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Integrating ecosystem services in transfer of development rights: a literature review

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Abstract

In recent years, transfer of development rights (TDR) programs have become widespread as a mechanism for implementing urban transformations and achieving planning goals. As market-based instruments, they facilitate land acquisition whilst avoiding compulsory purchases and minimizing public spending. By promoting urban transformation, TDR programs affect the provision of ecosystem services (ES) delivered by green and permeable areas. ES are essential for wellbeing, and the inclusion of ES in planning decisions promotes sustainable urban development. This research aims to provide a starting point for mainstreaming ES knowledge in TDR studies and application. Through a literature review, this paper aims to gain greater understanding as to what ways, and to what extent, ES have been considered so far in TDR studies and to identify if there is evidence that demonstrates how ES can be included in the design phases of TDR programs to improve their effectiveness in ensuring sustainable spatial transformations. The results show that the inclusion of ES can strengthen the ex-ante phase of TDR processes, supporting the development of the design features and paying greater attention to receiving areas identified during the process.

Keywords: Transfer of development rights; ecosystem services; literature review; planning policy; market-based instrument.

1.Introduction

Transfer of Development Rights (TDR) programs are market-based planning instruments that are designed to facilitate urban transformations. They stand out from other planning instruments because they enable land conservation and acquisition whilst avoiding compulsory purchase and minimizing public spending (Ferreira, 2020; Falco and Chiodelli, 2018). The development of TDR programs was underpinned by the spread of neoliberal economic policies since the late 1970s, which are characterised by reduced state intervention in public strategies in favour of private parties (Tasan-Kok and Baeten, 2012). Furthermore, the economic crisis of 2008 and the introduction of austerity policies led local administrations to experiment with land-based financing instruments and market exchanges between private actors to implement urban projects and achieve planning goals (Artioli, 2021; Ferreira, 2020). TDR programs allow landowners to sell the development rights (DR) assigned to their land plot (sending area) to another interested party who can use them elsewhere (receiving area). Then, the sending area can be transferred to the public administration free of charge, as often happens in European countries e.g., Italy (Serra, 2021) and Spain (Muñoz-Gielen, 2014), or, in some cases, as in the United States, the property remains unchanged, but a conservation easement is applied limiting the level of area development (Nelson et al., 2012).

Whilst receiving areas accommodate new development, sending areas are used to implement urban projects of public interest, such as transport infrastructures or social housing, but also to increase the supply of green and permeable areas that promote well-being for the local population and enhance a city's resilience. For this latter reason, TDR programs have been broadly used over the years as conservation tools for natural and agricultural areas of high ecological value (Crompton, 1990; Linkous, 2016; Chen et al., 2020; Harman and Choy, 2011)

and to achieve a wide range of environmental goals, ranging from the containment of soil consumption (Belena et al., 2013) to the management of flood risk (Ward, 2013).

By preserving sending areas, TDR programs can contribute to enhancing the provision of ecosystem services (ES) thus contributing to environmental planning goals (Claron et al., 2022; Slaev et al., 2022; Barrall and Guillet, 2023). Indeed, ES can mitigate some of the major challenges facing our cities, among others, biodiversity loss, air and noise pollution, heat island effect and water runoff (Gómez-Baggethun and Barton, 2013). However, it is important to note that TDR programs always imply new development in receiving areas which cause environmental impacts, reducing the provision of ES and compromising the achievement of environmental targets. Therefore, in order to foster sustainable urban transformations, TDR programs should be considered as instruments that aim to rebalance the mismatch between ES provided and needed within the city or between urban and rural areas rather than a merely conservation tool.

The environmental and social impacts generated by TDR programs must be carefully evaluated, and ES can have a role in doing this. Indeed, it is now widely recognized in literature (Cortinovis and Geneletti, 2020; Grêt-Regamey et al., 2017; Barò et al., 2016; Mascarenhas, A. et al, 2014) that the analysis of ES, through their mapping and assessment, can help to describe and quantify the consequences of urban transformations on the environment and citizens' well-being, providing a more comprehensive understanding of the trade-offs associated with land-use decisions (Cortinovis and Geneletti, 2020). In spatial planning, ES are a driver of innovation overcoming the quantitative approach of regulative instruments towards qualitative or performance-based approaches (Ronchi, 2021). Moreover, ES can strengthen the needs of groups normally under-represented in decision-making processes by emphasising the link between the natural environment and its beneficiaries (Hauck et

al.2013). Hence, if ES are mainstreamed into TDR processes, they could improve their effectiveness in achieving sustainability goals in several ways (e.g., by ensuring a balance between the ES provided by the sending areas and those lost in the receiving ones) and help move away from the narrow understanding of TDR as conservation instruments.

A rather extensive literature has been produced concerning TDR, reporting cases of programs implemented (Martinico et al., 2014) as well as methodological proposals (Schwaab, 2020) and literature reviews (Dyca,2020) comparing the potential and differences of these programs to prescriptive approaches in achieving sustainability goals. In these studies, ES are always implicitly involved because TDR programs influence the provision of ES through implementing spatial transformations. However, since part of the literature on TDR precedes the definition and development of ES concepts in planning, ES are not always explicitly considered and evaluated. Nevertheless these studies may represent a relevant source of analysis for collecting useful information to understand how ES may be included into TDR programs and thereby reducing the gap between studies on land-use instruments and ecosystem services.

The existing literature on TDR points out how this instrument has not always been effective in achieving the set goals due to errors in the development and implementation of programs (Walls and McConnel, 2007). This is because TDR programs are complex processes involving several parties and cannot be considered a *panacea* (Harman and Choy, 2011) always valid in the same manner, but they need to be adapted according to the different contexts and supported by the right assessments.

Pruetz and Standridge (2009) systematically identified ten factors that can influence the success of TDR programs. These factors can be defined as “internal”, if they are related to the design of the program, or “external”, if they are related to the context of the application, such

as the real estate market activity (Falco and Chiodelli, 2018). While for "external factors" planners and local administrations can only analyse the context to detect their presence before developing and adopting a TDR programs, for "internal factors" planners can act by improving the design of the program.

The design phase therefore represents an important field of research and experimentation to improve the effectiveness of TDR programs and to support local administrations that have a key role in establishing and linking their crucial features (Ferreira, 2020).

Through a literature review, this research aims to understand how knowledge and assessment of ES can be integrated into TDR process, providing a starting point for further studies and applications in planning practice.

This paper intends to address the following questions:

- *In what ways, and to what extent, have ES been considered so far in TDR studies?*
- *Is there evidence in the literature showing how ES can be included in the design of TDR programs?*

In order to address the two research questions, in Section 2 we present a background on TDR, regarding its main characteristics, and on ES in urban planning. In Section 3, we describe the research approach and the methodology adopted and in Section 4 we present the results. In section 5, we discuss the main findings, highlighting the differences between the research conducted on the theory of ES for TDR and the actual case studies applied. Finally, in section 6 we present the main conclusions of our research and the limitations of this study.

2. Background on transfer of development rights and ecosystem services

2.1 TDR successful factors and design

The design features defining TDR programs have been clearly identified by Walls and McConnel (2007) and further discussed and summarised by Linkous (2016) as follows: (1) designation of sending and receiving areas, (2) DR allocation rate, and (3) rules of DR transfer (density bonus and DR requirement in receiving areas). In addition to these three design features, we have recognised two other elements that local administrations must address to improve the design process of TDR programs. We have not found them explicitly in existing frameworks of analysis, but they are currently present in the literature (Pruetz and Standridge, 2009; Nelson et al., 2012; Colavitti and Serra, 2017; Falco and Chiodelli, 2018; Hou et al. 2018; Shahab et al. 2019). These two additional elements do not involve any planning actions aimed at changing density or land use, but they are essential to support the program design. For this reason, we have called them supportive actions: (a) public participation and (b) register of DR and advertising. The internal factors identified by Pruetz and Standridge (2009) are directly linked to the mentioned design features and supportive actions. In table 1 we have listed all 10 success factors by classifying them as internal or external and matching them to the design features or supportive actions that they can affect. Afterwards, we describe the design features and supportive actions while considering the internal success factors.

Table 1 – Successful factors by Pruetz and Standridge (2009) combined with design features and supportive actions

Factor	Internal/External to Program Design	Associated Design Feature/ Supportive Action
1.Demand for bonus development	External	
2.Receiving area customised to the community	Internal	Sending and receiving areas designation
3.Strict sending area developments regulations	Internal	Allocation rate
4.No alternative to TDR for further developments	External	
5.Market incentives	Internal	Rules of transfer
6.Ensuring that developers will be able to use TDR	External	
7.Public support for preservation	External	
8.Simplicity	Internal	Public participation
9.Promotion and facilitation	Internal	DR register and advertising
10.TDR bank	Internal	DR register and advertising

2.1.1 Sending and receiving areas designation

The identification of sending and receiving areas is a crucial and distinctive step of this instrument. Sending areas are plots of land targeted for preservation whose DR are transferred to another area. Receiving areas are plots of land designated to accommodate urban growth, where DR are transferred onto (Walls and McConnel, 2007).

The literature recognises two solutions for the identification of sending and receiving areas: dual zone TDR programs or single zone TDR programs (Johnston and Madison, 2007; Linkous 2014). Dual zone TDR programs, or also called non-bounded districts (Janssen-Jansen, 2008), can designate distant sending and receiving areas in distinct contexts, such as from rural to urban or peri-urban areas, within the same municipality or between municipalities. Instead, in the single zone TDR programs parcels of sending and receiving sites can be adjacent or far from each other but within the same bounded district.

The research carried-out by Pruetz and Standridge shows that receiving areas with attributes appreciated by the community (e.g., proximity to transport system) have improved the market attractiveness and the program success. As a rule, receiving areas in marginal or degraded zones are not optimal. However, all possible scenarios must be explored to select the best for each situation (Pruetz and Standridge, 2009).

2.1.2 DR allocation rate

The TDR allocation rate is the number of DR each sending area can potentially sell. This is a key step since attribution of DR credits, intended as building capacity, gives tangible form to the plan and its goals (McConnel and Walls, 2007). The DR are usually expressed as dwelling unit/ha (Linkous, 2016) or as square metres of floor area/square metres of land.

The two main methodologies for defining the number of DR to allocate are defined as *bottom-up* and *top-down* (Machemer and Kaplowitz, 2002).

In the *bottom-up* approach, DR are allocated based on land features of the sending area and the amount of future development will be the sum of the DR allocated to each sending area.

In order to assess the features of sending areas, planners must set criteria to follow, also based on the goals to achieve with TDR. Therefore, for example, sending areas can be assessed according to residential convenience or environmental importance criteria. In the first case, following residential criteria, sending areas classified as “urban” will be assigned a higher number of DR than “rural” or “natural” sending sites. On the contrary, following environmental importance, the more sensitive an area is, the more DR will be assigned to it. Such criterion of DR allocation has been applied in some TDR programs for promoting the conservation of environmental sensitive areas (Jhonston and Madison, 2007). Pruetz and Standridge (2009) showed that a low building capacity, with no other alternative in terms of

reward measures, is a successful feature for achieving environmental goals with TDR. They provide a threshold value of one unit per five acres in the sending site for the US context, which should not be exceeded.

The allocation based on a *top-down* approach concerns first the receiving areas and their capacity to accommodate new urban development. Therefore, with this method a total amount of appropriate development for the community is first defined and then distributed as DR to the sending areas.

2.1.3 Rules of DR transfer (density bonus and DR requirements in receiving area)

When the transfer of DR takes place between areas with the same real estate value, the market value of the DR remains unchanged and fair treatment between landowners is guaranteed. On the contrary, if the transfer takes place between two areas of different real estate values, the market value of the DR changes, assuming the value of the area where DR are applied. Therefore, in this case, to ensure fairness between landowners, the planner must regulate the transfer of DR (Renard, 2007) by setting a conversion coefficient.

If DR originate from a sending area with a higher market value than the receiving area (e.g., from the city centre to the periphery), a conversion coefficient (>1) is applied, increasing the number of DR above the baseline set in the plan. In this case, a higher number of DR allocated in the receiving area (density bonus) may trigger the market by increasing the attractiveness of TDR.

Instead, If the DR originate from a sending area with a lower market value than the receiving area (e.g., from the periphery to the city centre), a conversion coefficient may be applied (<1) to reduce the number of DR in the receiving area.

2.1.4 Public participation

The public participation process is fundamental to an effective design of a TDR program and the public administration has a leadership role in driving the process as well as providing technical assistance (Nelson et al., 2012). The participation path must start at the preliminary stage of the program, and it must include all interests present (Shahab et al., 2019). It may therefore be useful to establish an advisory committee representing the various community groups. At the first stage, an exchange of information and opinions between local administration and representative committee about current local conditions and potential TDR program takes place. After acquiring the necessary data, planning officers of the public administration will draw up potential TDR scenarios to be discussed with the committee. After receiving feedback, officers will revise the program until a final proposal satisfying the committee is reached (Nelson et al., 2012). As point out by Pruetz and Standridge (2009), TDR program with clear, well-defined, and effectively communicated targets increases public participation and stakeholders' approval, facilitating its implementation.

2.1.5 DR register and advertising

The local administration should establish a register to record the DR assigned to a land plot and its details: sending area with relative location, the owner, and the development potential. In doing so, the municipality can link supply and demand of DR and improve the transparency of TDR programs. Landowners and developers must know the DR available and how they can benefit from them (Nelson et al., 2012). For this reason, realising a consultable web page with a register could be useful to support the implementation of TDR programs (Pruetz and Standridge, 2009). In addition, the local administration can choose to establish a TDR bank, has in many cases happened in USA (Kaplowitz et al., 2008). A TDR bank is an intermediary

entity authorised by the government to buy, hold, and resell DR. This allows owners of sending areas to sell their rights even if there is not yet an owner of receiving areas interested in buying, and in this way the sending areas can be preserved without delay.

2.2 Ecosystem services in urban planning

Ecosystem services (ES) are defined as “the direct and indirect contributions of ecosystem to human wellbeing” (TEEB 2010), and from the publication of the Millennium Ecosystem Assessment (2005) they have been proposed as an innovative way to communicate the increasing alarms about the high levels of biodiversity loss and ecosystem degradation. The ES offer an additional proof for nature preservation (Mace, 2014) and their assessment can support decision-making processes (Daily et al., 2009).

Urban planning is the most relevant decision-making process for ES since it defines “where to put things” (Polasky et al., 2008). Urban planning determines land-uses and the spatial location of nature-based solutions and permeable areas, which are the main providers of ES. Moreover, urban plans, through the allocation of functions, influences the distribution of people within the city, who are the beneficiaries of ES and determine the demand for them (Barò et al., 2016). The inclusion of ES in planning decisions is widely advocated by both research and policy to ensure sustainable spatial transformations and to improve the quality of urban plans (Guerry et al., 2015; Diaz et al., 2015; TEEB, 2010). In the last few years, scientific research has produced and improved methods for mapping and assessing ES based on the supply and demand (Cortinovis and Geneletti 2020; Gret-Regamey et al., 2017; Haase et al., 2014; Burkhard et al., 2012). In this way, it is possible to outline interventions in order to satisfy the existing demand for ES and to assess the expected impacts of proposed interventions on current provision. The assessment of ES promotes compensation

mechanisms (Cortinovis and Geneletti, 2020) and TDR can support their implementation, acquiring areas where ES supply needs to be enhanced and transferring DR according to performance-based approaches. Performance-based planning approaches relies not on strict regulations, but on performance criteria suitable for achieving the long-term goals set by the plan. This means that spatial transformations must positively contribute to the goals of the plan fulfilling certain performance level to be approved. Thus, in this framework, the level of performance may depend on the impacts on the provision of ES and the ability to meet the demand for ES. However, despite the benefits of incorporating an ES approach in planning are widely discussed, the applications in planning practice remain rather limited (Longato et al., 2021).

3. Methods

Our method consists of three main steps and combines a literature review with content analysis. The first step involves the selection and classification of relevant publications found in the literature in order to provide an overview about the current research on TDR. The second and third steps (Section 3.2 and 3.3) address the two main research questions, whilst conducting a direct content analysis (Hsieh and Shannon, 2005) on the selected papers.

3.1 Publications selection and classification

We identified the relevant scientific publications in Scopus using the keyword “Transfer of Development Rights” and its synonyms. The search was performed on March 30, 2021, on the title, abstract and keywords fields using the string: (TITLE-ABS-KEY ("Transfer of Development Rights") OR TITLE-ABS-KEY ("Transferable Development Rights") OR TITLE-ABS-KEY ("Tradable Development Rights")). It resulted in 216 scientific publications from 1974 to

2021, which included book chapters and journal articles. From this first collection we removed the duplicates, the documents not in English, and those with no author references, which resulted in 212 scientific publications.

We read all abstracts of this first collection, reporting the information in a table containing: *publication year, author(s), title, country, and TDR's goals*. It is important to note that the "*TDR's goal*" did not refer to the general goal of the article, but to the objective of the TDR in the study, namely the reason why TDR was applied, or studied, in that case. In the table, we reported the same terminology that appears in the abstract and/or in the title to describe TDR's goals. Not all publications specified the TDR's goal in the title or abstract, because they mainly focused on certain features or technical instrument conditions such as market activity or transaction costs. In this latter case the column "*TDR's goal*" is replaced with "*TDR features/other*". The publications with no TDR's goal were 49.

We classified the remaining 163 documents according to the given goal. In this way, we could consistently identify all existing publications on TDR regarding environmental planning goals. Furthermore, with this methodology it was also possible to identify the other purposes for which TDR has been applied over the years. A total of seven categories emerged: environmental policies implementation, heritage conservation, urban transformation implementation, growth management, public infrastructures realisation, social housing promotion, and equity promotion. Due to the purpose of this paper, the category "environmental policies implementation" requires further investigation. We have therefore classified it into sub-objectives identifying the different types of environmental policies.

3.2 Consideration of ecosystem services

In this step, publications falling in the category *environmental policies implementation* were further investigated. This step is divided into two distinct analyses: the first one aims to assess the integration level of ES knowledge within scientific publications (Section 3.2.1); the second intends to identify the various categories of ES addressed (Section 3.2.2).

3.2.1 Level of ES integration

To assess the level of ES integration through a qualitative content analysis, we created a scoring system in line with previous research (Baker et al., 2012; Geneletti and Zardo, 2016; Cortinovis and Geneletti 2018). Table 2 shows the scoring system used, ranging from 0 (no integration) to 4 (high level of integration).

The highest level of integration (Level 4) was assigned to those publications that show strong evidence of ES concept, highlighting the positive effects of their provision on human well-being or the serious consequences of the lack of their provision. Level 4 requires the presence of a practical assessment of ES provision or demand, or at least the scientific publication must recommend potential indicators for ES evaluation.

After the scoring attribution, we classified the publications with ES concept evidence (level 1, 2, 3 and 4) in the different typologies of scientific research: *literature review*, *case studies* *report and methodology proposal*.

Table 2 – Level of ES integration

LEVEL	DESCRIPTION
0	No evidence of the ES concept
1	Evidence of the ES concept, implicitly or explicitly, only in the context description. The consequences of the lack of adequate ES provision or the positive effects of its improvement are not, or weakly, described.
	<p>Example A</p> <p><i>"..these legislative and policy frameworks require local governments to identify and implement options for preserving public interests such as beach access and coastal ecosystems.."(Robb et al.,2020)</i></p> <p>Example B</p> <p><i>"Policy contradiction in the rapid urbanisation in China comes from the twin demands for urban development land and urban expansion and the protection of cultivated land for food security." (Chen et al., 2020)</i></p>
2	Ecosystem services are defined and clearly linked to the ecosystem that provides them. However, the approach is not primarily structured around the ES concept.
	<p>Example A</p> <p><i>"Nowadays, BGI (Blue Green Infrastructures) have a broad appeal as they recreate a naturally oriented water cycle, while providing a variety of additional multiple benefits including air pollution reduction, carbon sequestration and landscape benefit." (Dyca et al.,2020)</i></p> <p>Example B</p> <p><i>"Many important ecosystem services can be provided by peri-urban areas, which remain in agricultural production, including: regulation of flood waters; storm protection; provision of biodiversity corridors; waste absorption; and fulfilment of cultural and spiritual needs."(Harman and Choy, 2011)</i></p>
3	The awareness of the importance of ES is clear and well highlighted throughout the entire study. However, it lacks practice application of ES assessment.
	<p>Example A</p> <p><i>"River floodplains are significant environmental resources in that they provide multiple ecosystem services. ... The essential point is that we must consider two types of environmental externalities related to the ecosystem services of river floodplains to make decisions on floodplain development. First, the development of river floodplains has opportunity costs in terms of lost ecosystem services..."(Mori, 2010)</i></p>
4	Strong evidence of ES concept and proposal/application of indicators for their assessment.
	<p>Example A</p> <p><i>"To prevent further sprawl from reducing the provision of ESs, the impact of policies on the spatial development of settlements and the resulting loss in ESs needs to be assessed. ... Here, it is our aim to exploit both statistical modelling and spatially explicit economic modelling to identify the impacts of different policies on urban development configurations and ESs." (Schwaab et al.,2020)</i></p> <p>Example B</p> <p><i>"GOUD strategy needs to be based on a careful evaluation of involved UES. Consequently, a set of indicators has to be established and calculated, according to UES to evaluate available data." (Martinico et al., 2014)</i></p>

3.2.2 Categories of ES involved

The relevant ES have been identified and classified for the papers that received a score above zero (Table 2). We selected The Economics of Ecosystems and Biodiversity (TEEB) classification (TEEB, 2010) as a reference to classify ES. Table 3 is an example of the method used and shows how the category and type of ES have been identified. We considered it appropriate to distinguish ES that directly responded to the TDR's goal (identified during the classification of documents in point 3.1), from those merely mentioned. Following the example in Table 3, we have considered the provisioning service "food" as directly linked to the main objective of TDR to ensure food security, and the service "recreation and tourism" as only mentioned.

Table 3 - Example of ES type involved according with TEEB classification

TDR's GOAL	EXCERPT OF PAPER	PROVISIONING		CULTURAL	
		Food	Water	Aesthetic information	Recreation & tourism
Ensure food security	<i>"...In recent years, the environmental sustainability of agriculture and the conservation of farmland has drawn much attention because of the increasing concerns regarding food security. Farmland often acts as a green core or green belt of a city, offering ecological benefits and leisure areas for citizens."</i>	x			x

3.3 TDR features analysis

In order to develop this section, we considered only publications with an ES integration level of 2, 3 and 4 since the topic of ES in documents classified in level 1 was too elusive for a systematic analysis concerning the design of TDR programs.

We performed an in-depth analysis based on the framework presented in Section 2 and summarised again in Table 4 for convenience. The design features and supportive actions identified are the key elements that we have explored to understand how ES knowledge

relates with them. Furthermore, we identified additional information - listed in Table 5 - to have a complete picture of TDR studies and programs reporting ES knowledge.

Table 4 – Framework of analysis. “Design features” based on Walls and McConnel (2007) and “supportive actions”

<i>Design features</i>	<i>Supportive actions</i>
1.Designation of sending and receiving areas	a. Public participation
2.DR allocation rate	b. Record of DR and advertising
3. Rules of DR transfer (bonus density and DR requirements in receiving areas)	

Table 5 – Framework of analysis.

<i>Information</i>	<i>Description</i>
Reason for TDR adoption	Major challenges identified in the context to be addressed by the TDR program.
Level of application	Municipal or inter-municipal TDR program.
Detail on data collective	Types of data utilised to develop TDR programs.

4.Results

4.1 TDR overview

The 163 publications selected refer to seven TDR macro-objectives in these percentages: environmental policies implementation 62%, heritage conservation 11%, growth management 11%, urban transformation implementation 10%, public infrastructures realisation 2%, equity promotion 2% and social housing promotion 2%. Table 6 contains the description of the targets and their shares, also represented in Figure 1.

By classifying and analysing 102 publications about “*environmental policies implementation*” we found that 32% of them responded to a general objective of reducing land consumption

and preserving open spaces including both rural-agricultural land and natural sensitive areas in rural and peri-urban contexts. The remainder of the publications referred to more specific environmental objectives. Several documents (26%) focused on TDR for the preservation of agricultural land, reporting case studies from the USA and China. Another share (21%) includes all water management actions to counteract climate change, such as flood risk in urban contexts and on coastlines, and the actions aiming to preserve water natural resources. About 17% of publications focus on TDR for the protection and enhancement of biodiversity. Few studies (3%) deal with TDR as reward and bonus measures to support sustainable energy systems, and only one (1%) explicitly discusses TDR to implement green infrastructures in urban settlements. Figure 2 summarises these percentages of environmental policy types.

Table 6 – TDR overview

<i>TDR Target</i>	<i>% of publications</i>	<i>TDR target description</i>
Environmental policies implementation	62%	Publications that discuss TDR to preserve farmland, natural areas, reduce land consumption, improve energy efficiency of building stock and reduce the negative environmental impacts of urbanisation.
Heritage conservation	11%	All those experiences and discussions about TDR program to maintain building stock, preserve historic centres or buildings of significant architecture.
Growth management	11%	Publications that discuss how TDR programs address and manage urban developments, without explicit reference to environmental impacts.
Urban transformation implementation	10%	Publications dealing with the management of built environment and the re-development of urban areas, such as brownfield sites.
Public infrastructures realisation	2%	All those experiences of TDR program in implementing specific infrastructures and public goods such as streets and sports facilities.
Equity promotion	2%	Publications that discuss the cases where TDR is applied primarily to reduce the inequality among landowners and citizens in public services distribution.
Social housing promotion	2%	Studies that investigate the experiences of TDR in providing public subsidised rental and residential units for sale at controlled prices.

Figure 1 – TDR's goals

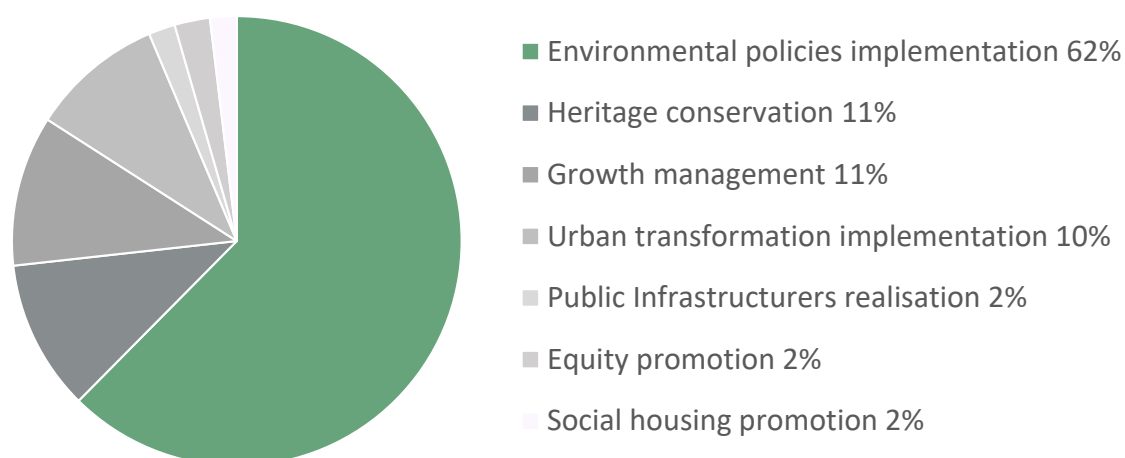
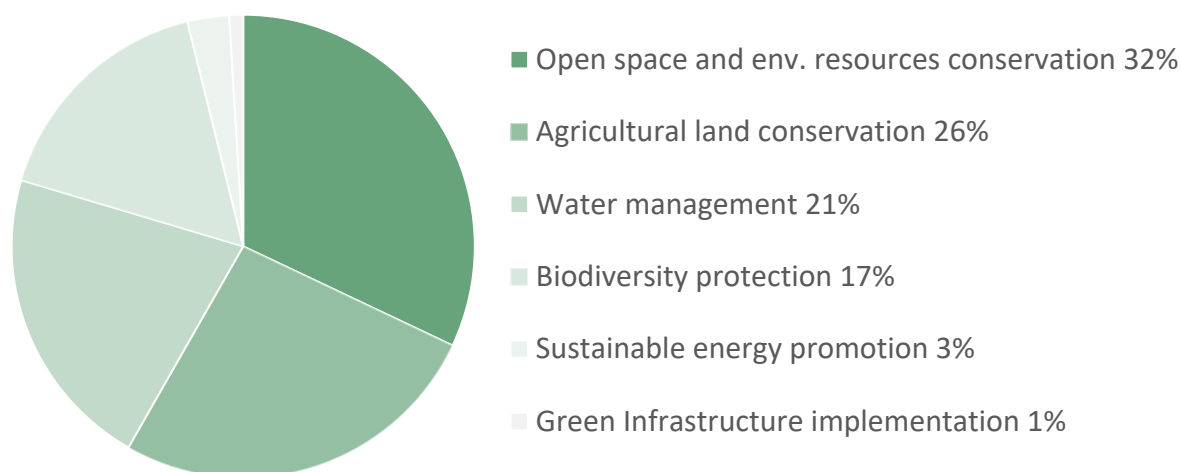


Figure 2 – TDR's environmental policy implementation types



4.2 Consideration of ecosystem services

4.2.1 Level of ES integration

The total number of studies on TDR and environmental policies was 102. However, 66 of these 102 referred to environmental goals without considering or mentioning the impacts and

benefits of environmental preservation on the community. Thus, only 36 studies included the concept of ES. Table 7 shows the results by detailing the number of the 36 scientific publications according to their level of integration with the ES concept and their typology (*literature review, case studies report, original research/methodology proposal*).

Table 7 – Results of ES integration level concept analysis

Level	N. of papers	Papers typology		
		<i>literature review</i>	<i>case studies report</i>	<i>methodology prop.</i>
I	28	6	15	7
II	3	1	2	
III	2	1		1
IV	3		1	2
Total	36	8	18	10

4.2.2 Categories of ES involved

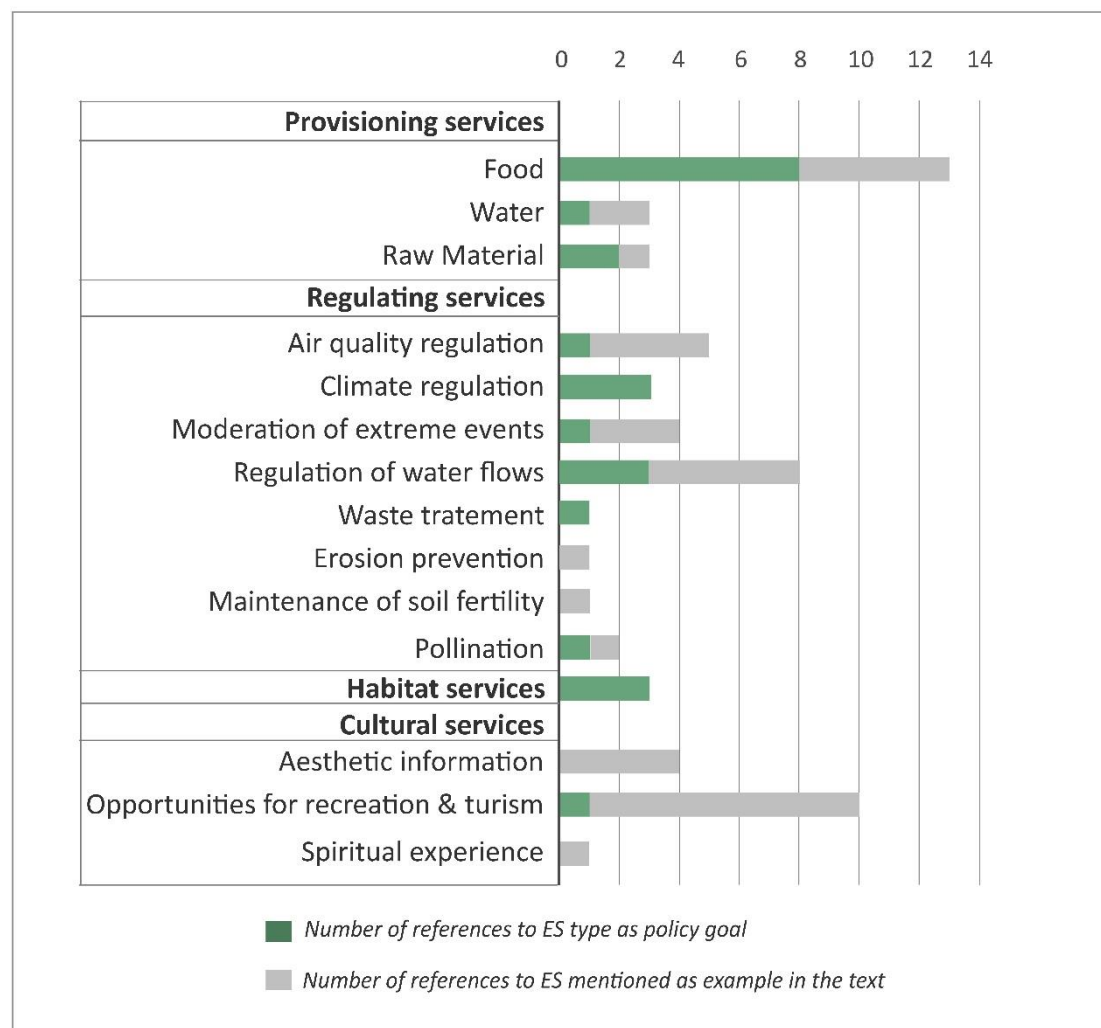
During the analysis of different ES categories involved, within 10 of the 28 publications related to the integration level 1 it was not possible to identify a specific type of ES since the concept was present (even implicitly using terms such as *ecological benefits, indirect use value, public goods, etc.*), but the publications failed to introduce any positive effects by the natural environment in detail. With regard to the remaining 26 publications (36 minus the 10 publications of level 1 mentioned above), figure 3 shows the overall results for the ES category and type involved, making a distinction between those directly related to the main aim of the TDR investigated and those merely mentioned within the research.

ES for the provision of food have been the most frequently considered in the goals to achieve through TDR programs, followed by the regulating ES for the mitigation of water flows.

Among the most frequently cited ES, there are habitat services and the cultural services for the provision of recreation and tourism.

The TEEB classification includes other services, such as ornamental resources or erosion prevention, which were not identified within the TDR studies and have therefore not been included in the figure 3.

Figure 3. Results of ES involved based on TEEB classification



Dark green colour highlights the number of times that ES are mentioned and directly linked to the goals of TDR.

Light green highlights the number of times that ES have only been mentioned in the text as an example of the benefits provided by green spaces but are not directly linked to the goal of TDR.

4.3 TDR features analysis

The analysis of the 8 publications with an ES integration level 2 and higher is presented in this section. The aim is to highlight the different contributions that ecosystem service methodology can provide to designing a TDR program as well as the possible shortcomings it can face (e.g., data issues) both in terms of design features and in terms of goals to be achieved via TDR program (reasons for adoption), level of application and data needed to carry out ES assessment. Table 8 below shows the details of the publications investigated.

Table 8. Detail of publications with ES integration level 2,3 and 4

Leve I	COD	Year	Authors	Title	Type
II	a	2020	Dyca, B. et al.	Common value: transferring development rights to make room for water	Literature review
	b	2019	Nair, D. et al.	The Biofin approach to biodiversity conservation in urban ecosystems: The case of Bangalore in India	Case study
	c	2011	Harman and Choy	Perspectives on tradable development rights for ecosystem service protection: Lessons from an Australian peri-urban region	Case study
III	d	2013	Parkhurst, G.M.	Payments for Ecosystem Services: Mechanisms to Achieve Desired Landscape Patterns	Literature review
	e	2010	Mori, K.	Can we avoid overdevelopment of river floodplains by economic policies?: A case study of the Ouse catchment (Yorkshire) in the UK	Methodology proposal
IV	f	2020	Schwaab, J. et al.	The difficulty of steering settlement development to reduce the loss of ecosystem services: an exploration of different development scenarios in Switzerland using spatially explicit land-use models	Methodology proposal
	g	2018	Privitera and La Rosa	Reducing Seismic Vulnerability and Energy Demand of Cities through Green Infrastructure	Methodology proposal
	h	2014	Martinico et al.	Green oriented urban development for urban ecosystem services provision in a medium sized city in southern Italy	Case study

4.3.1 Reasons for TDR adoption, level of application and data involved

Throughout the eight selected publications, the goal to realise resilient cities and landscapes capable of addressing contemporary environmental challenges is a common thread.

However, it was possible to identify two main reasons for the adoption of TDR in environmental policies. The first refers mainly to ecosystem *conservation/restoration* and includes all actions aimed at reducing the environmental impacts of urbanisation, preserving existing conditions (conservation of natural and rural characters) or returning to a previous environmental situation, such as the restoration of biodiversity in wetlands and the reconnection of habitat networks. The second reason for implementing TDR concerns the *enhancement* of ecosystems and refers to all programs that aim to provide a new ES flow or to drastically improve the current situation, as in the Catania case study where the accessibility of green spaces has quadrupled (Martinico et al.,2014).

By cross-referencing the reasons for adopting TDR in each publication (Table 9) with data on the level of application (Table 10), the findings show that TDR has been applied at regional and inter-municipal level in situations of urban growth for *conservation/restoration* purposes. At municipal level, it has been applied to provide a specific ES and to solve local urban issues such as climate change adaptation and accessibility to green spaces (*enhancement*).

Table 9. Reasons for TDR adoption.

Reasons for TDR adoption		
a	Integration of blue/green infrastructures for flood risk management	<i>enhancement</i>
b	Restoring opens spaces and habitat networks	<i>conservation/restoration</i>
c	Preserve natural resources in peri-urban areas	<i>conservation/restoration</i>
d	Achieve desirable landscape pattern to enhance the provision of ES	<i>conservation/restoration</i>
e	Management of river floodplains	<i>conservation/restoration</i>
f	Reduce the negative environmental impact of settlement development	<i>conservation/restoration</i>
g	Implement green infrastructure to seismic retrofitting and reduction of cooling dem.	<i>enhancement</i>
h	Enhance urban ecosystem services, especially cultural es	<i>enhancement</i>

Conservation/restoration: management of urban ecosystems, reducing the negative impacts of urban growth, maintaining the provision of ES, or restoring previous ecosystem conditions.

Enhancement: providing a new flow of ES or significantly enhancing the previous provision.

Table 10. Level of application

Level of application		
a	No data (literature review)	-
b	Bangalore metropolitan region	<i>intermunicipal</i>
c	Brisbane-City of Gold Coast-Shire of Duglas	<i>intermunicipal</i>
d	No data (literature review)	-
e	Catchment area	<i>intermunicipal</i>
f	Canton of Bern, region area	<i>intermunicipal</i>
g	Tremestieri	<i>municipal</i>
h	Catania	<i>municipal</i>

To understand which type of data has been used to assess the ES, we have considered the publications with the highest level of ES concept integration. The results highlight some important data issues for conducting a successful assessment. Schwaab *et al.* (2020) claim that in the Canton of Bern the assessment has been developed in a static way, using mainly land use data. However, this type of evaluation is not consistent in land management to face the temporal dynamics of ES provision, and for that an assessment based on land cover data is always recommended (Stürck *et al.*, 2015). At the same time, Martinico *et al.* (2014) point-out the difficulty of obtaining this type of data especially at local level, due to the lack of public administration resources. This is compounded by the local level's challenge of assessing ES based on an already clearly defined development project, which extends process time and requires more financial resources.

4.3.2. Design features and supportive actions

4.3.2.1 Design features: Designation of sending and receiving areas

Schwaab *et al.* (2019) utilised a methodology applied at regional level, in the canton of Bern in Switzerland, where the identification of sending and receiving areas takes place across

various municipalities categorised by type following national classification (i.e., urban, peri-urban, touristic, industrial, high-income, and so on) (Schuler and Joye, 2007). The study investigates two different scenarios for TDR programs and their impact on ES provision.

The results show that there is no clear better scenario, as they depend on the types of ecosystem service considered. In one scenario certain ES are encouraged to the expense of others, whereas in the second scenario the opposite result is achieved.

Privitera *et al.* (2018) explored a TDR program with sending and receiving areas distant from each. The authors focused only on sending areas without considering where receiving areas could be located. For the implementation of seismic retrofit and heat island mitigation, the most suitable sending areas for implementing green infrastructure were selected through an urban morphology analysis which led to identify clusters of buildings based on typology (e.g. detached or semi-detached houses) and ratio with open spaces (streets, courtyards, parking lots and small urban gardens).

The authors highlight that blocks of multi-storey buildings with a reinforced concrete structure appeared the most appropriate as sending areas accommodate new green spaces. Martinico *et al.* (2014) investigated a bounded district TDR program with both receiving and sending areas within so-called “resource zones” with the aim of acquiring several vacant or brownfield sites as sending areas suitable for the implementation of public green spaces. However, both in Martinico *et al.* 2014 and Privitera *et al.* 2018, a shortcoming is represented by the fact that sending and receiving areas were not identified on the basis of an assessment of existing ES but rather on the basis of other conditions (i.e., retrofitting costs, location, accessibility and service supply, environmental constraints, morphology, geological risk, microclimate, and noise pollution). The assessment was performed only a-posteriori to justify

the effectiveness of the project implemented through the TDR program and estimate the improvement achieved in terms of ES supply.

4.3.2.2 Design features: DR allocation rate

This section highlights that TDR studies so far have not really integrated ES methodology in defining DR allocation rates and that work needs to be done in this direction. In Privitera et al. (2018) and Martinico *et al.*, (2014) the DR allocation rate was determined following the *bottom-up* approach, according to the features of the sending areas. Specifically, Privitera et al. (2018) allocated DR to sending areas (blocks) based on seismic retrofitting costs, while in Martinico *et al.*, (2014), DR were allocated based on residential characteristics (location, accessibility and service supply, environmental constraints, morphology, geological risk, microclimate, and noise pollution) (see also Stanghellini and Cosmi, 2012). This means, for instance, that to assess an area against the criterion "microclimate", its suitability for residential use is evaluated according to the present microclimatic conditions. Hence, the "resources zone" located along the coast and on the hills of Catania, where the microclimatic conditions are suitable for housing, have been assigned a higher score, resulting in a higher final allocation of DR for sending areas within these "resource zones". This higher allocation of DR guaranteed that landowners agreed to participate in the TDR program. Finally, the methodological proposal of Schwaab et al. (2020) do not model ES to assign a specific number of DR to the sending areas. To achieve the aim of the paper of comparing the impacts of different spatial patterns on ES provision, the authors estimate the total future urban development on population growth statistics and then distribute it to all municipalities of the study area. Thereby, this method refers to a *top-down* approach.

4.3.2.3 Design features: Rules of DR transfer (density bonus and DR requirements in receiving area)

Concerning the rules for the transfer of DR, the literature reviewed in this section is not extensive and does not address this as a central point of discussion.

However, in the case-study of Catania (Martinico et. al,2014) the masterplan foresees that in the receiving areas new developments must observe environmental parameters, such as a minimum percentage of permeability and tree cover, to minimise negative impacts.

In addition, Schwaab *et al.* (2019) point out that the loss of ES in receiving areas could be reduced if the densities of new residential development are properly planned and carefully implemented.

4.3.2.4 Supportive actions: Public participation and DR register and advertising

The useful scientific publications to find information about public participation, DR register, and advertising were *Harman and Choy, 2011; Martinico et al., 2014; Nair et al., 2019.*

Martinico *et al.* (2014) point out how the concept of ES is of extreme importance to involve stakeholders in the TDR planning process. ES can promote the consensus on environmental goals to achieve and reduce conflicts between private and public stakeholders. However, practical applications are missing in this study.

Harman and Choy (2011) partially developed the theme of public participation and ES in their research through a methodology based on semi-structured interviews with different stakeholders. Findings show that there is a broad understanding of the potential ES provided by agricultural lands. Landowners are aware that through their actions they can enhance the provision of ES, even if the concept is not explicitly mentioned. However, to do this, they require financial incentives and government support. Harman and Choy (2011) conclude that

there is a degree of willingness on the part of both landowners and public administration to preserve these areas with the use of TDR, but first some major legislative barriers need to be overcome.

The documents analysed provide no in-depth discussions on the DR register and their advertising. Nevertheless, Nair et al. (2019) stress that the sale of DR could be facilitated by a third mechanism that combines supply and demand of DR, such as a TDR bank.

5. Discussion

5.1 Integrating ES in TDR

TDR programs are one of the market-based policy instruments that are proposed, as an alternative to traditional regulatory instruments, to address various planning and environmental problems. In the TDR approach, (i.e. zoning), the planner decides which areas to develop and which to preserve. However, unlike traditional zoning, the theory suggests that a market mechanism may then be used to achieve greater efficiency by ensuring that DR are 'traded' such that costs of the policy are minimised. TDR programs can have a high impact on ES, hence, the framework and the knowledge of ES can improve the decision-making during the TDR processes, providing a comprehensive picture of the various trade-offs present in land-use changes.

As reported in literature, until now, the (still rare) cases of incorporating ES into planning practice consist mainly of mapping and developing indicators to assess the impacts of urban plans or to increase stakeholder awareness about environmental issues (Gómez-Baggethun and Barton, 2013; Cortinovis and Geneletti, 2018; Longato et al., 2021). But due to their widespread use in urban planning, TDR programs represent an opportunity to mainstream ES in concrete land-use decisions. Besides, the framework of ES and the market-based

instrument of TDR have potential synergies since they emerged in the same context of neoliberal ideas to counteract environmental issues and the failure of public regulation. Indeed, traditional command and control instruments, relying on hierarchical regulations in a defined area, were not suitable to face environmental challenges in a socio-ecological system where elements are interconnected and located in distant sites that often cross administrative boundaries. In this perspective, the use of TDR can be suitable because it can capture the economic value of a land plot investing it in a site away from its origin (Dyca et al., 2020). If TDR are applied at a regional level, their potential to better manage the relationships of social-ecological systems increases, thus overcoming municipal limits. On the other hand, the framework of ES identified the benefits of natural environment on economic system and human wellbeing in material (e.g., cooling effect) and immaterial (e.g., spiritual experiences) “flow” that can be economically assessed and “internalised” into markets (Muradian and Gómez-Baggethun, 2013). The concept of ES provides planners with a framework in which preservation targets can be better formulated and prioritised. This is particularly important as there are concerns over TDR programs preserving more marginal lands (Shahab et al., 2018b), which are of lower environmental significance and market demand, compared to environmentally sensitive areas.

Based on this premise, investigating how to include ES in TDR processes can be relevant for innovating planning instruments and improving their outcomes in delivering sustainable cities and landscapes.

5.2 In what ways, and to what extent, have ES been considered so far in TDR studies?

As far as case studies are concerned, our literature review shows that the integration of ES is very limited. Indeed, eighteen of the case studies considered fall into the lowest level of

integration, and only one case study (Martinico et al.,2014) reaches the highest level (Table 6). In this last article, although the ES concept is broadly considered throughout the research, in the TDR program under analysis, an assessment of ES is developed only in an ex-post phase to evaluate the impacts of the program and not to select sending and receiving areas. This highlights a dichotomy between ES and urban planning practice, and how the process of mainstreaming ES into TDR programs has only just begun. The same consideration can be made for research studies on TDR (literature review and methodological proposals), for which, however, a small additional step towards integration is apparent.

5.3 Is there evidence in the literature showing how ES can be included in the design of TDR programs?

Although the integration of ES in the literature regarding TDR has been limited, some of the evidence identified shows how, by including ES concepts in the process, the quality of TDR programs can be significantly improved. For example, taking account of ES provided information that enabled to identify sending areas that are most crucial for the environment in terms of ES provision. Schwaab et al. (2019), evaluating the impacts of different TDR solutions on ES provision, demonstrated that for each type of ES considered there is a different ideal scenario of sending and receiving areas. This finding suggests the necessity to integrate the ES demand assessment within the study context, only on the basis of which an appropriate scenario can be outlined.

Two of the three useful studies for identifying information about the allocation rate involve a *bottom-up* approach that considers the characteristics of sending areas. According to this methodology, the ES knowledge can regulate the DR calculations (namely the number of DR created for each sending area) based on land parcels' importance for ES provision and

improvement. This means that a higher number of potential DR can be allocated to sending areas with higher ES values, and as a result, these areas can receive higher levels of compensation for selling their DR. Therefore, landowners of such land plots will have higher incentives to preserve their land. Nevertheless, this remains a difficult balancing act because if too many DR are allocated - even on the basis of ES evaluation - this risks undermining the sustainability goals of the TDR program. This limitation has also been demonstrated by an example of a TDR program implemented in the United States, which aimed to reward landowners in rural areas for the proper management of natural resources. However, in the end, too many DR were allocated, contradicting the main goal of preserving natural resources and supporting sustainable development (Johnston and Madison, 2007). On the other hand, if too few DR are allocated, landowners will not be interested in engaging in the program, making it ineffective. In fact, in the case study of Catania (Martinico et al., 2014; Stanghellini and Cosmi, 2012), even if the program objectives concerned environmental sustainability aspects, planners chose to select the areas and allocate the number of DR following residential and private convenience criteria to ensure the program feasibility (Stanghellini and Cosmi, 2012).

In this perspective, allocation based on the *top-down* approach is the most suitable for ensuring public interest and environmental benefits since it is based on a forecast of the overall new urban development demand in a community and the capacity of receiving areas to accommodate it.

Concerning the third design feature (density bonus and DR requirements in receiving area), when DR are transferred from the city centre to periphery (or from any sending area with higher real estate value than the receiving area) the number of DR are increased in order to trigger the market and raise the attractiveness in the TDR program (as mentioned in section

2.3). However, this may undermine sustainability targets if there are no rules in the receiving area to limit the environmental impacts of new building potential. For example, if DR are placed in already urbanised receiving areas by planning their densification, it is crucial to understand if this densification increases air and noise pollution or reduces the aesthetic quality of those settlements (Schwaab et al., 2019). Therefore, it is suitable for planners to set rules in the allocation and use of DR in receiving areas, such as a minimum percentage of pervious surfaces to be maintained or the implementation of nature-based solutions to minimise negative impacts and ensure an adequate level of ES supply. Moreover, if the allocation of DR is planned in undeveloped receiving areas, it is fundamental to assess their current provision of ES provision in relation to community demand for such ES. In this way, receiving areas can be selected while maintaining a balance between the demand and supply of ES.

Integrating ecosystem services into the design phases of TDR programs implies a much greater attention to receiving areas and to ES demand and supply around receiving areas for planning authorities. However, most of the studies reviewed do not consider receiving areas in their research work, focusing mainly on sending areas and the possible positive environmental effects of their preservation.

The integration of ES strengthens the *ex-ante* phase of TDR programs giving a solid and shared foundation on which environmental targets and the approaches to achieve them can be based. The *ex-ante* phase is also crucial for understanding local needs and raising the awareness among stakeholders of environmental goals to reach with TDR programs. The reviewed studies indicated that the inclusion of ES can foster public participation thus improving the program design and consequently its implementation. The ES concept is of high value for communicating the benefits of a planning policy and thereby increasing the level of

support and participation among stakeholders. Emphasising the provision of ES as a major goal of TDR programs can facilitate reaching the consensus on shared objectives and balancing conflicts between various stakeholders involved (Martinico et al. 2014). Moreover, previous research shows that without a participatory process, the introduction of TDR programs can lead to resistance from the side of landowners or the public, thus a collaborative approach that involves stakeholders in TDR policy design is always recommended (Shahab et.al. 2019). The participatory process is also crucial to understanding local needs and properly select receiving areas. In fact, as emphasised by Pruetz and Standridge (2009) in the ten success factors description for TDR programs, certain attributes of receiving areas can attract investors and thus facilitate the transfer of DR. However, the success factors may differ from the context, and therefore, it is first necessary to analyse the specific circumstances of each community to select the best receiving areas.

5.4 TDR weaknesses

The reviewed studies highlighted some limitations for TDR programs to achieve their goals. For example, their over-dependence on the level of demand for development and market activities has been mentioned by TDR critics; where markets do not function effectively, TDR programs ultimately fail to preserve valuable ecosystems. Also, landowners in sending areas within a TDR program sell their DR in a one-off transaction, which in theory protects lands in sending areas, e.g., farmlands, in perpetuity. However, the TDR program does not have a mechanism within itself to ensure that agricultural production continues. In other words, they cannot guarantee the provision of ES when preserved lands are sold. This highlights the need for using TDR programs in conjunction with other planning instruments, such as the

establishment of a stewardship or ecosystem service payment system, to ensure their provision of ES (Harman and Choy, 2011).

Mainstreaming ES knowledge within TDR programs, in conjunction with collecting the proper data for assessments, adds to an already complex process for local administrations that do not always have the necessary expertise and economic resources.

Nevertheless, developing an in-depth understanding of ES is essential in designing any planning policy instrument that attempts to foster urban sustainability.

6. Conclusions

This study reviewed the existing literature to investigate in what ways, and to what extent, ES have been considered so far in TDR studies and whether there is evidence showing how the consideration of ES can improve the design of programs. Our review demonstrated that there are a few, but increasing numbers of, studies that have included the concept of ES in the analysis of TDR policies. A reason for this is that part of the literature on TDR was developed prior to the emergence of ES in planning research. Consequently, the concept is often present, but in an implicit way. The ES approach gives a new interpretation to the research produced so far on TDR programs and indicates the novelty of our work. The main purpose of the review is to provide an initial starting point for future research and application in practice by reducing the dichotomy between planning instruments and ES.

From the review of existing literature, supported by appropriate considerations, it is possible to identify evidence which shows that the quality of TDR programs can be significantly improved to achieve environmental planning goals by integrating knowledge of ES. The inclusion of ES in TDR programs sheds light on the potential of understanding these

mechanisms not just as instruments for conservation, but for ensuring spatial transformations that take into account all existing trade-offs in land use decisions.

The integration of ES can strengthen the *ex-ante* phase of TDR processes, supporting the development of all the design features (sending and receiving area identification, allocation rate and rules of the transfer). Assessing the ES supply and demand ensure a balance between the ES provision lost, and the ES most needed from the perspective of citizens. The assessment of ES implies a major role on receiving areas during the processes of TDR, stressing their importance to ensure sustainable spatial transformations. Nevertheless, most of the studies reviewed do not focus on receiving areas in their research work but only emphasize the positive effects delivered by preserving sending areas. This, therefore, indicates the most urgent research gap to be addressed.

The review also underlines the potential of ES concepts to enhance the social and political acceptance of TDR programs and to increase public participation. Despite these benefits, the research shows the challenges facing local administrations to acquire and manage data to assess the impacts of TDR decisions on ES provision. This limitation adds to other weak points of TDR, such its overdependence on market activity and the need to work in conjunction with other instruments to ensure sustainable development.

The results obtained in this review, supported by further in-depth analysis of recent case studies, can guide local authorities in the development of TDR programs and in the achievement of environmental planning goals.

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