

Article

Compensating for Loss of Nature and Landscape in a Growing City—Berlin Case Study

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Abstract: By 2030, around 194,000 new dwellings will be built in Berlin, including almost 52,000 in 16 new urban districts. These and other interventions will impact the city's nature and landscape. An important means of compensating for these losses is a land-use planning eco-account adapted to Berlin's needs. It relies on a whole-city compensation concept consisting of three pillars: flagship projects, thematic programmes, and the integrated enhancement of existing land uses. Impacts can be offset in advance via the eco-account. The institutional and legal backgrounds, as well as the allocation of compensations to interventions and the principle of the loss–gain calculation using value points, are presented. Housing construction and its preponed compensation trigger land-use changes. Critical factors affecting this process were identified and categorised as population development, housing requirement, resulting intervention, land-use change, and preponed compensation. A modified causal loop diagram was created to visualise the interdependencies and link the polarities of the derived key variables. The challenges of compensation without a net loss of biodiversity and ecosystem services, as well as solutions for avoiding impacts to achieve the goal of no net land take, are discussed. The compensatory approach presented here could be transferred to other growing cities.

Keywords: causal relations; citywide compensation concept; eco-account; glossary; impact mitigation regulation; land securing; land-use change; mitigation banking; urban land-use planning; value-points

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1. Introduction

For most of human history, development-related interventions in nature were accepted. Only when the adverse effects could no longer be ignored were they subsequently, i.e., reactively, eliminated or at least mitigated. Even the recognition that certain natural areas are worth being protected did not immediately lead to the idea that interventions in nature should be assessed and compensated.

It was not until the 1970s that, in order to mitigate the environmental impacts of development, legislation was enacted at the national level, for example, the US National Environmental Policy Act of 1969 (NEPA) [1] or the German Impact Mitigation Regulation, which was adopted in 1976 as part of the German Federal Nature Conservation Act [2]. Not a bene: At the same time, the Club of Rome applied systems analytics to highlight the limits to growth as a predicament of humankind [3]. Over the last four decades, core principles for biodiversity offsetting have been applied worldwide, e.g., avoidance, no net loss, and a mitigation hierarchy, as well as pooling and trading offsets for unavoidable residual damages [4]. Compensation practices differ significantly according to different countries' legal and institutional frameworks [5]. In addition, there are approaches that link biodiversity offsets to strengthening ecosystem services [6].

In Germany, the causer of the intervention in nature or landscape is obliged to compensate for unavoidable impairments by implementing nature conservation and landscape management measures (offset measures) or to replace them (substitute measures) [7] (§ 15). Offsetting an impact is thus mandatory and legally binding and must be realised before or during project implementation. Compensations can be implemented in different schemes, either project-related—inside or outside the planning area—or pooled in an eco-account (mitigation bank) as “external compensation” outside the planning area [2,8] (p. 123).

Project-related offsetting ties all measures to a specific development project and is challenging to coordinate with the compensation measures of other projects. On the other hand, eco-accounts enable out-of-kind and off-site compensation, which can be decoupled in time and space from the intervention and its impacts. Thus, the development of a coherent landscape is made possible. Eco-accounts facilitate the often-difficult search for suitable compensation areas and can speed up planning processes. There is a wide range of expectations for eco-accounts: Küpfer and Arnold [9] see the eco-account as a key instrument to maintain and regain ecological qualities and biodiversity in landscapes “under pressure”, whereas for Brock [10], the significance of offsetting lies not only in the profit opportunities but also its productive power: it even legitimises coal mining and “ecologies of repair”. The prohibition of deterioration stipulated by the German Nature Conservation Act applies to all compensation schemes. A case study in Baden-Württemberg has shown that eco-account schemes help overcome many practical obstacles compensating for residual impacts [11] (p. 63).

The terms conservation banking, mitigation banking, bio-banking, or eco-account are sometimes used synonymously with habitat banking [12]. Use cases are, e.g., integrated aquatic planning and mitigation banking in Canada [13] or the Stream Mitigation Method of Texas (USA) [14]. Lave [15] states that “As of 2018, there were nearly 3500 mitigation banks in the United States, with sales estimated at least \$1 billion per year”. Nevertheless, there are risks associated with using mitigation banking, e.g., in the course of redistributing ecosystem services, as shown by the example of the Wetland Offset Arrangement in Florida [16]. Like in Germany, the state certifies the credits generated by mitigation banks and obliges permit applicants to purchase them [17] (p. 61). A comparison of the German impact regulation with the US wetland mitigation is provided by [18] (p. 36).

Regardless of the compensation scheme and the type of measure (offset or substitute), there is one essential requirement for the whole process. Interventions and compensations must be assessed in order to be able to balance them. Different balancing and evaluation methods have respective advantages and disadvantages: biotope valuation procedures, compensation area coefficients, cost-of-restoration approaches, and verbal argumentative methods [5].

German efforts to compensate for interventions are in line with EU aspirations, e.g., the EU Biodiversity Strategy for 2030 [19]. However, they are not always crowned with success. For example, the EU aims for zero net land take by 2050 [20] and thus calls for sustainable land management [21]. Germany has missed its target of reducing land consumption from about 130 ha/d in 2002 to 30 ha/d by 2020 [22] and postponed it to 2030 [23]. A practical example is the construction of a car factory near Berlin affecting water bodies [24] and forests, which shows the difficulties associated with interventions, despite implemented ecological compensation [25]. According to Mazza and Schiller [11] (p. 61), the way the Impact Mitigation Regulation is implemented shows weaknesses, e.g., in the lack of the long-term maintenance of compensation measures and adequate long-term monitoring.

Nevertheless, there are an increasing number of no-net-loss and offsetting policies and initiatives across Europe [26] (p. 246), and the proposed EU Nature Conservation Act [27] goes beyond balancing interventions by aiming to reverse previous interventions. It supports, *inter alia*, urban ecosystems by demanding no net loss of urban green space by 2030 and an increase in the total area covered by urban green space by 2040 and 2050 [28].

Berlin is both a German federal state and a city [29] (§ 1); therefore, state and municipal tasks are not separate. It follows that tasks that fall under its planning sovereignty can extend to the entire municipal territory. The city is growing, which intensifies competition for limited space [30], leading to the growing pressure of use on many areas, competing perspectives, and conflicts of interest and goals, as the Charter for Berlin's Urban Green Space [31] points out.

Both interventions and their compensations require space, leading to conflicts with existing land uses in a growing city. Against this background, to describe how the loss of nature and landscape can be compensated, the present case study aims to answer key research questions. (1) What is the legal and organisational basis of Berlin's eco-accounts? (2) Which processes and instruments form their functional framework? (3) What mechanism allocates ecological enhancements to interventions? (4) What are critical factors that affect land-use changes due to housing construction and its preponed compensation? (5) What are the main causal dependencies of these factors? (6) Which boundary conditions enforce the no-net-loss paradigm? (7) What options are available to avoid planned interventions?

This article will not explore individual examples but will try to provide an overview of the overall picture. For quick guidance, a short glossary is provided in Table A1.

2. Methods

The literature research included international, German, and Berlin-specific publications on the topic of this study. A query on Web of Science (WoS) for recent publications from 2020 onwards resulted in 260 hits when searching for "mitigation banking" and 6 hits for "eco-account". No current studies on the "Berlin housing market" were available in WoS. Recent internal Senate documents were used to verify the statements made in Senate publications. Where no studies were available, Berlin-specific facts were extracted from websites and included in the list of references. When available, the English version of the website was used, and in all other cases, the German version was retrieved.

The here-presented investigation focuses on the intervention and compensation system in Berlin. A system dynamics method, the causal loop diagram [32], is used to understand the complex interactions of variables determining the system's behaviour. This diagram type is neither a flow chart nor a functional diagram, and the connectors should not be confused with flows. They represent unidirectional interrelations between causal variables and effect variables. A causal link has positive polarity if an increase in the causal variable increases the effect variable and a decrease acts respectively equidirectional. A negative link polarity indicates that increasing the causal variable leads to a decrease in the effect variable and vice versa. In a previous study, we introduced a modified causal loop diagram syntax by adding ambiguous link polarity, indicating that the link polarity can only be given with case-specific consideration [33]. Ambiguous link polarity considerably simplifies the representation of the relationships since the underlying (possibly complex) causal interrelations of positive or negative link polarity do not have to be resolved and modelled.

A diagram type based on relational database schema is used to represent the creation and allocation of value points (cf. Glossary). The connectors show the relationship between the entities of the model, and the arrow direction corresponds to the access of one entity to another (access direction). All relationships have a cardinality of 1:n without explicitly noting this in the diagram.

The corresponding author of this study is a member of the LUP-EA and NCL-EA teams (cf. Glossary) of the Senate Department for the Environment, Urban Mobility, Consumer Protection, and Climate Action and has participated in discussions related to the topics of the present study.

Eco-account geodata of the "KompensationsInformationssystem Berlin" were downloaded from a Web Feature Service [34]. The update presented in this study was obtained

from internal administrative data to be published in the near future. The data were processed using the geographic information system QGIS 3.22.

Limitations

In the present study, the system boundary has been extended to one important cause of intervention (population growth) and concomitantly limited to compensation by eco-accounts. The other possibilities for compensation schemes, as well as compensation in the neighbouring Federal State of Brandenburg, are not considered. The large number of actors involved was also not taken into account.

3. Impact and Compensation

3.1. Growing City of Berlin

The urban development plan Housing 2030 states that Berlin's population grew by 245,000 from 2011 to 2016 and is expected to grow by an additional 180,000 inhabitants from 2017 to 2030 [35] (p. 15). This will lead to 3.91 million in 2030 and 3.96 million in 2040 [36]. To meet the housing demand, 194,000 dwellings need to be constructed by 2030 [35]. Local authorities have developed the Berlin Strategy 2030 [37] and are constantly evolving spatial plans at the citywide level, such as the land-use plan (zoning plan, [38]), various urban development plans (StEP), and the landscape programme [39]. Even if sustainable settlement development is pursued according to the principle of "internal over external development" [30], the Berlin municipality will develop 16 new urban quarters with almost 52,000 flats in the coming years [40], which corresponds to about 27 % of the demand by 2030.

3.2. Impact Assessment

A guideline for the assessment and balancing of interventions has been developed in the Berlin administration. This guideline serves to qualify the assessment and balancing of interventions in nature and the landscape in the Land of Berlin and contains the detailed procedure for determining compensation and a simplified procedure for determining cost equivalents. An extension set is available for compensation measures in areas outside the intervention area. In addition to operationalising the impact regulation, the guideline also addresses species protection and the compensation of legally protected biotopes. Nine value carriers express the performance and functionality of the protective goods in the form of value points, which are determined in area units of 1000 square metres of equal impairment intensity [41] (p. 7). In this way, the Berlin method enables a loss–gain calculation.

Key elements for the assessment are five protective goods and a value carrier: soil, water, climate, flora and fauna, land- and cityscapes, and recreation (cf. Table 1). Two superordinate types are distinguished: natural regime and landscape/recreation.

Table 1. Protective goods and superordinate types, adopted from [41] (p. 54).

Protective Goods Type		Protective Goods
Natural regime		Abiotic: soil, water, and climate
		Biotic: flora and fauna
Landscape/recreation	Land- and cityscapes (with recreation as a value carrier)	

A legal opinion has clarified that protective goods of different types should be treated separately [42]. The calculation of the necessary compensation for an area is carried out by experts, whom the investor usually pays.

3.3. Compensation by Land-Use Planning Eco-Accounts (LUP-EAs)

The building law compromise (cf. Glossary) enables the land-use planning eco-account (LUP-EA), an eco-account scheme in which a municipality can directly coordinate urban development with the required offset by preponed compensation. It is a voluntary instrument of the municipality [43] (p. 4). The necessary temporal and spatial decoupling of the LUP-EA from development is regulated in the Federal Building Code (cf. Table A2). The municipality—not the developer—is responsible for the correct implementation of compensations: the LUP-EA is managed by the public administration and focuses on public projects [43] (p. 5).

The development of the above-mentioned 16 new urban quarters is the subject of urban land-use planning. Here, an environmental assessment will be invoked, systematically recording the environmental concerns in urban land-use planning to prepare the basis for proper consideration. The assessment must also examine whether the urban land-use plan is planning an intervention in nature and the landscape according to the Federal Nature Conservation Act (BNatSchG) and whether and how this can be avoided and/or compensated for (cf. § 2 (4) (1) in conjunction with § 1a (3) Federal Building Code (BauGB) [41] (p. 11)).

The Berlin authorities have elaborated a whole-city compensation concept [39] (p. 12), which identifies areas that have an increased need for action for nature and the landscape and are thus suitable for various compensation measures. These measures can be planned on a larger scale to improve the natural regime, the climate, biodiversity, and the landscape and thus the population's well-being. Compensation becomes more effective, the development of open spaces is streamlined [39] (p. 13), and multifunctional capacities to address different targets in one area can be better utilised. The advantages and opportunities offered by the use of LUP-EAs [43] (p. 11) are:

- Instead of isolated measures, Berlin will develop interconnected landscape areas and biotope networks, thus achieving significantly higher effects for nature and the landscape. Maintenance and development costs generally decrease with larger areas.
- Compensatory measures can be integrated into overall urban greening concepts.
- The (new) urban nature is already developed before the intervention, which shortens compensation periods and reduces the need for compensation.
- The planning periods for development plans are shortened by eliminating the time-consuming search for compensation areas. Costs for land are reduced through early acquisition.

The organisation and management of the various LUP-EAs are carried out by the eco-account team of the Berlin Senate Department for the Environment, Urban Mobility, Consumer Protection and Climate Action (SenUMVK). This includes communication and cooperation with stakeholders, particularly the Berlin Senate Department for Urban Development, Building and Housing (SenSBW).

The development of the LUP-EA in Berlin takes place on state-owned land that can be made available by Senate resolution, e.g., the eco-accounts of the Malchow wetland landscape [44] or of small water bodies (Blue Pearls for Berlin) [45]. Figure 1 shows the spatial scope of four eco-accounts established by Senate resolutions and one approved by the upper nature conservation authority. This securing of land is a precondition for legally assigning compensation areas to a land-use plan and its offset requirements. The groundwork for an LUP-EA consists of extensive unpublished data collection and landscape planning. Further eco-account areas are being planned.

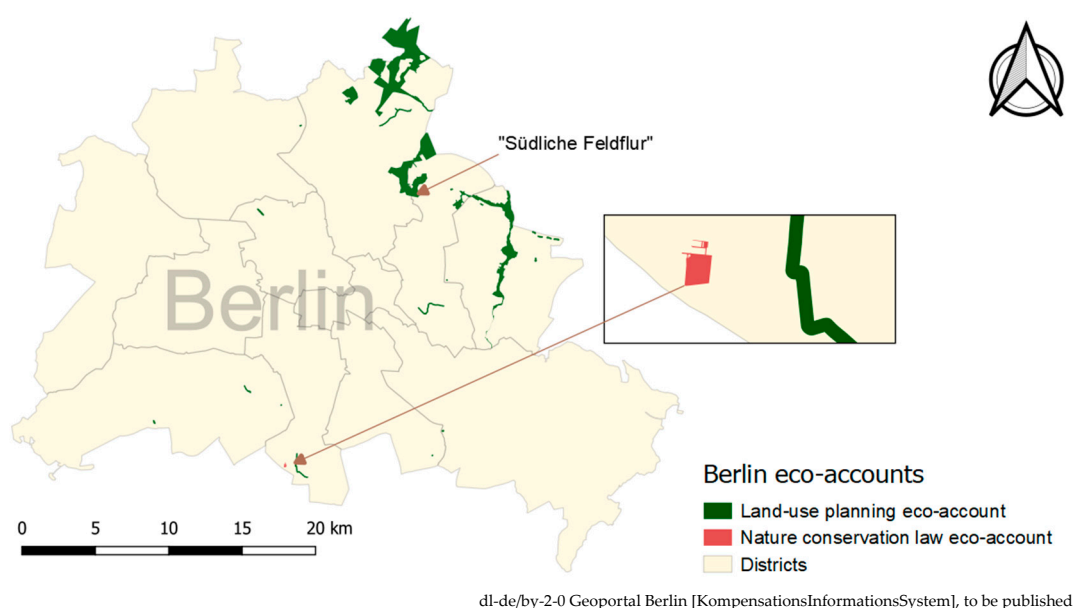


Figure 1. Areas dedicated to land-use planning eco-accounts (LUP-EAs) by Berlin Senate resolution and one nature conservation law eco-account (NCL-EA) approved by the upper nature conservation authority of Berlin; status December 2022 (to be published in Berlin Geoportal).

The overall urban compensation concept strategically bundles the necessary compensation and assigns it to three pillars (cf. Table 2), which relate to different fields of action. Thus, preponed compensation is linked to the further development of Berlin’s green infrastructure, also in order to create additional recreational areas for Berlin’s growing population.

Table 2. Strategic pillars of the overall urban compensation concept, adopted from [43] (p. 16).

Pillar	Examples
Flagship projects	“Malchower Auenlandschaft”, Open landscape “Blankenfelder Feldmark”, forest pasture landscape “Hobrechtsfelde/Buch”, green belt Berlin South, biotope network “Wuhletal”, near-natural sewage farm landscape “Karolinenhöhe” and “Gatower Feldflur”
Thematic programmes	Blue Pearls for Berlin: ecological upgrading of wetlands and small bodies of water, climate adaptation of the city centre: the greening of buildings and courtyards
Integrated enhancement	Production-integrated compensation on agricultural land, more biodiversity in green spaces and parks, compensation measures in forest areas

The first pillar aims to develop demarcated landscape areas within the city’s open space system through large-scale flagship projects. One example is the Malchow wetland landscape [44], and an information sign (cf. Figure A1) features the slogan “Berlin eco-account secures urban green space and housing for future generations”. That translates into “new residential areas will not be approved without compensation”. The area “Südliche Feldflur” (cf. Figures 1 and 2)—belonging to the Malchow wetland landscape—is located in the immediate vicinity of an urban neighbourhood and will provide improved greenery for people living in “Neu-Hohenschönhausen”.



Figure 2. Eco-account subarea “Südliche Feldflur” in the vicinity of the urban quarter “Neu-Hohenschönhausen” (October 2022, G.F.M. Baganz).

The second strategic pillar of the overall urban compensation concept is thematic programmes that address the land shortage. A comprehensive compensatory effect is achieved by defining types of measures that are distributed over the entire urban area but can be bundled thematically. An example of that approach is small water bodies, the so-called “Blue pearls” [45]. Urban ponds are important for species protection, e.g., for bats, as exemplified by the urban landscape of Rome, Italy [46].

The third pillar is the integrated enhancement of existing land uses through compensation measures that increase the ecological value of an area while maintaining its use. One approach is production-integrated compensation in agriculture, where farmers continue to cultivate their fields but at the same time implement ecologically effective measures. This approach corresponds to the obligation of § 15 (3) BNatSchG, which stipulates that agricultural structural concerns are to be considered, and valuable soils should only be taken up to the extent necessary. The results of a German study show that farmers are generally willing to implement compensation measures [47]. A striking example is skylark windows and strips (cf. Figure 3), which improve the habitat for the increasingly rare skylark, other ground-nesting farmland birds, and hares in intensively used fields [48] (p. 38). This approach is in line with the Charter for Berlin’s Urban Green, which calls for the ecological upgrading of agricultural areas with the aim of environmentally sound land management [31].



Figure 3. Production-integrated compensation in agriculture: skylark strips as species protection measures (October 2022, G.F.M. Baganz).

Compensation measures in forest areas are another approach to “use the potential for stabilising forest ecosystems and the landscape water balance through the development of diverse, near-natural and deciduous mixed forests within the framework of ecological forest management” [49] (p. 6).

3.3.1. Allocation of Compensation

The allocation of compensation to interventions follows a scheme that is shown in a simplified form in Figure 4. The basis for the allocation of compensation in an LUP-EA is complex areas, a Berlin-specific solution. These areas act as containers for measure-affected areas that do not have to be connected. Thus, several measures are bundled, and value points can be charged to the eco-account due to ecological enhancements. Each value point corresponds to a proportion of the complex area. On the other hand, the impact of an intervention is also assessed in value points, which thus can be debited from an eco-account. The area character is a property of both interventions and compensations and facilitates ecologically correct allocation. The cardinality of the relationships (represented by connectors) shown in Figure 4 is 1:n in each case. The internal management of different LUP-EAs and the allocation of value points take place with the help of a relational database.

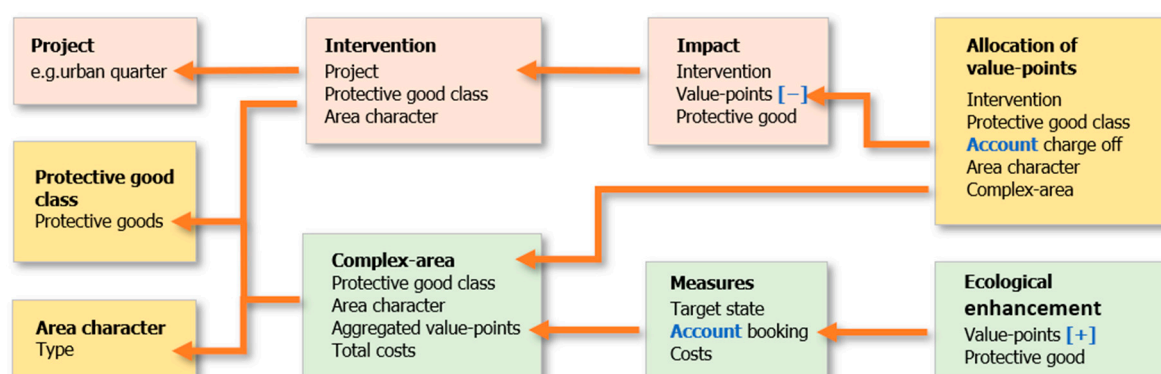


Figure 4. Simplified scheme for allocating ecological enhancements to interventions through value points in a land-use planning eco-account (LUP-EA); compensation required for species protection and legally protected biotopes is not included in this figure.

Nota bene: The formal allocation of a complex area or its parts (areas, not value points) to the intervention project takes place with the corresponding legally binding regulation in the urban development plan.

After the polluter pays the principle, costs for preponed compensations can be claimed as soon as the site of the intervention can be used for, e.g., construction or commercial purposes. All costs incurred by the Land of Berlin in the context of establishing and maintaining an eco-account can be refinanced to the same extent as for project-related compensations. There are at least two means of reimbursement: an urban development contract or a cost reimbursement contribution [43] (p. 13).

Areas taken up for compensation are reported to the Berlin Compensation Information System. They can be viewed on the Berlin Geoportal (cf. KompensationsInformationsSystem) or downloaded via Web Feature Service.

3.4. Compensation by Eco-Accounts under Nature Conservation Law (NCL-EA)

There is no explicit legal regulation concerning eco-accounts in Berlin, unlike, e.g., in the German federal state Baden-Württemberg, which regulates the establishment of eco-accounts under the nature conservation law (NCL-EA) by ordinance [50]. Nevertheless, it is possible in Berlin to set up an NCL-EA according to § 16 BNatSchG and § 18 Berlin Nature Conservation Act (NatSchG Bln) upon application to Berlin’s superior nature

conservation authority [51]. NCL-EAs are not managed by the municipality but can be set up by various private or public stakeholders. They tend to manage smaller areas than LUP-EAs.

4. Principles of Land-Use Change

“Land is one of our greatest assets. How it is used and managed affects everyone’s prosperity and quality of life” [52]. This is a statement that also applies to Berlin. The Berlin administration responsible for building projects is SenSBW, and eco-accounts are the responsibility of SenUMVK.

An initial rough calculation from 2016 of the expected impact of eleven urban quarters with approx. 33,000 new dwellings results in a total area of almost 500 hectares for development, including the soil sealing of approx. 174 hectares. Most of the land taken up in this scenario is currently open land, with agricultural use predominating on 165 hectares [43] (p. 9). Currently, a rough impact assessment from a citywide perspective has been jointly prepared by SenSBW and SenUMVK. This assessment analysed approx. 100 planned projects for housing, commerce, transport, and social infrastructure, which will lead to the sealing of approx. 470 hectares of soil. There is a citywide search for potential areas for eco-accounts and project-related compensation. The use of eco-accounts, i.e., the allocation of compensation to interventions, is determined by an interdepartmental steering committee. As the approval of projects depends on secured compensation for their impacts (besides e.g. monetising), it is important to prioritise project access to eco-accounts.

Housing construction and its preponed compensation will trigger land-use changes, and we identified critical factors that affect the functioning of this process. The derived variables are grouped into five main themes: population development, housing requirement, resulting intervention, land-use change, and preponed compensation. To provide an orientation to the interrelationships of the variables, their dependencies are shown in Figure 5 as a modified causal loop diagram. This diagram type is a systems mapping method that contributes to the understanding of and communication about a system [53] (p. 5, p. 14).

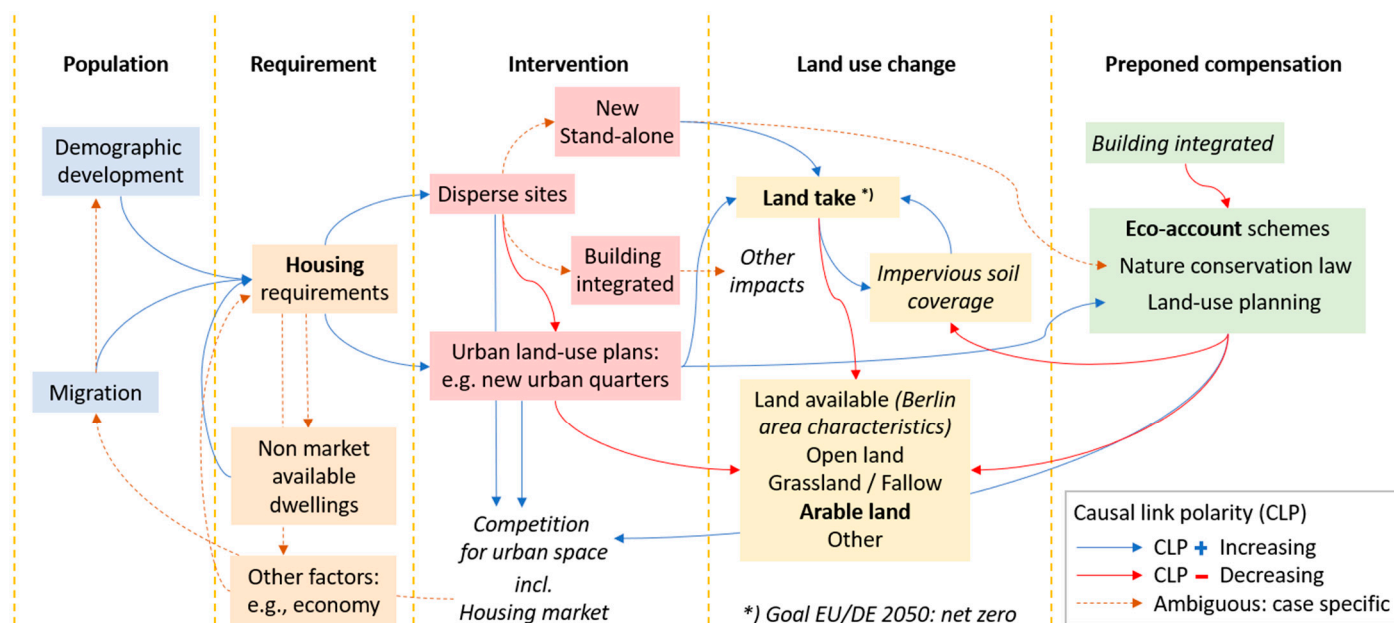


Figure 5. Main causal chains from population development to land-use change with regard to housing construction and its preponed compensation by eco-accounts; other types of intervention and project-related compensation are not considered.

Demographic development and migration determine population development; both variables influence housing needs through positive link polarity. An equidirectional influence is also exerted by non-market-available dwellings: in Berlin, 6.8 % of dwellings were unoccupied in 2018 [54], partly due to speculative housing vacancies [55]. If these variables increase, housing demand increases accordingly, and vice versa. The sum of other mechanisms affecting the housing market is case-specific, e.g., (1) the neoliberal shift in housing policy in Berlin [56], (2) improving needs-based housing provision by encouraging small households to move out of large flats [57], (3) a number of holiday apartments [58], or (4) increased living space per capita, which itself results from a complex set of conditions [59,60]. Housing requirements cause interventions on a significant scale; however, it is beyond the scope of this study to assess to what extent possibilities besides new construction have been exhausted.

New neighbourhoods are implemented within the framework of urban land-use plans and can therefore make use of LUP-EAs. This also applies to dispersed sites if they are within the scope of development plans. High ecological building standards function as compensation within the planning area and thus significantly reduce the need for external compensation.

Dispersed sites account for the majority of the housing to be built, either stand-alone or building-integrated. The latter does not require land, but construction activity can lead to interventions (e.g., tree cutting). All sites increase the competition for urban space, but sites that are not building-integrated or do not use already-sealed locations consume land and increase impervious cover while reducing available land. According to the Berlin area characteristics, the land is categorised as open land, grassland/fallow, arable land, and other. As noted above, much of the planned land to be taken up is arable. Both eco-account schemes, LUP-EA and NCL-EA, compensate for at least some of the resulting interventions, but regarding land, the German impact regulation cannot counteract the increasing scarcity of land due to building development [61]. Critical feedback loops emanating from the eco-accounts include reductions in sealed soil, the reduction in available land, and increased competition in urban space.

5. Discussion

5.1. *Challenging to Reach: No Net Loss*

Germany's Federal Act for the Protection of Nature prohibits the deterioration of nature or the landscape by impacts of interventions [7]. This approach is pursued by many legal entities. In 2018, it was estimated that commitments to have “no net loss” and a “net positive impact” on biodiversity by governments, intergovernmental bodies, banks, export credit agencies, individual companies, and non-governmental organisations exist in up to 100 countries [12]. The paradigm of no net loss has gained global significance, and to this end, biodiversity offsets are increasingly being explored and promoted [62]. Specific ecosystem services, e.g., soil-based, are also integrated in this approach [63]. No net loss is a challenge; for example, an analysis of the current USA banking network reveals regional gaps in achieving no net loss [64].

Besides the difficulties with no-net-loss compensation that can be resolved through better organisation and control, there are also problems inherent to biotope quality. Morris, et al. [65] pointed out the following: (1) The distinctive features of individual ancient woodlands may result from centuries of management, and the climatic conditions under which ancient forests developed may have been quite different from current ones. The objective is to create woods that may eventually have a similar value, but it is unknown whether the process will be successful. (2) Calcareous grasslands, which are very similar to old semi-natural grasslands, need at least 100 years to develop. (3) The success of compensatory habitat creation is uncertain in many terrestrial situations. Thus, compensatory offsets cannot be considered a consistent and reliable delivery mechanism for sustainable development [65]. We do not completely agree with this verdict, but we also see

difficulties in consistently compensating for losses. Against this background, the intention of the EU Biodiversity Strategy for 2030 to reverse biodiversity loss [19] (p. 3) is a real challenge.

There are also implementation deficits in Germany. In a case study in Südbaden, in southwest Germany, 124 compensation measures from 2007 to 2017 were subjected to a performance review. The study revealed considerable deficiencies in the implementation of compensatory obligations under the building law, indicating that the impact regulation's legal and nature conservation requirements are often not met [61].

Paying for the impact of an intervention instead of compensating in-kind avoids this problem from the causer's point of view. By monetising compensation obligations, the responsibility to ensure that no biodiversity loss occurs shifts to the municipality. The average cost of a value point in Berlin was EUR 1274 in 2020, excluding land provision and VAT unless a specific cost estimate is available [41] (p. 127). Tucker [66] states that payments for offsets are often estimated based on standard charges rather than actual costs, as these are only known at the very end of the process. He found that the cost per hectare in 2003 in the federal state of Thüringen ranged from EUR 17 to EUR 156 for forest creation, from EUR 1231 to EUR 168,129 for grassland creation, and from EUR 36 to EUR 172 for wetland creation. The present study's authors did not find any research on whether the replacement funds in Berlin have led to no loss of nature or landscape.

In the USA, the concept of mitigation banking was implemented based on the principle of "like for like" and should thus lead to zero net loss of environmental assets. However, Burgin [67] found that the outcome of wetland mitigation was only moderately successful. Levrel, Scemama and Vaissière [16] identified eight risk categories associated with mitigation banking from different wetland studies, e.g., from (1) facilitation rather than a limitation of intervening development projects, through (2) lack of long-term management and bankruptcy, to (3) the reversal of ends and means by protecting the market rather than the environment. Theis and Poesch [68] point out that habitat creation must increase to avoid net losses from mitigation banking.

Tucker, et al. [69] have developed guidance with extensive suggestions and checklists to achieve no net loss or even net gain in biodiversity and ecosystem services. The BUND [70] suggests the following: (1) Other areas must be unsealed accordingly for any new sealing through construction projects. (2) Compliance with compensation and replacement measures must be consistently checked; if the implementation is inadequate, subsequent improvements must be enforced. (3) To control land consumption, the loss and gain of green open spaces as well as the extent of sealing must be recorded transparently in a area land-use balance.

However, even if compensatory measures have been implemented, the created high-quality ecological areas are still exposed to risks, e.g., from the construction of wind turbines [71].

5.2. Adequate Monitoring

Biodiversity offsetting is a complex process with significant risks of failure. Experience shows that the adequate monitoring of each offset is needed by the competent authority to ensure its objectives are achieved [26] (p. 250).

Monitoring is pivotal to measuring the effectiveness and outcomes of ecological measures, including compensation [69]. Experts at a workshop on monitoring in the context of ecosystem restoration noted that bringing back the rarest and most sensitive species or the full range and degree of ecosystem functions can be increasingly complicated and should be monitored accordingly [72]. Monitoring results should be available on a central platform [61]. For the Berlin LUP-EA, monitoring—as a critical task—is the responsibility of the Senate administration [43].

5.3. Impact Avoidance First

A project that will change the land surface or the groundwater level constitutes a significant impairment. In the decision-making cascade of the Impact Mitigation Regulation, it is obligatory first to check whether the impact can be avoided. However, if not only the impact but also the intervention can be avoided, it cannot cause impairment and thus has no residual impacts.

This approach is followed by all strategies aiming at “no net land take”; the difference between land use and land take is not discussed here, but reference is made to a corresponding study [73]. An option is to avoid converting currently undeveloped open space or agricultural land into new settlements [74] (p. 9). Another option is to consider what the land is needed for, such as in Berlin for housing construction. A study concluded that 985 ha is available for housing extensions without taking up undeveloped land, mainly on large car parks, single-storey supermarkets, other single-storey buildings, and vacant lots [75]. It is also proposed to create around 150,000 flats by adding wooden floors to existing buildings [76]. This roofscape potential may not be fully exploitable, as there is competition for use. Berlin has launched subsidy programmes for green roofs, solar panels, and rainwater retention [77], and commercial use is also possible [78]. However, some of these uses can be combined multifunctionally with housing. Another study used the example of Berlin to develop a spatial strategy for the urban cultivation of land, which could relieve the rural area [79].

In addition, the tension between urban planning and environmental protection could be resolved through urban environmental protection [80]. For example, the impact of housing construction and housing on the environment could come more into focus, and conflicts of goals must be worked out to arrive at compromise solutions [81].

As an instrument to at least reduce land take, the general pricing of land use oriented towards the climate protection goal could be an effective way to ensure nature conservation and climate protection alike [82] (p. 18)

5.4. Transferability to Other Systems

There is certainly not one general compensation approach that fits every national regulatory framework and every intervention. Shrinking cities, for example, can recycle brownfield sites for compensation purposes or even return urban land to nature for a net gain in biodiversity. Nevertheless, a global study on impact mitigation and biodiversity offsets published in 2011 with a worldwide comparison of compensation approaches found that the German Eingriffsregelung is in an advanced stage, and there is a broad interest in learning from it [18] (p. 225). The present Berlin case study reports the implementation of an eco-account under the municipality’s responsibility and could lead to inspiration for other growing cities on how to compensate. Additionally, Berlin signed the European Circular Cities Declaration [83], which calls for embedding circularity principles in urban planning [84]—an excellent opportunity to reduce future compensation requirements.

6. Conclusions

The Berlin urban land-use planning eco-account is a strategic instrument within the framework of the whole-city compensation concept for mitigating development impacts, especially housing construction. This instrument is pivotal for the enhancement of biodiversity, recreation, and blue-green infrastructure in Berlin. The Berlin Senate administrations SenSBW and SenUMVK have jointly prepared a rough assessment of the project’s impacts from a citywide perspective. An interdepartmental steering committee carries out the respective allocation of compensation to interventions. A holistic approach, early impact assessment, the exploitation of multifunctional capacities, and the timely securing of land are the basis for successfully compensating for the loss of nature and landscape in Berlin as a growing city.

A systems analysis of different subdomains clearly shows critical variables influencing land-use change and impervious soil coverage. The variables are, e.g., the demand for new housing that can be reduced by exploiting various potentials and the use of building-integrated or already-sealed sites to prevent further soil sealing. Eco-accounts enable out-of-kind and off-site compensation, which can be decoupled in time and space from the intervention and its impacts. Under these boundary conditions, enforcing the paradigm of no net loss of biodiversity is critical. Strict adherence to the guidelines and adequate monitoring are necessary to achieve this goal.

The demand, its coverage, the resulting impacts, and the required compensation form a system. If the system boundary is shifted away from individual development projects towards the urban whole, solutions for avoiding impacts are conceivable, which enable no net land take.

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Appendix A

Table A1. Glossary.

Term	Explanation
BauGB	Germany: Federal Building Code [85].
BNatSchG	Germany: Federal Nature Conservation Act [7].
Building law compromise	The building law compromise introduced in 1993 (§ 1a para. 3 sent. 1 BauGB) stipulates that the nature conservation Impact Mitigation Regulation with its avoidance and compensation obligation is not binding in urban land-use planning, unlike, for example, project permission through planning approval. The urban impact regulation is subject to planning considerations according to § 1 para. 3 BauGB. [86] (p. 17); § 18 BNatSchG regulates the relationship to the BauGB.
Compensation	Germany: According to § 15 (1) (2) BNatSchG, the originator of an intervention is obliged to compensate for unavoidable impairments through nature conservation and landscape management measures (compensatory measures) or to replace them (substitution measures) [7]. Compensations can be preponed (=> eco-account) or project-related. Synonym for => offset.
Compensatory mitigation	United States: Under CWA Section 404, compensatory mitigation means the restoration (re-establishment or rehabilitation), establishment (creation), enhancement, and/or, in certain circumstances, preservation of wetlands, streams, and other aquatic resources [87].
Eco-account	An eco-account facilitates the offsetting of environmental impacts of development through a => land and measures pool. In Germany, two schemes of eco-accounts co-exist [11] (p. 5), => LUP-

	EA and => NCL-EA; comparable with => mitigation bank. Stockpiling of compensation measures is the subject of § 16 BNatSchG. This is not to be confused with ecosystem accounting [88], the measurement of nature's contribution to the economy and human well-being [89,90].
Eco-point, value point	"Eco-points, which are attributed to both development impacts and the outcomes of compensatory measures, are used as measures of environmental losses (debits) and gains (credits); the purpose is to ensure that positive impacts from compensation measures are at least equivalent to the negative impacts arising from the development" [11] (p. 5); in Berlin, the term value point (Wertpunkt) is used equivalently [41] (p. 32).
Ecosystem	"Dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit, and includes habitat types, species habitats and species populations" [27] (p. 34).
Impact Mitigation Regulation	Germany: Regulation to mitigate and compensate for impacts of developments related to habitats, soil, water, climate, air quality, and the aesthetic quality of the landscape [2].
Land and measures pool	Inventory of land and measures for compensation requirements [43] (p. 32); comparable to a compensation pool [2].
Land-use planning eco-account (LUP-EA)	Eco-account established under the Federal Building Code, "bauleitplanerisches Ökokonto" [51] or "baurechtliches Ökokonto" [11]
Mitigation bank	(1) A (wetland) mitigation bank sells compensatory mitigation credits to permittees, whose obligation to provide compensatory mitigation is then transferred to the mitigation bank sponsor [91]; (2) A private (usually for-profit) entity selling mitigation credits to developers [92]; comparable with => eco-account.
NatSchG Bln	Berlin Nature Conservation Act.
Nature conservation law eco-account (NCL-EA)	Eco-account established under the Federal Nature Conservation Act (BNatSchG), "naturschutzrechtliches Ökokonto".
Offset	Synonym for => compensation.
Protective—good	Anything that is to be protected from damage due to its immaterial or material value (https://sns.uba.de/umthes/de/concepts/00605306.html , accessed on 17 December 2022), i.e., soil, water, climate, flora and fauna, land- and cityscapes, recreation.
Protective—good type	Berlin: Superordinate type of protective goods, i.e., natural regime and landscape/recreation.
SenSBW	Berlin Senate Department for Urban Development, Building and Housing
SenUMVK	Berlin Senate Department for the Environment, Urban Mobility, Consumer Protection and Climate Action

Table A2. Legal basis for LUP-EA in the Federal Building Code [43] (p. 10), [85].

Paragraph	Paraphrase
§ 1a para. 3 sentence 3	As far as this is compatible with orderly urban development and the objectives of regional planning, as well as nature conservation and landscape management, the representations and

	determinations according to sentence 1 can also be made elsewhere, i.e., other than at the site of the intervention.
§ 135a para. 2, sentence 2	Compensatory measures can be carried out prior to construction measures and allocation.
§ 200a, sentence 2	A direct spatial connection between intervention and compensation is not required insofar as this is compatible with orderly urban development and the objectives of regional planning, nature conservation, and landscape management.

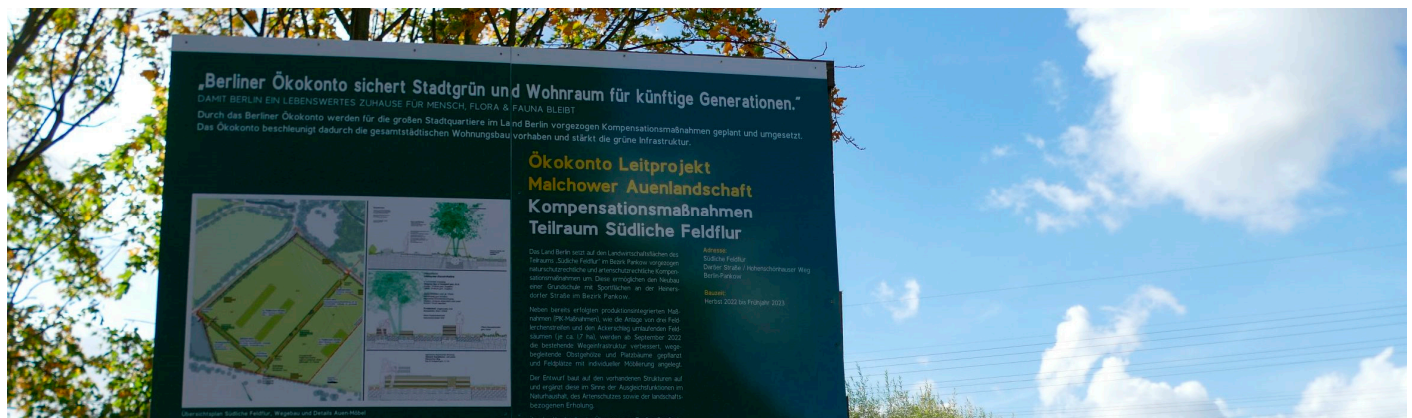


Figure A1. Information for the public: eco-account flagship project, Malchow wetland landscape, compensation measures in subarea “Südliche Feldflur”: (Oct. 2022, G.F.M. Baganz).

Note

- For quick retrieval of a source in extensive documents, the page is given as e.g. (p. 201).

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