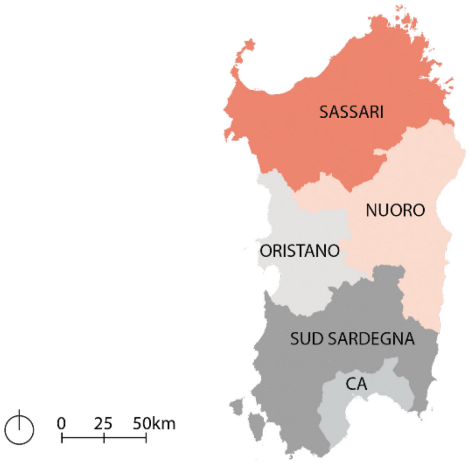

Fig. 1. Four provinces of Sardinia region and Metropolitan City of Cagliari (CA)

To gain a deeper understanding of the existing measures and actions regarding reutilization of disused railways, urban planning documents of Sassari are examined in the next section.

2.2 Planning Documents of Sassari

Strategic Plan 2009 (Provincia di Sassari).[1] The provincial strategic plan mentions industrial areas in abandoned condition such as decommissioned mining sites but neither propose a general objective for "abandoned industrial areas" nor specify "railway". While the plan includes certain objectives regarding environment, cultural areas, green areas, mobility networks etc, it lacks a comprehensive intervention strategy or specific projects aimed at revitalizing abandoned industrial areas.

[1] Provincia di Sassari (2009) Piano Strategico: Provinciale Rapporto Integrale [Provincial Strategic Plan: Full Report] https://ptpc.provincia.sassari.it/Pianificazione/PATTONO-PSP/Rapporto%20integrale.pdf (last accessed 5 March 2024).

Guidelines for the development of the Provincial Strategic Plan (Linee Guida Per L'elaborazione Del Piano Strategico Provinciale).[2] This document discusses general concepts concerning projects tied to strategies tailored to the environmental landscape. It refers to territorial characteristics and high environmental quality and only mentions "abandoned industrial areas" with no specific reference to "railways". It highlights challenges regarding the significant resources required for environmental rehabilitation by providing cost estimations in broad terms, however, it does not specify the typologies.

Strategic Plan 2007 (Comune di Sassari).[3] The Strategic Plan of Sassari (2007) defines 4 themes in order to achieve the goal "Sustainable Sassari (Sassari Sostenible)" which are environmental system (urban parks, green, landscape etc.), new energy scenarios and waste management, heritage public and private housing, urban and urban mobility. The directives include transformation and regeneration plans more in relation with historic centers. Most importantly, it mentions "greenways" in "Direction D2: Environment". The direction of intervention "environment" follows the ecosystem approach that consider the environmental system in the multiplicity of its aspects and possible forms of use, and poses the emphasis on the functions of the ecosystem, on the interconnections between the different uses and on the rules to be respected, according to the principles of sustainability deriving from recognition that the territory contains a finite set of resources, for commensurate activity levels with nature's carrying capacity and need to conserve biodiversity. This directive includes the strategy to support the sustainable use of resources with activities related to ecotourism, nature tourism and networking of areas with a strong naturalistic and cultural value. It also includes the project "La Strada Del Verde" which defines a system of routes dedicated to non-motorized traffic that connect the natural and historical-cultural resources of the area with urban settlements. The project acknowledges the use of disused railway routes as well following the objectives of Italian Greenways Association. The actors involved in this project are listed as follows: Environment and Public Green Sector, Maintenance Sector, ATP (Azienda Trasporti Pubblici Nuoro), FdS (Ferrovie della Sardegna), Province of Sassari, neighbouring municipalities.

While the project definition of "La Strada Del Verde" is very important to reclaim disused railways and for their integration into green infrastructure network considering their ES supply, its focus should expand beyond urban settlements as railway lines cross peri-urban areas as well. Mentioning neighbouring municipalities in actors paves the way for collaborated efforts to achieve the ultimate goal of sustainable cities, however, since 2007, there is still a long way to go. The Directive 2 focusing on environment provides important goals towards areas with environmental and cultural value, however, to show concrete progress, there is a need for identification of intervention areas in order to provide specific actions.

[2] Provincia di Sassari (n.d) Guidelines for the development of the Provincial Strategic Plan [Linee Guida Per L'elaborazione Del Piano Strategico Provinciale]. Resource document. https://ptpc.provincia.sassari.it/Pianificazione/PATTONO-PSP/Linee%20guida.pdf (last accessed 5 March 2024).

[3] Comune di Sassari (2007) Piano strategico della Città di Sassari: Progetti—Allegato 1.3 [Strategic plan of the City of Sassari: Projects—Annex 1.3]. Resource document. porto / https://www.sardegnaterritorio.it/documenti/6_83_20100526092101.zip. (last accessed 5 March 2024).

Environmental Report 2012 (Comune di Sassari).[4] Environmental Report of 2012 has several mentions of interventions related to dismissed railways. In article "3.7.5 The unresolved areas within the compact city" it specifically mentions "railways" as part of industrial areas that can be transformed. According to the report, artisanal and disused railways cover a total area of 25 hectares and are mainly located in the railway yards (fascio ferroviario) and in the Via Verona area. The report also mentions a railway regeneration project for Porto Torres a potential ecological corridor in relation with "neglected valley system" of Sassari in article "3.7.2 The valley system and the linear park". It proposes a linear park of 6km along the Railway line of Porto Torres. This is a project that the PUC (Piano Urbanistico Comunale) considers to be a "backbone" with priority for intervention and the report mentions its cornerstones as follows: the connection between the valleys, with their recovery and their introduction into the urban system, ensuring their continuous pedestrian use and the creation of a linear park parallel to the railway for Porto Torres. According to the report, this is an opportunity to regenerate along these settlement situations lacking in terms of urban quality (service provision, lack of equipped public spaces, usable green areas, etc.).

Urban Planning Sector-The Integrated Programme: Framework Document 2019, Comune di Sassari (Settore Pianificazione Urbanistica - Il Programma Integrato: Documento Di Inquadramento 2019).[5] Following the PUC objectives, the Integrated Program Framework Document of March 2019 mentions the project for Porto Torres which was also mentioned in Environmental Report of 2012. The document highlights that it links the peripheral system of the city and with its diverse functions, it has the potential to become a significant and vital attraction for the entire Sassari suburban area. It also mentions archaeological complexes and industrial heritage areas that connects to Porto Torres. This document acknowledges the railway areas being decommissioned, the potential of disused railway lines to connect diverse areas of cultural value and proposes areas of interventions.

Outcomes of Planning Documents. Examining these planning documents reveals that at the provincial level, integrated reports or pacts are signed by various municipalities. However, specific actions at the provincial level are not explicitly mentioned. Notably, documents at the capital city level are more detailed, outlining a few areas of intervention. Since 2007, municipal reports and documents have been aligning in terms of goals related to repurposing dismissed railways, with each one focusing on different aspects of particular projects. They have been developing frameworks and becoming more precise in identifying intervention areas. However, the process is progressing slowly and still lacks specific actions. The proposed methodology in this paper is beneficial in this

[4] Comune di Sassari (2012) Piano Urbanistico Comunale di Sassari. Rapporto Ambientale. Resource document. [Municipal Urban Plan of Sassari. Environmental Report]. Resource document. https://puc.comune.sassari.it/pucweb/elab/Allegati/Allegato_M1_VAS_rapporto_ambientale.pdf (last accessed 5 March 2024).

[5] Comune di Sassari (2019) Settore Pianificazione Urbanistica. Il Programma Integrato: Documento di Inquadramento – Oggetto 7.1. [Urban Planning Sector. The Integrated Programme: Framework Document – Object 7.1]. Resource document. https://www.comune.sassari.it/.galleries/doc-documenti_old/ALL.-A-PIRU_DOCUMENTO-DI-INQUADRAMENTO.pdf (last accessed 5 March 2024).

context since it identifies areas with high recreation potential based on environmental and cultural value, examines their connectivity levels within existing slow mobility routes and determines the intervention areas through the superposition of disused railway routes. Disused railways hold immense potential for revitalization, as they offer opportunities to enhance slow mobility networks and connect areas of significant cultural value.

3 Application of Methodology: Dismissed Railways of Sassari

The focus is on three railway lines, shown in Fig. 2; one is the main line from Sassari to Palau (Sassari-Tempio-Palau or Sassari-Luras-Palau) which is 150.2 km long and is a part of Trenino Verde. The other one which is connected to this line as well is the 28 kms stretch from Luras to Monti. These two stretches are connected in Luras and they differ in certain characteristics. The third one is Tirso-Chilivani which is 78.48 km. "The Ferrovie Abbandonate[6]" offers a comprehensive database of abandoned railways in Italy, including these stretches. According to their data, the shorter stretch from Luras to Monti is partially paved. While the part between Luras and Calangianus is transformed into an ordinary asphalted road, the part from Calangianus to a little before Monti is transformed into a path that can be followed by bike or on foot. Along the route, abandoned or partially collapsed service buildings exist which are considered as potential service areas for visitors in this study.

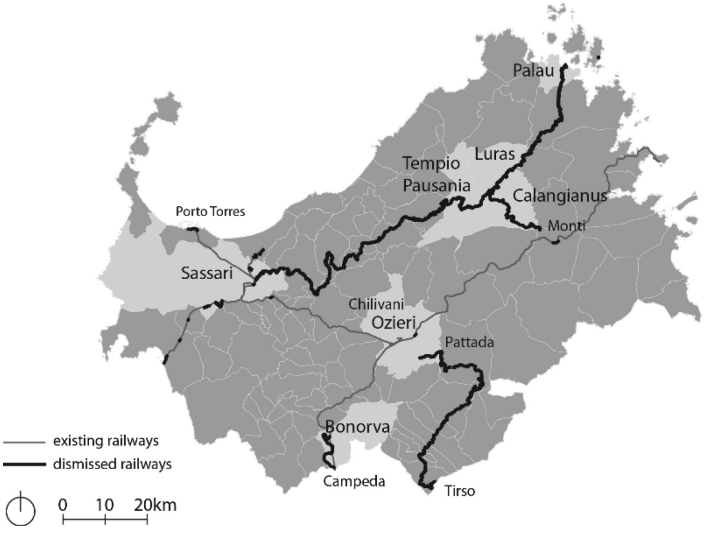

Fig. 2. Dismissed Railway of Sassari

The proposed methodology outlined in the following paragraphs will reveal the precise intervention points and elucidate the "how" aspect of implementation. While

[6] Ferrovie Abbandonate. Linee ferroviarie chiuse al traffico. Retrieved from https://www.ferrovieabbandonate.it/dismesse.php?t=dismessa (last accessed 5 March 2024).

numerous research and municipal documents provide guidance on what needs to be done in general terms, they often lack detailed information on the execution process.

3.1 Methodology

To assess and evaluate the nature-based recreation potential in Sassari province, an adjusted version of ESTIMAP Recreation model is adapted which was initially created by the European Commission's Joint Research Centre to map ecosystem services across Europe [5, 6]. The original model consists of 2 modules. First module is mapping the Recreation Potential (RP) which is referred to as ecosystem-based potential map, the second module includes human inputs which are available infrastructures that is shown with a proximity map considering distance from roads and residential areas. While the original model uses 3 parameters to map RP which are i. degree of naturalness in land cover, ii. Presence of protected areas, iii. Presence of water related elements; these parameters are sometimes tailored to fit different contexts in different research studies such as the works of Cortinovis and Genelletti as well as Isola et al. [7–9]. As shown in Fig. 3 that explains the adaptation of the methodology, the input parameters used to map RP in this study are as follows: i. degree of naturalness in land cover, ii. Presence of protected areas, iii. Presence of areas of interest. For the second module, the human inputs, slow mobility network components such as biking, hiking and trekking routes are considered instead of roads. This strategic choice aligns with the emphasis on promoting nature-based activities, thereby discouraging reliance on automobiles. The second module results show us the availability of slow mobility networks. After obtaining the two modules, through cross-tabulation analysis, areas with significant recreational potential that lack sufficient connectivity to slow mobility routes can be identified. The final step involves overlaying the abandoned railways layer to assess the potential of existing routes for repurposing. All the analysis is done withing the QGIS Desktop 3.20.3 version. This analysis reveals the cultural ecosystem services supply potential inherent in the existing railway routes, presenting them as valuable resources to be utilized effectively. Final results enable us to identify which areas to prioritize for improvement along the existing railway line, enhancing connectivity to facilitate greater access and utilization.

For the first parameter of RP, the degree of naturalness, scores ranging from 0–9 is assigned to Corine Land Cover 2018 classes based on Hemeroby Index values outlined in Isola et al. [9], originally proposed by Paracchini and Capitani [10]. For the purpose of this study, the codes that start with 5 which shows water bodies are given the values of 1 or 0 to differentiate between being an inland or marine water. Marine water codes 521, 522, and 523 are assigned a score of 0 due to their minimal contact with land boundaries, whereas codes 511 and 512 receive a score of 1 as they experience comparatively more disturbance being situated within land boundaries. Land cover categories are typically assigned a single value, except for agricultural and forest areas were depending on the degree of management practice intensity they can get one of the three values presented in Table 1 showing correlations between hemeroby index and CLC classes. Following the approach presented in Isola et al. [9], for the agricultural areas which are represented by codes starting with 2, nutrient inputs and the density of livestock is considered to define which of the three values are given showing low-medium-high intensity. For forest areas,

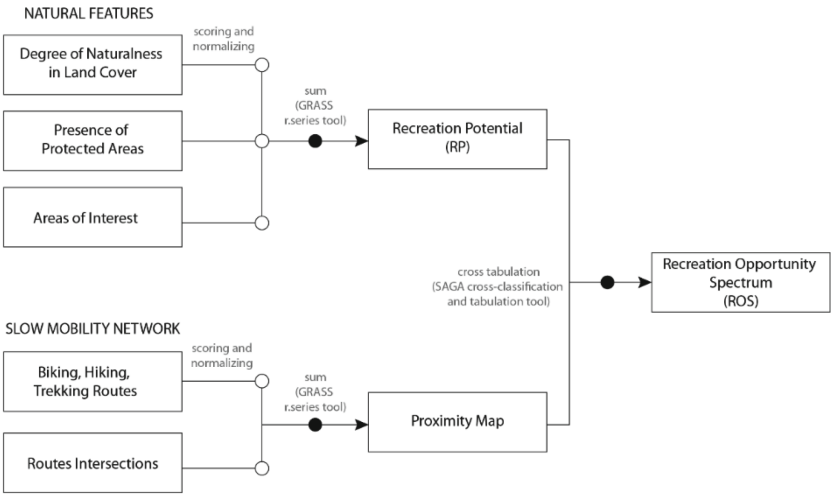

Fig. 3. Adaptation of ESTIMAP-Recreation Model for Sassari. Modified after Zulian et al. (2013)

which are represented by codes starting with 3, the difference between the actual existing vegetation and the potential vegetation presence in the case of no human activity is used as a proxy.

Table 1. Hemeroby Index (HI) values of CLC classes. Adapted after Paracchini and Capitani (2011) and Isola et al. (2022)

CLC codes (artificial)	HI	CLC codes(agricultural)	HI	CLC codes(forest – seminatural)	HI	CLC codes(wetlands)	HI	CLC code(water bodies)	HI
111	9	211	5–6–7	311	2–3–4	411	2	511	1
112	9	212	5–6–7	312	2–3–4	421	2	512	1
121	9	213	5–6–7	313	2–3–4	422	6	521	0
122	9	221	4–5–6	321	2–3–4			522	0
123	9	222	4–5–6	322	2			523	0
124	9	223	4–5–6	323	2				
131	8	231	3–4–5	324	2				
132	8	241	4–5–6	331	2				
133	8	242	4–5–6	332	1				
141	8	243	4–5–6	333	2				
142	8	244	3–4–5	334	6				

The nitrogen levels in kg per province as well as the livestock density (livestock unit/ha) per municipality of Sardegna is obtained from the extensive data presented in

Isola et al. [9] in which they utilize data from the National Census Institute for the information on nitrogen and the data from the National Zootechnical Register for the number of livestock.

For the nitrogen input, Sassari's nitrogen level from 2019 which is 1569000kg divided by the total ha of agricultural areas which make a sum of 448047 ha gives us the number 3.5 which scores as low according to the standards given by Paracchini et al. [10] shown in Table 2. Then for all Sassari province, nitrogen level was considered low. Consequently, in municipalities where livestock density is also low, the intensity of management practices is likewise regarded as low, leading to the assignment of the smallest value among the three options. Vice versa, in areas with higher livestock density, management practices tend to intensify accordingly.

Table 2. Intensity of management degree according to Nitrogen input and Livestock density classes. Sourced from Paracchini et al. (2011).

	Low input	Mid input	High Input
N input (kg/ha)	>0–30	>30–150	>150
Livestock density (LU/ha)	>0–0.5	<0.5–1.2	<1.2

For forest and seminatural areas, represented by the codes starting with number 3, as suggested in the Sardinian context, the distance between the current vegetational situation and the potential vegetation state is proposed to describe the disturbance level. For this purpose, Isola et al. [9] resort to Bacchetta et al. [11] which conducted mapping to determine the potential distribution of vegetation series and geoseries in Sardinia. By comparing the actual forest vegetation with the potential distribution through spatial intersection, patches classified as "311," "312," "313," or "321" were assigned hemeroby index values of 2, 3, or 4, depending on how well the current land cover matched the potential vegetation, with lower values indicating better compatibility. Looking at the results of the forest disturbance levels provided by the work of Isola et al. [9], one could simplify the calculations in the case of Sardegna since the scores generally are the same within each code. Which means the hemeroby index for forest areas are considered as following: 311 – "2", 312 – "4", 313 – "3", 321 – "2".

After assigning the hemeroby index values from 0 to 9 to each CLC codes, the degree of naturalness is obtained by normalizing the values between 0 to 1 in equal intervals, with 1 representing max degree of naturalness.

To obtain the RP, 3 parameters are needed as raster inputs with scale from 0 to 1. After obtaining the first one which is degree of naturalness in land cover, the other two parameters are rasterized. The second and third parameters, indicating the presence of protected areas and areas of interest, are scored as either 0 or 1. A value of 1 indicates presence, while 0 indicates absence.

For the protected areas, national parks, regional parks, natural reserves, Natura 2000 sites and areas defined as Siti di Importanza Comunitaria (SIC), Zone Speciali di Conservazione (ZSC), Zone di Protezione Speciale (ZPS), which refers

to "Sites of Community Importance, Special Conservation Zones, Special Protection Areas" are considered. The protected areas are mapped using the following two layers. First layer is «Art. 142 - Parchi e riserve nazionali o regionali (dati indicativi)» downloaded from Sardegna Geoportale[7] and appearing as "ART142_PARCH_RIS_NAZ_REG_INDICPolygon" in GIS environment and the second one is «N2000_spatial_IT_2023_12_15_region_WGS_1984_UTM_Zone_32N» downloaded from the website of Ministero dell'Ambiente e della Sicurezza Energetica (MASE)[8] showing N2000 Sites including SIC, ZSC and ZPS.

For the areas of interest, cultural sites, caves, landscape assets, identity assets, archaeological assets, monumental trees, natural monuments which are mapped using 7 layers downloaded from Sardegna Geoportale: «luoghi_della_cultura», «grotteCaverne», «BP» (Beni paesaggistici), «BI» (Beni Identitari), «ARCHEO» (BeniArcheologici), «alberi_monumentali_agg_18_09_2023», «monumentiNatistituitiLr31_89».

After obtaining the three input rasters, the sum of them represents our RP map. In this map, a pixel value of 1 indicates areas where all three input layers overlap, signifying the highest recreation potential as seen in Fig. 4.



Fig. 4. Recreation Potential Map (RP) of Sassari.

The second module, as explained before, is tailored to fit into the context of sustainability as a strategic decision to promote nature-based activities, aiming to reduce dependence on motorized traffic. Hence, the emphasis shifts from conventional road networks to components of slow mobility networks such as biking, hiking, and trekking

[7] Sardegna Geoportale [Official Website for geospatial data of the Sardinia Region]. https://www.sardegnageoportale.it/webgis2/sardegnamappe/?map=aree_tutelate (last accessed 5 March 2024).

[8] Ministero dell'Ambiente e della Sicurezza Energetica (MASE). https://www.mase.gov.it (last accessed 5 March 2024).

routes. To create the final output, which is proximity map, two components are considered. First are the slow mobility routes and the second is the intersection points of routes since they symbolize areas that has higher connectivity. Hiking and trekking routes are sourced from the "Sardegna Sentieri[9] "database which is available online and the biking routes are sourced from "Sardegna Ciclabile[10]" which are visible online, however, not available for download. Hence the biking routes data was provided through the courtesy of the head of the group responsible for designing the regional cycling plan.

After obtaining all the routes that constitutes the slow mobility network, the next step is to perform the Proximity Analysis. For the purpose of this study, two parameters are of importance, the density of routes in the area and the intersection points of the routes since they are a proxy of connectivity. Hence two proximity analysis are going to be performed in order to the create the final Proximity Map. For the first parameter, the "line density" of QGIS is utilized to calculate the density of routes within the area which then is used as an input for the proximity tool. For the intersection points, the proximity tool of QGIS is used to show the distances and the spatial relationship between features. The sum of the two raster maps, one showing the routes density and the other showing the intersection points of the routes, gives us the final Proximity Map as seen in Fig. 5, with value 1 showing maximum proximity.



Fig. 5. Proximity Map based on slow mobility network in Sassari.

After obtaining the RP map and the Proximity map, the Recreation Opportunity Spectrum (ROS) map can be created through cross tabulation analysis. To do so, the

[9] Sardegna Sentieri [Online catalogue for pedestrian paths]. https://www.sardegnasentieri.it/en/sentieri (last accessed 5 March 2024).

[10] Sardegna Ciclabile [Official website showing all cycling routes in Sardinia] http://www.sardegnaciclabile.it/site/itinerari/ (last accessed 23 February 2024).

SAGA Cross-classification and tabulation tool is used. The final output presents a cross-tabulation of nine values, reflecting the relationship between recreation potential and proximity to slow mobility networks. On one axis, the levels of recreation potential are categorized as high, medium, or low. On the other axis, proximity to slow mobility networks is similarly categorized. As seen in Fig. 6, each cell in the resulting table showing the combination of these two factors represented on the ROS map, providing a comprehensive understanding of which areas have high recreation potential versus less connectivity to slow mobility networks. For instance, the blue colour represents the areas with the highest RP and highest proximity to slow mobility networks while the red colour represents the lowest RP with lower proximity. The green colour represents areas with high RP with lower proximity, suggesting that the accessibility could be improved by utilizing disused railway lines.

The final step of the methodology is the overlay of abandoned railway lines on the ROS Map. For creating the abandoned railways layer, combination of different sources is used. First in Open Street Map (OSM), using the Overpass Turbo tool, the tag "railway:disused" gave the shapefile data which then was compared to other sources such as Ferrovie abbandonate (the project showing all disused railways lines in Italy). After comparison, the data obtained from OSM matching with existing sources is used together with «DGBT_10K_22_V03_01_ELEMENTO-FERROVIARIO_DISUSO» downloaded from Sardegna Geoportale.

The superposition of the disused railways layer on the ROS Map, shown in Fig. 7, shows us the potential intervention areas considering the high recreation potential and less connectivity, and the railway routes' relation with these areas.

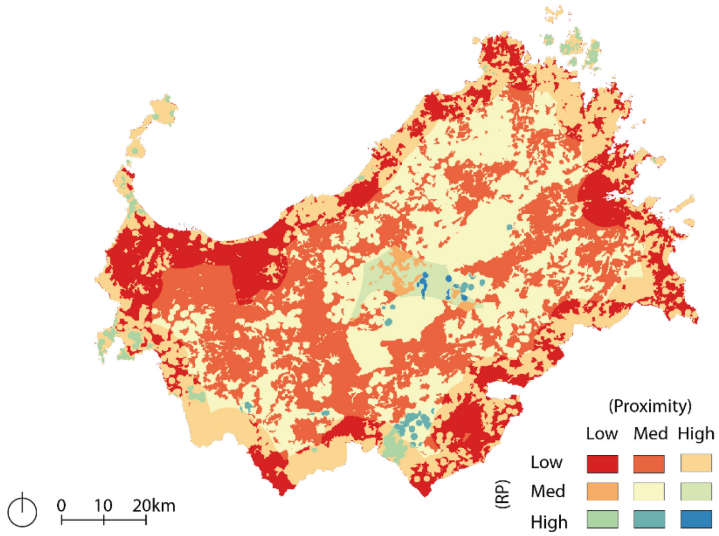

Fig. 6. Recreation Opportunity Spectrum (ROS) map of Sassari.

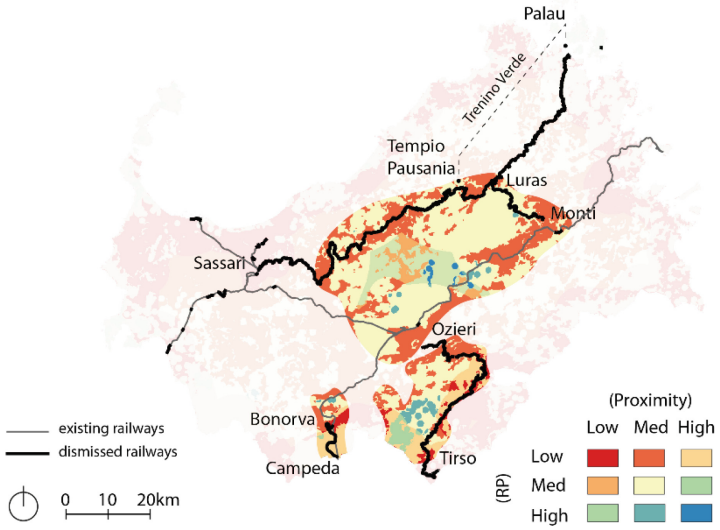

Fig. 7. Cultural ES potential of disused railways in Sassari (Areas of interest are highlighted by reducing the opacity level of the remaining portions of the map)

4 Findings and Recommendations

Figure 7 shows areas with high recreation potential along the railway routes which needs better connectivity. There are bike routes available in 3 stretches which are Palau – Tempio Pausania – Sassari route, Luras Monti and Tirso – Ozieri routes. However, the frequency of use is considered, utilizing Strava Global Heatmap[11], we can see that the routes are not frequently used on foot for hiking, trekking or walking. This might be because the services in these routes might be limited to accommodate hikers and trekkers.

ROS map shows us the intervention areas where there is potential for cultural ES provision along the disused railway routes. Using the information regarding the condition of these areas, following recommendations can be made.

4.1 Palau – Tempio Pausania – Sassari

The 150.2 km long rail line has a large number of areas of interest along its direction. It is a well-connected and most popular route since it connects the west to the east in Sassari province. The route is partially used by Trenino Verde which is a touristic train that operates in summer months. Part of the main line (Sassari to Palau) that is a part of Trenino Verde is between Palau-Tempio which is about 59 kms. An example of a transformation of disused railway site where there are few trains operate can be found in Mexico. The project "Parque Lineal Ferrocarril De Cuernavaca / Linear Park

[11] Strava Global Heatmap. Retrieved https://www.strava.com/maps/global-heatmap?style=dark&terrain=false&sport=All&gColor=hot&gOpacity=100&labels=true&poi=true#8.78/40.9203/8.8602 (last accessed 5 March 2024).

Cuernavaca Railroad" that was awarded in the 10th International Landscape Biennale in Barcelona[12]. This can be a good example because of the strategies they have such as "system of public spaces", "weaving neighbourhoods" and "muti-scale impact".

There is already a biking route following the railway line. Since it connects to the capital of the province, it may provide more connections. In this route, only the part between Tempio Pausania and Luras can be accessed by bike or on foot. Since Luras is also the starting point of the shorter stretch that is mentioned earlier, the route Tempio Pausania – Luras – Monti can be better connected and improved. Although there are areas that connect to hiking and trekking trails, in terms of pedestrian access, there are currently limited connections. Given that this stretch serves as a crucial hub for multiple routes, it's imperative to suggest interventions that enhance user experience. These interventions may include implementing signage elements for better navigation, enhancing security measures, ensuring regular trail maintenance to minimize disruptions, providing an adequate number of stops, and offering essential services at these stops to cater to the needs of users. Since the Trenino Verde offers touristic activities, public areas for people to enjoy areas with views can be improved with adequate number of seatings, shade providers, offering facilities for food and water to cater to the needs of visitors. Finally, the fact that it crosses through a large number of "comune" which are local administrative districts that constitutes provinces, its capacity to weave communities should be acknowledged. As demonstrated by the success of Cuernava Linear Park, it is imperative to ensure active participation from communities in the creation of various public spaces along the route, particularly in areas where the stretch traverses through more urbanized areas.

4.2 Luras – Monti

This is a 23 km long stretch and in Luras there is connection to the previously mentioned route. The Trenino Verde route stops here before it arrives to its final stop, Tempio Pausania. Therefore, since it is already accessible by the touristic train ride, it offers a good historical context considering that the visitors can enjoy the actual train ride before they can have a walk along the route. After the analysis 15 areas of interest are identified that are of max 15 min distance from the route. These are 3 cultural places from "luoghi della cultura" layer, and 12 landscape assets which are a part of the "beni paesaggistici" layer according to the categorization of Sardegna Geoportale. The cultural places consist of 2 museums and 1 tomb which are Tomba di Giganti Di Pascaredda, Museo del Sughero and Museo Diocesano di Arte Sacra Santa Giusta. The landscape assets that exist along the route are 10 rural settlements typical to the north of Sardinia that are called "stazzo", 1 church and 1 "nuraghe" which are a typology of ancient megalithic buildings typical to Sardinia. 12 of these points of interest lcoates in Calangianus such as Stazzo Montada, Stazzo Vacciledu, Stazzo Bal di Trau, Stazzo Frati Satta, Stazzo Mastruledda, Stazzo Venapiccina, Stazzo Pitreddu, Stazzo Ambrogio Mossa, Stazzo Lu Rustu and Chiesa della Madonna delle Grazie, 1 in Berchidda such as Stazzo Alzola Dei Reste and 1

[12] International Landscape Biennale in Barcelona [Official Website of the Biennale]. Parque Lineal Ferrocarril de Cuernavaca. (2018). Retrieved from https://landscape.coac.net/parque-lineal-ferrocarril-de-cuernavaca (last accessed 5 March 2024).

nuraghe locates in Monti boundaries. More areas of interest exists if the diameter is expanded, for the scope of this study, the diameter of 750 m is considered an adequate distance since it can walked in 15 min.

4.3 Tirso – Ozieri and Bonorva-Campeda

Tirso-Ozieri is a 78.48 km long stretch where there is a cycle route available as a part of the project "Ciclovia Sardegna". Hence, it is already recognized as a slow mobility route by authorities. Although it is a very important step towards reusing disused railway sites for recreational activities there is still room improvement. According to Ferrovie Abbandonate, the railway site does not have the tracks anymore. It is invaded by spontaneous vegetation which increases its value. Between Chilivani and Pattada it has recently been converted into a bridle path and the line offers some works of art along the line which are in good condition. The small houses and buildings of the former stations still exist which can provide necessary services to recreational users such as bike maintenance, assistance, food and water etc. This route is well connected to previously mentioned routes however there is no slow mobility route that connects it to Bornova-Campeda route where another abandoned railway line exists with abandoned buildings. Since the line in Bornova is rapidly deteriorating according to the information received from Ferrovie Abbandonate, the connection to the existing cycle route would enhance the conditions through regenerative strategies. There is an operating line near this site, hence it is accessible by surrounding towns. From Oziero to Monti, which is the start of the route that is previously mentioned, there is a biking route. This route connects the two abandoned railway route (Tirso to Ozieru and Monti to Luras). Similarly, a connection can be provided between Bonorva – Campeda route and Tirso – Ozieri, possibly through a slow mobility route between Bonorva and Ozieri. This would allow for a more connected system in the larger scale.

10 areas of interest are identified within the 750 m distance along the Bonorva-Campeda route. 2 Nuraghe, 1 church, 3 necropolis, 1 archeological site (recinto), 1 cave, 1 museum and 1 not classified. This shows great opportunities for recreation opportunities. After providing a connection to larger routes, several shorter routes can be tailored within the area of the stretch for each typology of user depending on the visitor profile. These can be thematic routes that connects historical sites or sports routes that has level of difficulties depending on the topology. In this kind of historical context, it is important for the visitor to be able to read the historical layers of the site and learn about its story. Hence, guiding elements and highlighted features to make the history visible to the user should be designed accordingly.

5 Conclusion

Railways hold immense potential to be a part of the GI strategies thanks to their capacity to provide multiple ES. This study specifically focuses on cultural ES within the context of Sassari province. The methodology provides a comprehensive analysis by mapping the relationship between areas suitable for nature-based recreation based on their cultural ES provision and the availability of slow mobility networks. The focus on slow

mobility networks demonstrates a commitment to encouraging non-motorized activities and promoting a sustainable way of living. Identifying areas based on this method, and then delving into detailed analyses for each route to identify potential interventions, serves as a guide for promoting action and furnishes decision-making authorities with valuable information.

Sassari province was selected in this study due to its characteristics that blends history, culture, industrial heritage and natural landscapes. The high number of abandoned railways in diverse conditions, some of which are partially operating for touristic purposes, some are a part of the slow mobility network, some lacks connectivity etc. provides a range of intervention possibilities and lesson to learn from. Therefore, the significance of this study extends far beyond the confines of Sassari province. It serves as a model for regions worldwide grappling with similar challenges of revitalizing disused railways and brownfields while preserving cultural identity and enhancing environmental sustainability.

However, there are some limitations. The available data is crucial for this method; presence of areas of interest, available slow mobility routes, especially their current condition is not easy to find in each region. In this study, all available data pertaining to the mentioned parameters is utilized. However, to further enhance the quality of this research, it is essential to ensure that the input data is not only up to date but also as comprehensive as possible. This will contribute significantly to the accuracy and completeness of the findings.

Due to the paper's scope, statistics regarding beneficiaries have not been included. However, integrating beneficiary demands into the equation, along with user analysis including user typologies and their respective needs, would yield more precise results and be more effective in encouraging authorities to take action.

The research underscores the significance of typology-specific work in reutilizing brownfields as part of green infrastructure strategies by focusing on disused railways. This highlights the necessity for further investigation into alternative typologies of brownfields and exploration of additional groups of ecosystem services to effectively showcase their potential.

Acknowledgments. This article was produced while attending the PhD program in Sustainable Development and Climate Change at the University School for Advanced Studies IUSS Pavia & University of Cagliari, Cycle XXXIX, with the support of a scholarship financed by the Ministerial Decree no. 118 of March 2nd 2023, based on the NRRP - funded by the European Union - NextGenerationEU - Mission 4 "Education and Research", Component 1 "Enhancement of the offer of educational services: from nurseries to universities" - Investment 4.1 "Extension of the number of research doctorates and innovative doctorates for public administration and cultural heritage".

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Gasparrini, C., Terracciano, A.: Messina. Green and Blue Infrastructures for the Re-urbanisation of the City. In: Arcidiacono, A., Ronchi, S. (eds.) Ecosystem Services and Green Infrastructure. Cities and Nature. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-54345-7_14
2. Posner, S., McKenzie, E., Ricketts, T.: Policy impacts of ecosystem services knowledge. In: Proceedings of the National Academy of Sciences **113**(7), 1760–1765 (2016) https://doi.org/10.1073/pnas.1502452113
3. MA: Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC (2005)
4. O'Brien, L., de Vreese, R., Kern, M., Sievänen, T., Stojanova, B., Atmiş, E.: Cultural ecosystem benefits of urban and peri-urban green infrastructure across different European countries. Urban Forestry & Urban Greening **24**, 236–248 (2017). https://doi.org/10.1016/J.UFUG.2017.03.002
5. Zulian, G., Paracchini, M., Maes, J., Liquete Garcia, M.: ESTIMAP: Ecosystem services mapping at European scale. EUR 26474. Luxembourg (Luxembourg): Publications Office of the European Union (2013). https://doi.org/10.2788/64713
6. Paracchini, M.L., Zulian, G., Kopperoinen, L., et al.: Mapping cultural ecosystem services: a framework to assess the potential for outdoor recreation across the EU. Ecol. Indic. **45**, 371–385 (2014). https://doi.org/10.1016/j.ecolind.2014.04.018
7. Cortinovis, C., Geneletti, D.: Mapping and assessing ecosystem services to support urban planning: A case study on brownfield regeneration in Trento. Italy. One Ecosystem **3**, e25477 (2018). https://doi.org/10.3897/oneeco.3.e25477
8. Geneletti, D., Cortinovis, C.: Identifying Ecosystem Service Hotspots to Support Urban Planning in Trento. Cities and Nature, Part **F335**, 153–165 (2021). https://doi.org/10.1007/978-3-030-54345-7_12
9. Isola, F., Lai, S., Leone, F., Zoppi, C.: Strengthening a Regional Green Infrastructure through Improved Multifunctionality and Connectedness: Policy Suggestions from Sardinia. Italy. Sustainability **14**, 9788 (2022). https://doi.org/10.3390/su14159788
10. Paracchini, M.L., Capitani, C.: Implementation of a EU wide indicator for the rural-agrarian landscape. Water (2011). https://doi.org/10.2788/26827
11. Bacchetta, G., Bagella, S., Biondi, E., Farris, E., Filigheddu, R., Mossa, L.: Vegetazione forestale e serie di vegetazione della Sardegna (con rappresentazione cartografica alla scala 1: 350.000) [Forest vegetation and serial vegetation of Sardinia (with map at the scale 1:350,000], Fitosociologia **46**(1), 3–82 (2009)