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The Effectiveness of Master Plans: Case Studies of Biologically Active Areas in Suburban Zones

Abstract: Sustainable development on a local scale requires well-functioning instruments in the spatial planning system. Any weakness in the planning system may result in forms of spatial development that are socially, environmentally or economically disadvantageous. Therefore, the aim of this study was to examine whether master plans and land development monitoring in the Polish system are effective instruments in shaping sustainable spatial development. The factor analyzed was the share of a biologically active area and four villages located near a regional city were analyzed. Data from master plans, cadaster and orthophoto maps were used in this study. Verification of land use made it possible to evaluate whether the properties meet the provisions of spatial planning documents. In each of the analyzed villages, properties that do not meet the provisions of master plans were identified. In one of the villages, more than half of the properties had a smaller share of biologically active areas than permitted by the local law. The research also analyzed alternative scenarios of the potential impact of the application of permanent vegetation on sealed surfaces. These results showed that using green roofs, for example, can significantly reduce the problem of local laws being broken. The results quantitatively confirm that the provision of master plans in the Polish system are not effective tools in regulating land development.

Keywords: master plan, spatial planning, effectiveness, suburban zone

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1. Introduction

Rapid urbanization processes can be observed in many cities around the world [1–8]. Similarly, the dynamic development of Wrocław in Poland in recent decades has strongly affected the suburban zone, with it coming under the pressure of urban sprawl [9–11]. Due to insufficient investments in urban renewal [12, 13], urban inhabitants are escaping from the "urban hustle and bustle" to the suburbs and new buildings are being constructed to meet the needs of new residents. This phenomenon can vary in different municipalities depending on rural governance approaches [14], however, in most cases urbanization can significantly change the old design pattern of villages and their character [15, 16]. Residents formerly from the city adjust villages to their urban standards – closed settlements are created, and the houses of new residents serve only for accommodation purposes [17]. The whole process of such dynamic urbanization brings with it many adverse environmental effects such as the increased consumption of environmental resources, landscape fragmentation, increased soil sealing and reduced biologically active areas in the land use structure. All such impacts can be reflected by the amount of biologically active areas which can be detected from remote sensing data. The new form of suburbs reduces the amount of biologically active areas due to residential and commercial development. The legal definition of a biologically active area in Polish conditions can be found in the Regulation of the Minister of Infrastructure of 12 April 2002 on the technical conditions to be met by buildings and their location [18]. A biologically active area is an area that is covered with vegetation or water founded on native soil and 50% of the surface of terraces and roofs are permanently covered with vegetation.

Biologically active areas perform many functions defined as ecosystem services, which are divided into the following groups: provisioning, regulating, habitat and cultural services [19]. A lack of green space affects many aspects of residents' lives. It can cause adverse conditions such as increased air pollution [20], increased temperatures threatening human life and functioning [21], increased traffic noise [22] or the occurrence of local floods [23, 24]. Apart from reducing problems in a built environment, biologically active areas can have added value connected with recreational functions or the possibility of food production [25, 26]. This proves how biologically active areas are important in creating functional, safe and sustainable spaces for human settlement.

In the Polish legislation, the share of biologically active areas is locally regulated by master plans [27]. In principle, master plans are the basis for permission being issued to investors. This permission covers both the construction of a building (or buildings) as well as the possible arrangement of a plot of land. Such a permission is issued before the investment is carried out and should be verified once the construction is completed, before the permission to use the real estate properties are constructed. However, there is no verification process of the land development results

after the construction of real estate properties. This makes it possible for investors or users to change the land use later, contrary to the provisions of the master plan. Such changes can include constructing new parking places, playing fields or pools. All of these construction types may result in additional sealed surfaces which reduce the share of biologically active areas.

Observations provide qualitative input to the discussion on the effectiveness of master plans in regulating the share of biologically active areas, however to date there has been no quantitative analysis evaluating this problem. Therefore, the aim of this research is to use quantitative approaches to verify whether the development of real estate in the suburban zone of Wroclaw complies with the provisions of master plans.

Case studies were performed, with the detailed data on a plot level used to understand fine-grained development on an individual level. This study also compares local applications of master plans at the sub-local level. Thus, the building, city and regional levels are connected with this approach. This research will allow us to answer the question of whether master plans are effective tools in regulating the conditions of urban development. The results of the study may contribute to the discussion on the effectiveness of spatial planning system and the protection of biologically active surfaces, not only covering the preparation of master plans themselves but also the future monitoring of land development.

The paper is structured as follows: section 2 describes the study areas and materials used to conduct the study, the methodological approach is presented in section 3, section 4 presents the results of the study, and, finally, a discussion and conclusions are to be found in section 5.

2. Materials and Study Areas

The study areas consist of four villages located in the suburban zone of Wrocław: Krzeptów (Kąty Wrocławskie municipality), Domasław (Kobierzyce municipality), Karwiany (Żórawina municipality) and Nadolice Małe (Czernica municipality) (Fig. 1). Selected municipalities are differentiated in terms of land use, location in relation to the city, population, type of development (Fig. 2), and the period when master plans were introduced. There are some differences in the built environment design patterns that characterize each village.

Krzeptów is clearly divided into a new and old part. The older part is strictly systematized and its layout is simple and clear. A string of multi-storey residential buildings is located in the center. The remaining part is dominated by low-rise single-family houses of varied appearance, but together they form a coherent landscape. The old part of the village is traditional and refers to the historical urban layout. It has a branched form and there is a significant distance between the neighboring buildings.

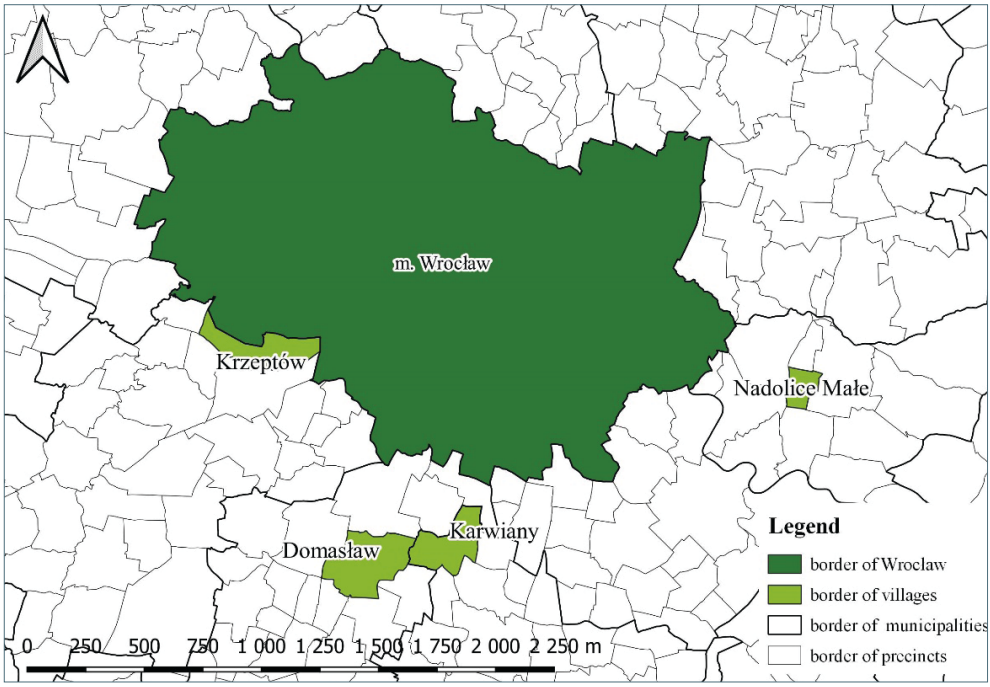

Fig. 1. Study area

Fig. 2. Type of development in:
a) Krzeptów; b) Domasław; c) Karwiany; d) Nadolice Małe (photo M. Błasik)

Domasław is the most diverse village in the list in terms of existing buildings. The development includes one- or two-storey detached houses, terraced houses, three- or four-storey public buildings and multi-family houses or houses in the immediate vicinity of farm buildings, which are typical for rural development.

Similarly to Krzeptów, there is a strong division in Karwiany between the native part of the village and the newly established one. The new part has a pattern and repetition of plot development, and its shape is simple and compact. Detached or terraced houses with a maximum of two floors prevail. The whole area is fenced off from the rest of the village, forming closed settlements limiting accessibility to the area.

The development of Nadolice Małe is uniform, with detached and semi-detached houses prevailing. There are no large, enclosed housing estates in this village. Most new buildings are the result of private investments. On the other hand, those that are built by a developer are frequently small, containing three to six buildings. They are open and coherent with the existing buildings.

The data and materials used in this study can be divided into three groups: master plans, cadaster data and orthophoto maps. Master plans were used as the basis for classifying land uses and requirements to the share of biologically active areas for each property. Master plans were enacted by municipality councils. For this study, the following master plans were used:

- Local spatial development plan for Krzeptów village – Resolution no. XLVIII/353/02 of 25 April 2002 [28];
- Local spatial development Plan for Domasław village – Resolution no. XXI/256/12 of 31 August 2012 [29];
- Local spatial development plan for part of Karwiany – Komorowice II village – Resolution no. XVI/99/2005 of 28 September 2005 [30];
- Local spatial development plan for Nadolice Małe village – Resolution no. XXXIV/289/2010 of 29 April 2010 [31].

Detailed borders of real estate plots and buildings were obtained from cadaster data (Polish: Register of Land and Buildings). Orthophoto maps for selected periods were available within the WMS on the Geoportal of Lower Silesia [32]. The data from the orthophoto maps enabled us to identify different surfaces and their types on each plot.

3. Methods

This analysis is divided into two stages: legal requirements and identification and calculation of the property development measurements of the real estate. Legal requirements were defined based on text analysis of master plans with a special focus on the identification of the shares of the biologically active area divided into different land uses. Based on the analyzed master plans it was possible to set the assumptions necessary to classify real estate properties for further analysis. These assumptions are as follows: there is a valid master plan, the minimum biologically active area is specified in the text of a master plan, the property was developed after

the adoption of the plan, and the year of construction completion is a minimum of 2 years (the average time for the construction of traditional brick houses) after the adoption of each master plan. Verification of construction completion was made based on cadaster data (attribute: year of completion). Only real estate fulfilling all the criteria were vectorized in the next steps.

Property development measurement was carried out based on the vectorization of sealed surfaces from orthophoto maps in GIS software (QGIS ver. 3.16). The vectorization process allowed us to create the database presenting changes of sealed areas in the real estate development from completion of construction to 2020. The data obtained through vectorization allowed us to compare the average area of the plot and the built-up area (only the building after construction). Based on the vectorized data, statistics with a share of biologically active areas for each plot were calculated. The selection of the representative villages (described in section 2) serves as an initial part in the research part in order to characterize the different design patterns in rural areas. Based on these stages, the legal requirements were compared with the quantified statistics for biologically active areas. Comparative statistics to evaluate villages from four different municipalities were also computed. Additionally, scenario-based analysis was carried out. Based on the legal conditions, which allow 50% of the surface of terraces and roofs permanently covered with vegetation to be included, it was evaluated how many properties would fulfil the requisite legal requirements.

4. Results

The analysis of the master plans showed that, despite the fact that the suburban zone of Wrocław developed over a similar period, different municipalities have various approaches in setting rules according to biologically active areas. Moreover, local decision-makers have different visions in terms of the future land use structure of their rural settlements. The results of the minimal shares of biologically active areas in each village is presented in Table 1.

Table 1. Minimal shares of biologically active areas permitted in master plans

Land use	Krzeptów	Domasław	Karwiany	Nadolice Małe
Single-family housing [%]	30	50	–	70
Single-family housing with services [%]	–	40	–	50
Multi-family housing [%]	30	30	–	–
Services [%]	30/50	15/20/30	10	30
Housing in agriculture [%]	–	60	–	–

Source: own study based on master plans

Based on the collected data, it can be observed that residential development sites have higher requirements with respect to the minimum percentage of biologically active areas. The lowest value is assigned to areas with a service function in Karwiany, amounting to only 10%. Based on the review of master plans and orthophoto maps according to the real estate classification criteria (defined in section 3), 159 real estate plots were selected for the further steps of the research.

The largest set of properties qualified for the analysis are the property situated in the village of Domasław (77 real estate plots). The following villages had accordingly: Krzeptów – 52 plots, Nadolice Małe – 19 plots, Karwiany – 11 plots. Every real estate sealed area (such as gazebos, sheds, playing fields or driveways) was vectorized from orthophoto maps (Fig. 3).

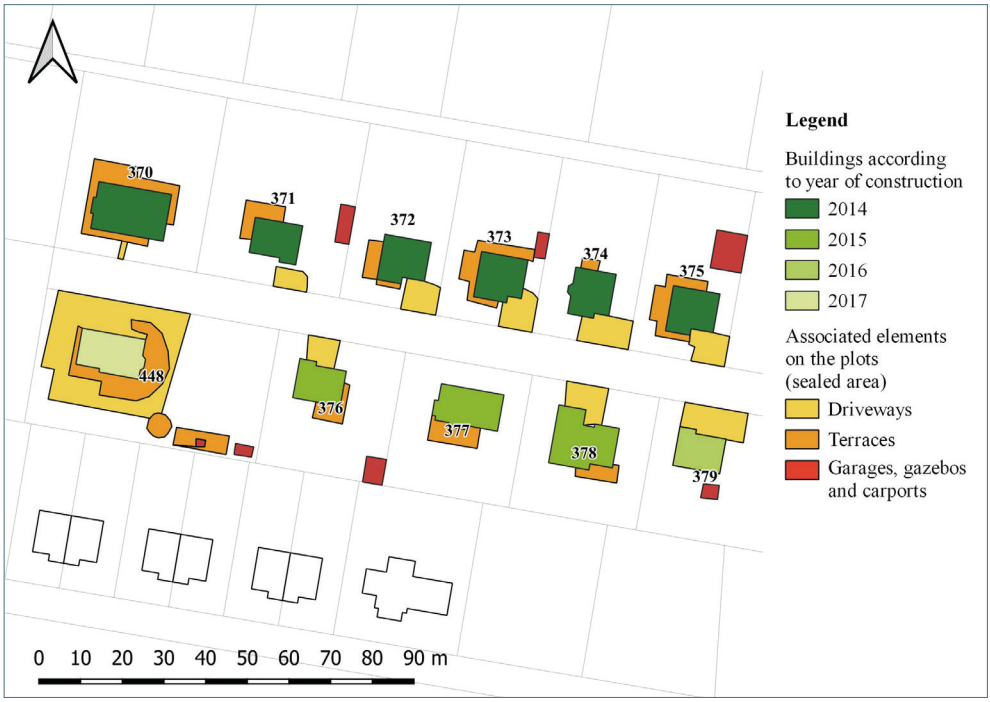

Fig. 3. Buildings according to year of construction and associated elements

From the evaluation of real estate according to their development in line with the requirements of master plans, it can be noticed that the greatest problem with non-compliance of local regulations can be observed in Domasław. The properties that do not meet the minimum standards of biologically active areas in Domasław constitute 57% (44 out of 77), in Nadolice Małe – 26% (5 out of 19), in Karwiany – 9% (1 out of 11) and in Krzeptów – 6% (3 out of 52) (Fig. 4). All these properties had a residential function, except for the plots located in Karwiany. The characteristics

of real estate in each village covering average plot size, average built-up area and average biologically active are presented in Table 2.

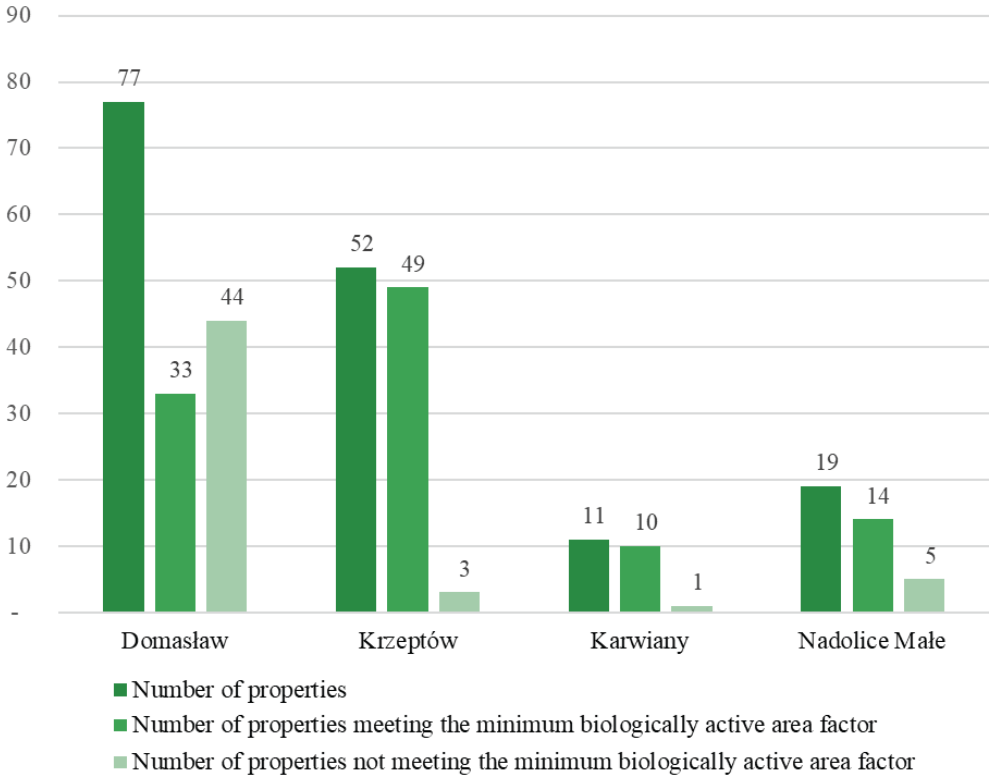

Fig. 4. Number of analyzed plots (split by fulfilling legal requirements)

Table 2. Characteristics of real estate in villages

Land use	Krzeptów	Domasław	Karwiany	Nadolice Małe
Average plot size [m^2]	881	962	483	1438
Average built-up area [m^2]	137	129	89	129
Average biologically active area [m^2]	556	661	344	1160

Properties vary between villages in terms of plot and built-up areas. The largest average plot and the largest average built-up area are characteristic for Nadolice Małe village, while the indicator of the minimum biologically active areas for this district is 70%. With such large areas of plots, the realization of such a high indicator is not that problematic for investors even in the long run. In Krzeptów, on the other hand, one of the lowest average plot areas and one of the highest average

development areas can be observed. With the simultaneous low index of minimum biologically active areas (only 30%), they allow owners to meet the requirements of master plans. In Karwiany there was a relatively small sample of analyzed plots, that is why a relative value of plots which do not fulfill the legal requirements might be not representative (9%; 1 out of 11 plots). However, in case of Karwiany it is important to highlight the fact that the minimal share of biologically active areas permitted in master plans is the lowest – only 10%. Therefore, compared to other villages, regulations were the most liberal in this case.

Domasław is the village for which the largest number of properties was catalogued, and at the same time within this village, the most noticeable problem is the failure to meet the minimum standards of biologically active areas, as 57% of the properties are unable to meet it. The average area of the plot in this village is 962.08 m^2, and the average area of the buildings is 129.42 m^2 – which is 13% of a plot. Taking into account the fact that the minimum share of biologically active areas for Domasław amounts to 50%, after constructing a residential building the investor is left with 37% (the average of 346.35 m^2) of the plot area to designate as sealed areas. 346.35 m^2 seems to be a sufficient area for utilization. However, plots failing to meet the minimum share of biologically active areas most often concerns properties with a much smaller (than the average 962.08 m^2) plot area – about 500 m^2, mainly in the case of terraced housing.

The use of orthophoto maps does not allow us to verify the exact materials covering each surface. Considering the fact that the legal definition of a biologically active area allows 50% of the surface of terraces and roofs permanently covered with vegetation to be counted, additional analysis was carried out, with two alternative scenarios calculated. The first one (S1) assumed permanent vegetation covering roofs of houses and garages. The second scenario (S2) assumed covering roofs of houses and garages as well as terraces with permanent vegetation (Tab. 3).

Table 3. Number of properties not meeting the minimum biologically active area factor in different scenarios

Type of scenario	Krzeptów	Domasław	Karwiany	Nadolice Małe
S0: Sealed surfaces	3	44	1	5
S1: Permanent vegetation on roofs	0	9	1	1
S2: Permanent vegetation on roofs and terraces	0	1	1	0

The obtained results from alternative scenarios show that, although covering artificial surfaces with permanent vegetation does not solve the problem completely, however, it may significantly reduce it. In the case of Krzeptów and Nadolice Małe, all of the real estate can fulfil legal requirements. In Domasław a significant drop was observed (from 44 plots to 9 plots in S1 and 1 plot in S2). The only village in which alternative development would not change the situation is Karwiany.

5. Discussion and Conclusions

The conducted research shows that municipalities approach the need to provide biologically active areas in different ways. These shares differ between municipalities and types of land use classes and the variation may depend on the distance from the central city or the time when the master plans were adopted. This can be seen on the example of the master plan from 2012 for Domasław village and the master plan from 2002 for Krzeptów village. The difference between these plans is 10 years, the average plot size is similar, and the required proportion of biologically active areas is 50% for Domasław and 30% for Krzeptów. The study covered too small a number of villages to determine whether a statistically significant relationship exists. However, even such a small sample as four villages confirms that the character of suburban villages is diversified and generalizations may distort the image and problems of these areas.

Common to all the villages analyzed is the fact that land development is often not implemented immediately with the construction of buildings. This was observed by verifying orthophoto maps from different years. It is possible that investors decide to realize the land development later due to the cost of the construction project. Taking into account the moment of control of master plans' provisions with the actual state in the field (i.e., at the stage of the finalization of the construction investment) the effectiveness of master plans cannot be expected. Master plans are only effective at the design stage and shortly after construction is completed. In the long run, further modifications within the property are not verified, allowing investors to modify the land cover of a plot later. The obtained results confirm that, in the case of each of the analyzed villages, a property can be identified whose development is inconsistent with the provisions of master plans. The analysis of alternative scenarios showed that a significant reduction in the violation of the local law in terms of biologically active areas can be achieved by using permanent vegetation, for example in the form of green roofs.

Finally, the obtained results allow the research objective defined at the beginning of the paper to be answered. In each of the analyzed villages there are properties that do not implement the provisions of master plans. The results from the selected villages confirm that the provisions of master plans regarding the minimum percentage of biologically active areas are not respected by all properties. The lack of a mechanism to verify compliance suggests that the ultimate fulfillment of these requirements is the result of an individual decision of an investor, rather than the provisions of a master plan. In the future, these surveys could be supplemented by qualitative research which should gather knowledge and opinions of investors regarding their awareness of the regulations included in master plans and their influence on investment decisions. Qualitative studies on the effectiveness of formal and legal procedures are conducted in the field of other regulations [33], so they could be a basis for the development of similar research in the field of spatial planning. Protection of agricultural land by means of a Spatial Planning system is an international problem, and research in that domain is also being carried out in other countries [34].

A limitation that may have influenced the results obtained in this research is the use of orthophoto maps. The available data did not allow the verification of whether the type of artificial surface used was characterized by full sealing of the terrain or if it was partially permeable. Taking into account the fact that the regulations of some local governments allow the inclusion of semi-permeable surfaces as a fraction of biologically active areas, it is possible that some properties meet the regulations resulting from master plans. However, the available data did not allow for a more precise verification of the share of the surface area on the parcels. However, orthophoto maps were used due to the problem of access to private properties [35].

This study quantitatively confirms the problem of inefficiency of the spatial planning in the current legal system, mostly due to a lack of land development monitoring. When amending the law on spatial planning, it would be worthwhile to take this aspect into account and include such changes that would cause the provisions of master plans to be respected. One possibility could be to connect the control of the share of biologically active areas in spatial planning with the system of fees for rainwater drainage [36]. The other option for increasing the effectiveness of master plans could be to promote public participation in spatial planning. During public consultations it might be possible to balance different groups of interests (often opposing) including both public authorities and the private sector. Public participation in the decision-making process in spatial planning is verified as a potentially successful approach [37] and can be supported by modern tools [38]. Future studies could also analyze spatial planning documents in relation to public participation during their preparation.

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