Meaning of protected areas in ecological sustainable city development

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Abstract. Protected areas are the key elements of the green infrastructure and environmental city frame that provide variety of ecosystem services to the people as well as serve as the centers of investment attraction. The total area of the protected lands of Khabarovsk is 583.57 ha (1.5% of the city area): 5 protected ones of regional significance, 24 areas of local significance. There are 117 species observed in the dendroflora of all protected areas, which is relatively close to the natural biodiversity indicator. The reserve for expanding the protected areas network in Khabarovsk is mainly represented by the lands of the Russian Ministry of Defense, floodplain lands, the adjacent areas to the water protection zones of small rivers in the city, and ecologically restored technogenic sites. In addition to the forest type areas this will permit to create water and meadow-marsh protected plots, which meets the representativeness criteria of the natural ecosystems of the Amur River Region. The case study of a protected area called Orekhovaya Sopka, allows seeing that keeping record of the ecosystem services increases both the economic and the environmental values of the territories. The results may be applied in: municipal management.

1. Introduction

The maintenance of protected areas of federal, regional and local significance in the Russian Federation is built into the system of global conservation of nature [1] and serves as an effective tool for stabilizing and improving the environmental situation in the cities. Nowadays, theoretical and methodical approaches to organize local protected areas have been least developed due to a number of reasons. Unlike the local government that is mostly involved in solving issues in social and economic spheres, the federal and some regional authorities are somewhat interested in environmental problems and their solutions. Additional problems are caused by the qualified personnel shortage, and coordination of all parties interested in the effective use of urban lands [2].

Protected areas represent the core of the green infrastructure [3, 4], the centers of the biodiversity conservation [5–9] the provision of ecosystem services to the people [4, 10], and the formation of the ecological city frame [11]. High natural and anthropogenic risks, close proximity to residential and industrial areas, engineering and transport infrastructure make it extremely complicated for the urban protected areas to function properly. The protected territories belong to the urban landscape system, represent the part of the historical and architectural scenery and provide space for the sports, health, tourism and cultural activities. The environmental function is an obvious priority that includes the conservation of biodiversity, regulation of the microclimate, protection of the soil cover, etc. despite the multifunctional use of protected territories.
The preservation of the biological diversity is becoming the major of multiple approaches that are directed to increase the sustainability of urban ecosystems [6, 12].

A system of particular municipal activities is being built to provide the sustainable development of the urban territory. The integrity of the natural sites is ensured by the legal status of the protected areas. Those sites are able to provide a wide range of ecosystem services, and therefore to increase the economic value of protected urban lands. Not only unique ecosystems are being protected but also typical natural complexes among the protected areas $A = \pi r^2$ of local importance in the cities. The urban territories with ecological value, as well as disturbed or technogenic areas that are suitable for the ecological restoration are being primarily referred to as protected objects. The singularities of forming the protected areas network in the cities are being of interest to both Russian [11, 13–15] and foreign researchers [16].

There is a lack of sufficient study of the functioning problems of the protected areas of local importance in the Russian cities as well as in the cities of the Far Eastern Federal District. Failure of providing landscape and thematic large-scale maps, innovative development projects would not allow objectively reflect on current environmental status of the protected lands that serve as a base for monitoring, and integrate their activities into the socio-economic development of the city.

Research objective: to identify the role of protected areas of local importance in the environmentally sustainable development of cities (case study of Khabarovsk).

2. Object and Methods

This paper includes the materials of long-term geobotanical research that applied the method of onsite floristic description, inventory data of urban plantings dated 2002–2021, processed by the staff of the Institute of Water and Ecological Problems of the Far Eastern Branch of the Russian Academy of Sciences. The structure of plant communities of the protected areas of local significance was explored, the relative vital state of the tree stands was found [17].

The ecosystem services evaluation included calculating the ability of the territory to intercept water in the form of precipitation, thereby purifying it, preventing soil erosion and unloading urban rainfall sewers according to the formula [18]:

$$R_B = \frac{\Delta Cr \times r}{Sl},$$  \hspace{1cm} (1)

$R_B$ – estimate cost of water protection function of plantings (rubles);

$\Delta Cr$ – volume of water obstructed by plantings (m$^3$);

$r$ – cost of 1 m$^3$ of water for given economic zone (rubles/m$^3$);

$Sl$ – forest coverage of the water collected area (%).

The research methods included an analysis of regulations, cadastral passports of the protected areas of Khabarovsk, their investment plans of development, topographic and thematic maps, statistical and archives of the Department of Environmental Protection and Natural Resources of the Khabarovsk City, the Institute of Water and Ecological Problems of the Far Eastern Branch of the Russian Academy of Sciences, the Far Eastern Forestry Research Institute.

3. Research results and their discussion

One of the indicators of sustainable development is the share of protected areas in the total city area. Due to the natural conditions differences, territory development duration, the level of socio-economic development, cultural and historical traditions, etc. the direct comparison of the protected areas categories in various cities is not appropriate. During the forest zone functioning analysis of protected areas in the cities (Table 1) it was noted that in Ekaterinburg all protected areas occupy 17.0% of the total city area [2].

The territory of Perm has been developed for about 300 years and they managed to save its valley landscapes and unique urban forests – the etalons of broad-leaved spruce-fir forests of Perm Region. The area of all protected territories in the total area of Perm was 13.6% in 2017, and its increase is planned to reach 15.9% by 2019. The percentage of large massifs with natural landscapes out of the
protected areas is comparatively high here as well, equaling 98.8% in 2017. In Magadan, an increase to 9.8% of the protected territories’ area occurred due to the inclusion of the sea coastline (Table 1).

Part of naturally preserved landscapes is 52% of the total area of all the protected areas of the Khabarovsk City, despite 162 years’ period of territory development and settlement. Only 11 of the protected areas of local importance (295.0 ha) are located within natural landscapes of various levels of transformation. The Khabarovsk’s system of the protected areas includes all significant green massifs, that occupy only 1.5% of the total area of the city (Table 1), including 0.9% of local protected areas.

Nowadays, the modern Khabarovsk is the center of socio-economic, educational, cultural, sports and tourism activities of the Far Eastern Federal District. The city is located in the zone of mixed coniferous and broadleaf forests. Initially, its urban vegetation was represented by island small-leaved forests, hazel, larch forests and swampy meadows. Coniferous-deciduous forests mostly found their location on the elevated plots at the foothills of Bolshoi Khekhtsir island, on the Voronezh heights, on the highlands of the Amur river.

Table 1 Protected areas (PA) in Russian cities (2018).

| City name, founding date | Total city area, km² | Total population as on 01.01.2021 | Total area of PA, ha / PA | Total population of the total city area, % | Number of the urban PA of various importance | PA categories of local importance |
|-------------------------|----------------------|-----------------------------------|--------------------------|------------------------------------------|--------------------------------------------|----------------------------------|
| Khabarovsk, 1858       | 388.7                | 618 150                           | 563.1 / 1.5              | Regional significance – 5                | Natural monument – 1; park-zone – 14; nursery – 1; small public garden – 7; natural recreation complex – 2 |
|                        |                      |                                   |                         | Local significance – 24                  |                                            |                                  |
| Magadan, 1939          | 1 215.82             | 96 022                            | 2889.3 / 9.8            | Local significance – 12                  | Protected natural landscape – 6; guarded coastline – 5; landscape/garden art monuments – 1 |
|                        |                      |                                   |                         | Local significance – 4                   | Natural monuments – 1; protected natural landscape – 2; recreational area – 1 |
| Irkutsk, 1652          | 277.0                | 587 256                           | 197.5 / 0.7             | Local significance – 4                   | Protected landscape – 13; historical and natural complex – 3; natural and cultural memorial park – 1 |
| Perm, 1723             | 799.0                | 1 000 679                         | 10875.6 / 13.6          | Regional significance – 2                | City park – 10; monuments of landscape architecture and design – 4; park-exhibition – 2 |
| Ekaterinburg, 1723     | 495.0                | 1 377 792                         | 19740.6 / 17.0          | Regional significance – 33               |                                            |                                  |

The green areas of Khabarovsk have gone through the traditional way of rapidly developed Far Eastern settlements – from general destruction of the soil and vegetation cover to a clear realization of the necessity to preserve fragments of natural landscapes. According to the state records of the protected areas, there are 29 protected areas with a total area of 583.7 ha, 5 of them are regional significance and occupy 210.7 ha; 24 of them are local importance – 373.0 ha.

The reason to organize urban protected areas is to secure landscape and biological diversity; to form green infrastructure; to maintain the ecological balance of the territory; to create comfortable environment; to study different processes in urban systems; to develop the environmental education and enlightenment; to energize sports and recreational activities and tourism. Besides, the protected area “Nursery garden of decorative plants” (117.1 ha) was included in the natural-agricultural complex of the city. In accordance with the classification by the International Union for Conservation of Nature [1], the protected areas of local importance belong to the VI category – the protected area with sustainable use of their natural resources. In Khabarovsk, the whole system of the protected areas of local importance includes 24 objects (Table 2) with a regulated protection and usage schedule.
Table 2. Protected areas of local significance of the Khabarovsk City

| No  | PA of local significance                                      | PA type area/area (ha) | Vegetation description                                                                 | Amount of plant species / species in the Red Book of the Khabarovsk region, pcs. |
|-----|---------------------------------------------------------------|------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1.  | Park zone of Sanatorium Amurskiy                            | Park zone /13.19       | Natural and artificial communities                                                     | 132 / 1                                                                           |
| 2.  | 50-th Anniversary of USSR Park                              | Park zone /20.3        | Natural and artificial communities                                                     | 84 / 1                                                                            |
| 3.  | Green grove of Topographic College                           | Park zone /37.92       | Natural and artificial communities                                                     | 75 / 1                                                                            |
| 4.  | Poplar trees grove near the hospital No 10                   | Small Public Garden    | Artificial plantings                                                                  | 25 / 0                                                                            |
| 5.  | Gagarin Park                                                 | Park zone /8.78        | Artificial plantings                                                                  | 113 / 0                                                                           |
| 6.  | Gorkiy Small Public Garden                                  | Small Public Garden    | Artificial plantings                                                                  | 41 / 0                                                                            |
| 7.  | Small Public Garden near school No 38                        | Small Public Garden    | Artificial plantings                                                                  | 31 / 0                                                                            |
| 8.  | Birch grove on Mate Zalki Street                            | Small Public Garden    | Artificial plantings                                                                  | 29 / 0                                                                            |
| 9.  | Railway park near the children's railway                     | Park zone /1.4         | Artificial plantings                                                                  | 46 / 0                                                                            |
| 10. | Gaidar children park                                        | Park zone /2.41        | Artificial plantings                                                                  | 76 / 0                                                                            |
| 11. | Gastello Small Public Garden                                | Small Public Garden    | Artificial plantings                                                                  | 48 / 0                                                                            |
| 12. | Park zone of Sanatorium Bogdanovka                          | Park zone /14.7        | Natural and artificial communities                                                     | 146 / 1                                                                           |
| 13. | Dolphin Park zone                                           | Park zone /15.04       | Artificial plantings                                                                  | 48 / 0                                                                            |
| 14. | Park zone near distillery                                   | Park zone /6.06        | Natural and artificial communities                                                     | 91 / 1                                                                            |
| 15. | Nursery of decorative plants                                 | Nursery / 117.14       | Natural and artificial communities                                                     | 125 / 1                                                                           |
| 16. | Daldisel Park                                               | Park zone /2.52        | Natural and artificial communities                                                     | 83 / 1                                                                            |
| 17. | Small Public Garden DORA in Red river settlement             | Small Public Garden    | Artificial plantings                                                                  | 35 / 0                                                                            |
| 18. | Small Public Garden near combined heat and power station-1  | Small Public Garden    | Artificial plantings                                                                  | 24 / 0                                                                            |
| 19. | Park of Navy Officers’ House                                | Park zone /2.88        | Natural and artificial communities                                                     | 70 / 1                                                                            |
| 20. | Dynamo Park                                                 | Park zone /24.44       | Artificial plantings                                                                  | 231 / 1                                                                           |
| 21. | Land plot Pchelka                                           | Park zone /23.9        | Natural communities of different stages of digression                                 | Not researched                                                                   |
| 22. | Land plot near Berezovka settlement                          | Natural recreational complex / 18.45 | Natural communities of different stages of digression                                 | Not researched                                                                   |
| 23. | Land plot Orekhovaya Sopka                                  | Natural recreational complex / 47.16 | Natural communities of different stages of digression                                 | Not researched                                                                   |
| 24. | Small Public Garden near Gorkiy settlement                   | Park zone /4.65        | Artificial plantings                                                                  | Not researched                                                                   |
A wide range of various categories of the protected areas could be considered a territorial planning and improving tool for the environmental situation in the cities. The certain specifics of urban and economic developments of Khabarovsk territory have predetermined the typology of the protected areas of local importance, identifying 4 individual categories: natural recreational complexes, park zone, nursery, small public garden.

Based on an analysis of the representativeness of the system of local importance protected areas it was found that mostly forest types are being protected in ecosystems. The expansion of the city area by including the Russian part of Bolshoi Ussuriysky Island will allow the creation of protected water and meadow complexes in accordance with the spatial presence of regional natural ecosystems. In 2015, the Pchelka site (23.9 ha), located near the suburban land, was included in the protected areas of local importance network which gave an opportunity to preserve the wetland-swampy species diversity. The amount of the protected objects varies from 0.4 (parks) to 117.1 ha (Nursery of decorative plants). The connecting elements in the network of the protected areas are the valleys of the Amur and other small rivers of the city, open spaces, linear planting, engineering and transporting infrastructure.

The insignificant amount of the total area of the protected objects does not allow them to perform environmental protection functions in full. Out of 24 total the protected areas of local importance, 21 objects do not exceed 25 ha (Table 2); there is a lack of large (more than 25 ha) coastal recreational territories in Khabarovsk. The need to increase the area of the protected lands has been dictated by the sustainable development tendency which is important for the cities in the forest zone [11].

The fragments of preserved natural vegetation and areas with artificial planting are included in the network of protected areas due to the absence of urban forests of Khabarovsk. Unique natural landscapes were preserved in the Amur floodplain in the protected areas of the Park zone of Army’s Sanatorium Amurskiy, founded in 1937. Mixed oak trees, typical Far Eastern forest bushes and grasses, ash trees, mixed aspen and ash-elm tree stands represent primary vegetation here. A combination of natural phytocenoses and artificial plants with a relatively high level of biodiversity was noted in the park area of the Bogdanovka Children’s Sanatorium. The land allocated for the children’s dispensary in 1927 contributed to the 7.2 ha of mixed oak-forest and ash-forest plots preservation, which are the perfect examples of broadleaved and mixed forests of the Amur Region. Phytocenosis with a multi-tiered structure, diverse set of subordinate synusiae, and reliable undergrowth of native tree species have survived despite the high level of anthropogenic load on these two protected areas. Dioscorea nipponica Makino that is protected and listed in the Red Book of Khabarovsk Territory [19] grows around here. It also could be found in the green zone of the topographic college and the parks such as the 50th Anniversary of the USSR Park and Dynamo.

The weak degraded groups of species are widely spread in phytocenoses of park zones, small public gardens, recreational areas. The aboriginal forest vegetation of Khabarovsk accounts the total of 130 species and the dendroflora of all the protected areas of local importance including 59 species of tree type and 58 species of bushes and vines which is quite close to the natural biodiversity indicator. The common species are Populus Simontii Carriere, Ulmus pumila L., Fraxinus mandshurica Rupr., Populus nigra L., Betula platyphylla Sukaczew. The large share of introduced species could be observed in parks and small public gardens (Populus balsaminifera L., Populus nigra L., Ulmus laevis L. и U. pumila, Morus alba L., etc.), as well as invasive species.

The protected areas of local importance are under “stress of urbanization”. The rapid degradation of natural ecosystems was caused by the poor ecological environment and its intensive use. Mainly, the vegetation cover has gone through irreversible changes including species composition, living condition and functions in the ecosystem. Parks, natural recreational complexes are in high demand throughout the year for recreation. As a result, the spatial structure and the volume of the plantings have changed [9], the open spaces are growing with brushes of introduced tree species (U. pumila, Acer negundo L., P. simontii). For example, the overall structure of Dynamo Park is represented by 44 species of tree plants and 25 species of bushes. In the past few years, conifers have been planted here which increased their share in the tree stands to 10.4%, although broadleaf species prevail (89.6% of all trees). The dominants among the tree plants are U. pumila (19% of all trees in the park), F. mandshurica (15.8%) and P.
According to the evaluation of the scale of the relative living conditions of the plants [17], the tree stand in the park was marked as healthy (the $Ln$ coefficient is 85.5%).

The reserves for the formation of the protected areas of local importance in Khabarovsk are the lands of the Russian Ministry of Defense as well as green areas that have been transferred to the municipality. The possibility of increasing the total area of the protected territories could be reached by securing the floodplain landscapes in the Russian part of Bolshoi Ussuriysky Island and parts adjacent to the water protective zones of small rivers of the city. It is important to create oversized protected objects that would include a variety of landscapes (forest, meadow, swamp). In Khabarovsk, the large expansion of the protected areas is planned to take place at the Park of the Olympic Reserve School (123.5 ha).

The performance of the protected areas is poorly integrated into the socio-economic development of the cities. The world and domestic urban planning experience allows seeing the possibility of creating the protected areas of local importance through the ecological restoration of technogenic landscapes. At this point, the technogenic territory included in the protected areas network of Khabarovsk in 2015, namely, Orekhovaya Sopka (47.2 ha), deserves attention. It is located near the area of the apartment building construction (development period 2016–2027) with occupancy of 76,000 people, where it is planned to create a recreational area located within walking distance for residents. The calculations show [18] that the monetary value of the water preserving function at Orekhovaya Sopka is 49,808 rubles based on the green area of 141,500 m$^2$ with average annual precipitation amount of 673 mm considering the forest cover of the water saving area of 30% and the cost of 1 m$^3$ of water according to the Tax Code of the Russian Federation – 0.26 rubles (part of the Amur river’s watershed).

This research has shown that the recovery and the maintenance of geographically based biodiversity in the protected areas should go along with the principle of supporting natural processes of phytocenoses and considering the naturally existing potential of ecosystems. The assisting methods include protecting meadows, shambolic and irregular grass mowing, banning leaves racking, removing turf in small areas to support nesting for burrowing insects, protecting old trees for bird nests making purposes, and limiting the planting of decorative introducers. The protection against accelerated degradation of urbophytocenoses and reduction of the maintaining cost of the protected objects will depend on excluding the technologies that are dated and environmentally inappropriate. A high recreational demand requires the assortment of species. The analysis of the vitality of species in urban environments must be carried out in order to recover the tree vegetation. Urban stress tolerant species include $B. \ platyphylla$, $Larix gmelinii$ (Rupr.) Kuzen.. $Q. mongolica$. Species with moderate stability include $F. \ mandshurica$ и $J. mandshurica$. From an economic point of view, both of these types are less expensive during the post-planting care and can be used to restore vegetable cover at the protected natural sites.

4. Conclusion

The development of the system of the urban protected areas is focused on improving the ecological conditions of a territory and preserving biodiversity. Local authorities are legally granted the power to create the protected areas considering the individual features of settlements. The percentage of the protected areas in the total city area is one of the indicators of their sustainable development.

The protected areas of local significance as a whole as well as a large part of all protected areas of Khabarovsk are definitely important for sustainable development: they balance out the aggressive urbanized environment, represent the main elements of the city’s green infrastructure and ecological city frame, and provide ecosystem services to the people. The total area of Khabarovsk’s protected areas is 583.7 ha (1.5% of the city’s area), 5 of them are areas of regional importance and 24 of them are areas of local importance. The conservation and development of the protected areas of local importance network is possible by increasing their total area, ensuring territorial integrity, improving the quality of protection, maintenance and use.

The multifunctional use of the protected areas will allow providing effective potential development of their natural resources, to take into account the cost of ecosystem services, to increase the investment
attractiveness of the protected urban lands and to satisfy people’s demand for fully equipped and free public recreational zones.

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