Green and Blue Urban Infrastructure
Innovation for Northern Eurasia

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Linking green infrastructure to urban air quality and human health risk mitigation in Russia

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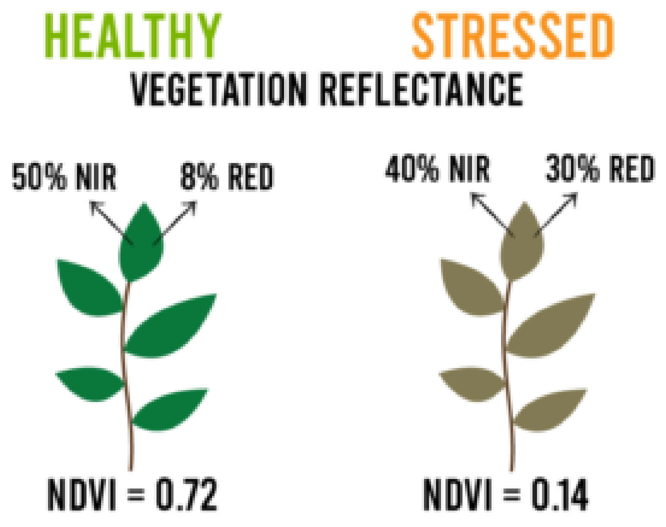
The key functions of green spaces in cities

- Reducing dust and air pollution
- Gas protection role of green spaces
- Wind protection role of green spaces
- Influence of green spaces on thermal regime
- Influence of green spaces on air humidity
- Influence of green spaces on wind formation
- The significance of green spaces in noise control
- Decorative and design functions of green spaces

Method of vegetation quality assessment

The most popular and actively used vegetation index is NDVI - Normalized Difference Vegetation Index

The better the vegetation condition during the growing season, the higher the NDVI value.



$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where:
ρ(NIR) - reflection in the near-infrared spectrum range;
ρ(Red)- reflection in the red spectrum range.

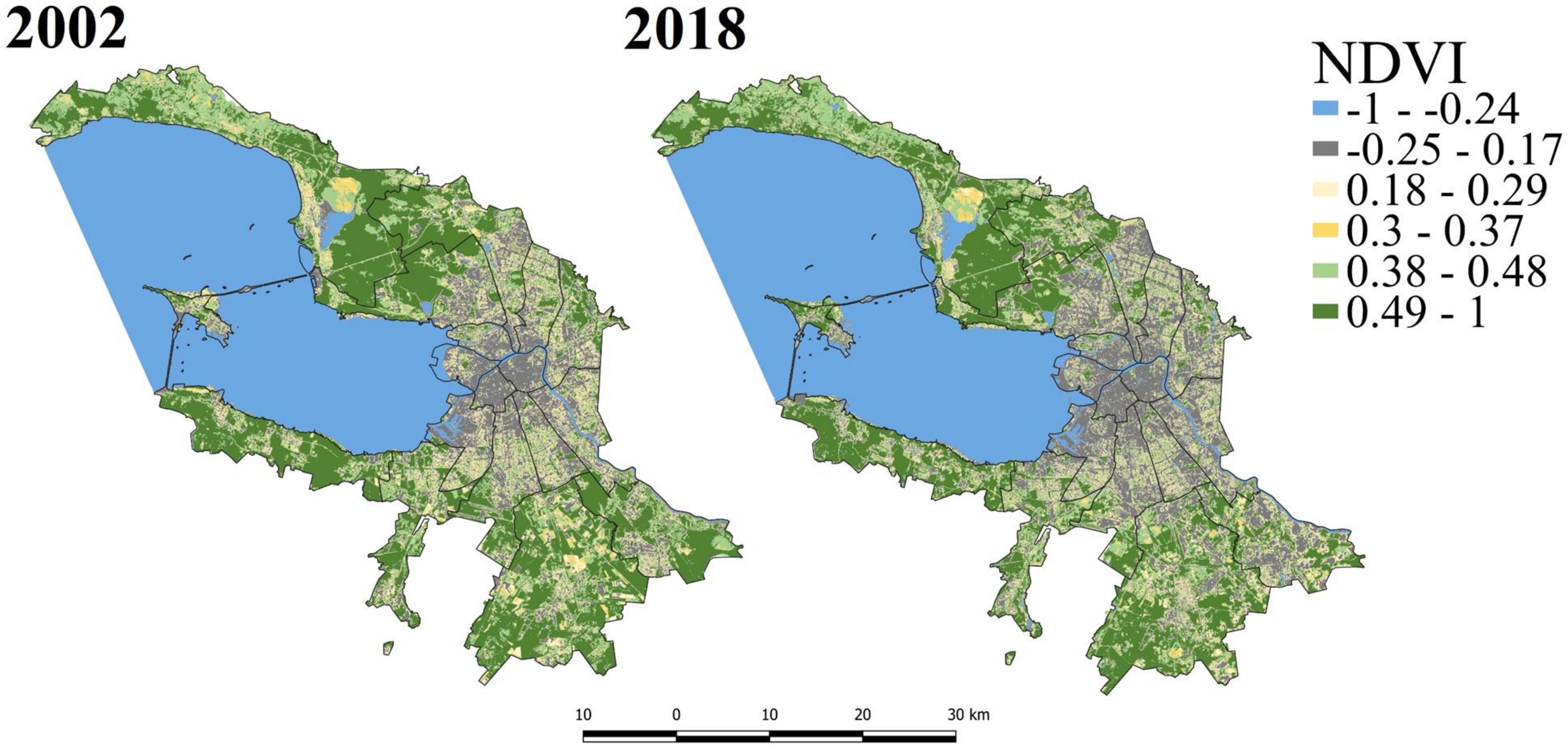
To calculate the NDVI index, 45 remote sensing images from the Sentinel 2 and Landsat 7/8 mission for the period 2010 to 2016 were used.

(https://earthexplorer.usgs.gov/)

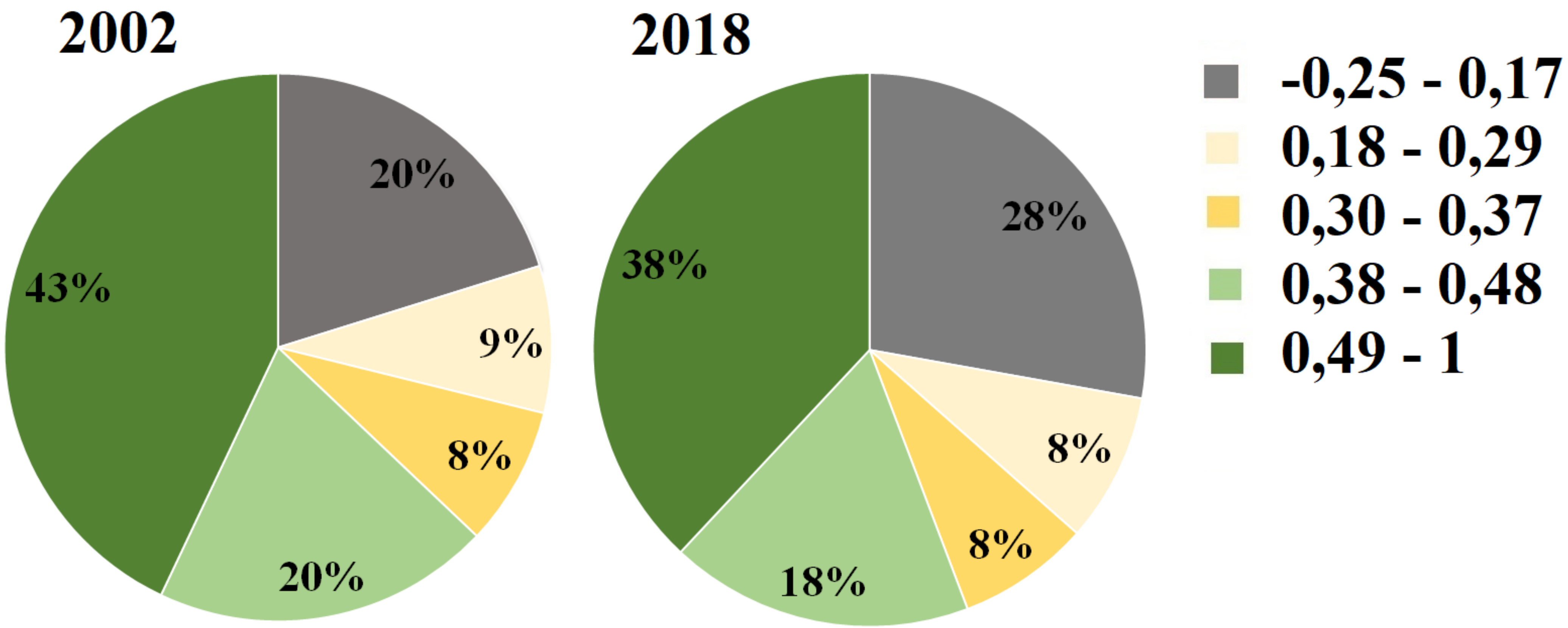
NDVI value for different objects

NDVI value	Object
0,49 – 0,8	High degree of vegetation development, good condition
0,38 – 0,48	Moderate degree of vegetation development, satisfactory condition
0,30 – 0,37	Low degree of vegetation, poor condition
0,18 – 0,29	Open soil, very low vegetation, severely depressed
0	Clouds
-0,05	Snow and ice
-0,25	Water
-0,5 and low	Artificial materials (concrete, asphalt)

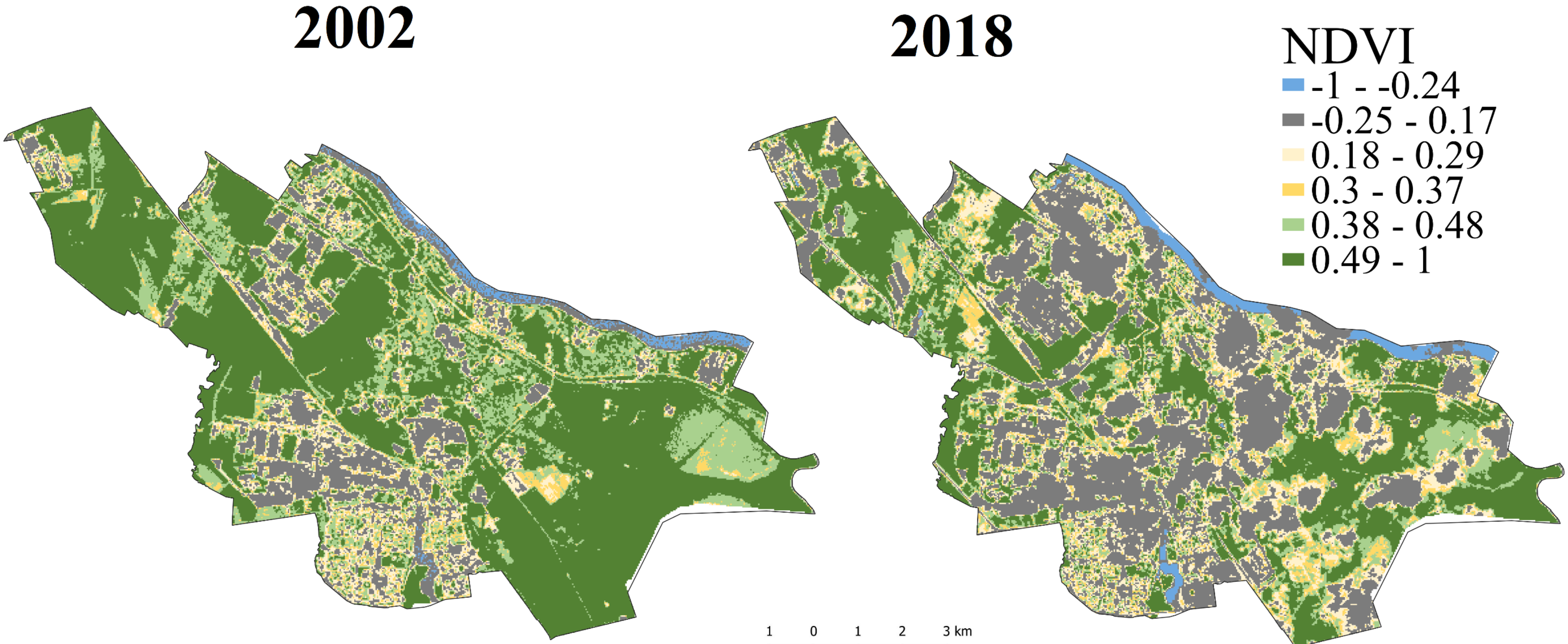
Distribution of NDVI index values in the Saint-Petersburg



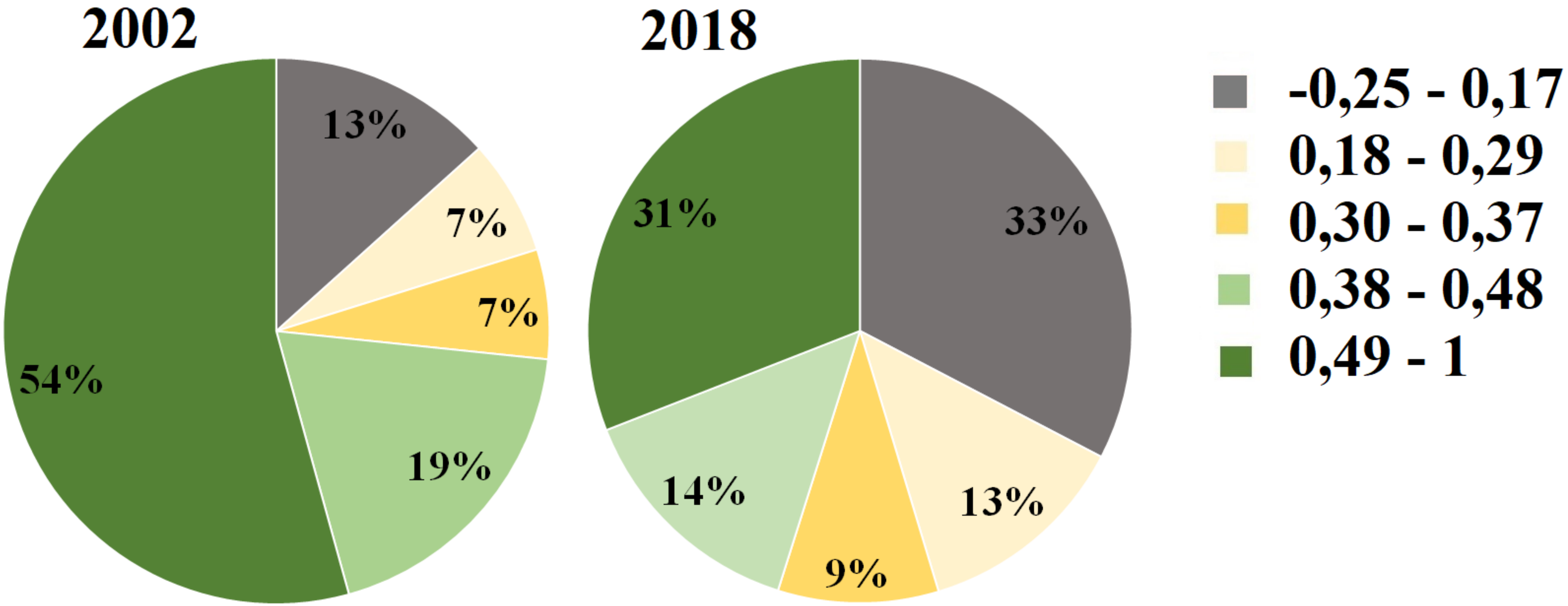
Percentage distribution of St. Petersburg area related to different objects, according to the NDVI index classification



Distribution of NDVI values on the territory of Kolpino District



Percentage distribution of the area of Kolpino district related to various objects, according to the NDVI index classification

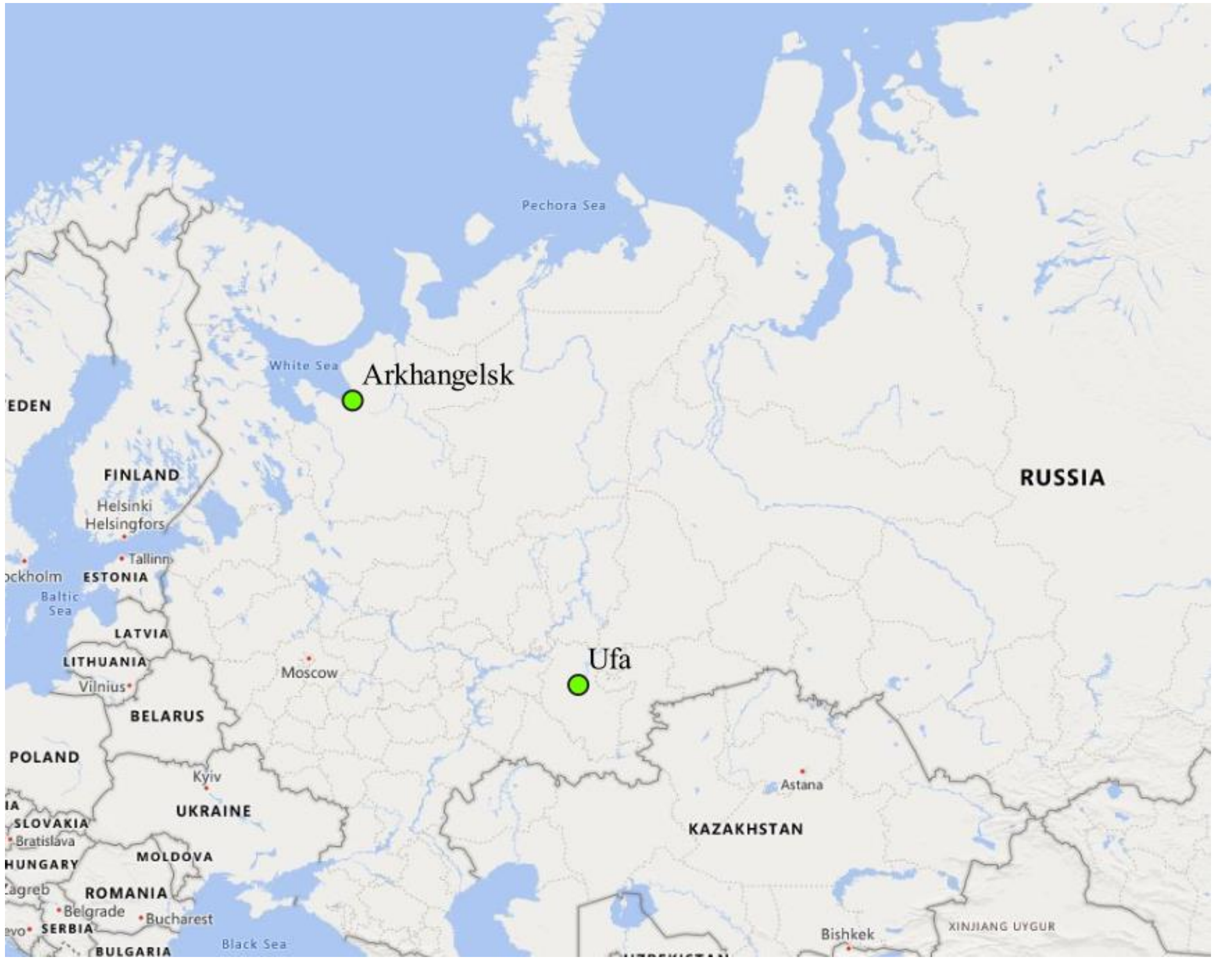


Green infrastructure as a major factor in the development of industrial cities

The main goal of this research is to assess the impact of green spaces on public health risks.

The following steps have been taken:

- Estimate the health risk in two fundamentally different cities - Arkhangelsk (Arctic zone) and Ufa (Continental zone)
- Evaluation of the quality and quantity of green spaces in these cities
- Assessing the impact of green spaces on risk with mapping and statistical analysis



Location of cities

Key air pollution settings

Ufa is the capital of the Republic of Bashkortostan, one of the largest economic, cultural, sports and scientific centers of Russia, an important transportation hub.

The population is more than 1.1 million people.

According to the atmospheric pollution index (API) the city is characterized by an increased level of air pollution API = 12.4.

(main contribution: benz(a)pyrene, nitrogen dioxide, PM10).

Ufa power station

Oil refinery in Ufa

Arkhangelsk is a large industrial city in northern European Russia with a population of 348,343. (2019).

The city has many large industrial enterprises, such as pulp and paper mills, thermal power plants, and wood processing plants.

The quality of the atmospheric air in the city, which is characterized by an increased level of pollution and is determined by exceeding the annual average MPC of formaldehyde and benz(a)pyrene.

Arkhangelsk power station

Arkhangelsk Pulp and Paper Mill

The system of green spaces in cities

UFA

Salavat Yulayev Garden

Lesovodov Park

Gafuri Park

Green spaces in Ufa are presented by parks, squares, bulwars, green areas along roads and squares.

In Ufa, each citizen has 25-30 m² of territory for vegetation

ARKHANGELSK

In the city center, green spaces are extremely dense, represented by small parks and squares.

In Arkhangelsk there are only 2.4 m² of green spaces per citizen.

Methods for assessing air pollution in Russia

In Russia, the main method for determining the quality of atmospheric air is the analysis of exceedances of maximum permissible concentrations (MPC)

Disadvantages of the MPC concept:

- it does not indicate what kind of impact on living organisms will take place
- the MPC concept does not take into account that there is no safe dose for certain substances (carcinogens)

Method for calculating carcinogenic risk

Individual carcinogenic risk (ICR) is an estimate of the probability of developing an adverse effect in an exposed individual (the risk of developing cancer in one individual out of 1,000 individuals (1×10-3)).

For the standard parameters of an individual, the averaged parameters for an adult were used to calculate the LADD as given in the guidelines (Environmental health risk assessment: - Guidelines for assessing human health risks from environmental hazards).

The method for calculating ICR according to the WHO guidelines for assessing health risks (Environmental health risk assessment: - Guidelines for assessing human health risks from environmental hazards) is based on the connection of data on the value of exposure (dose) LADD and the value of carcinogenic potential (unit risk) SF (Slope Factor)

$$ICR = LADD \times SF,$$

where: LADD is the average daily dose during life, mg/(kg × day);

SF is the slope factor, (mg/(kg × day))-1.

$$LADD = [C \times CR \times ED \times EF]/[BW \times AT \times 365],$$

Where: LADD - average daily dose or intake (I), mg/(kg × day);

C - concentration of the substance in the contaminated medium;

CR - entry rate of the contaminated medium;

ED - duration of exposure, years;

EF - frequency of exposure, days/year;

BW - human body weight, kg;

AT - exposure averaging period (for carcinogens AT = 70 years);

365 - number of days per year.

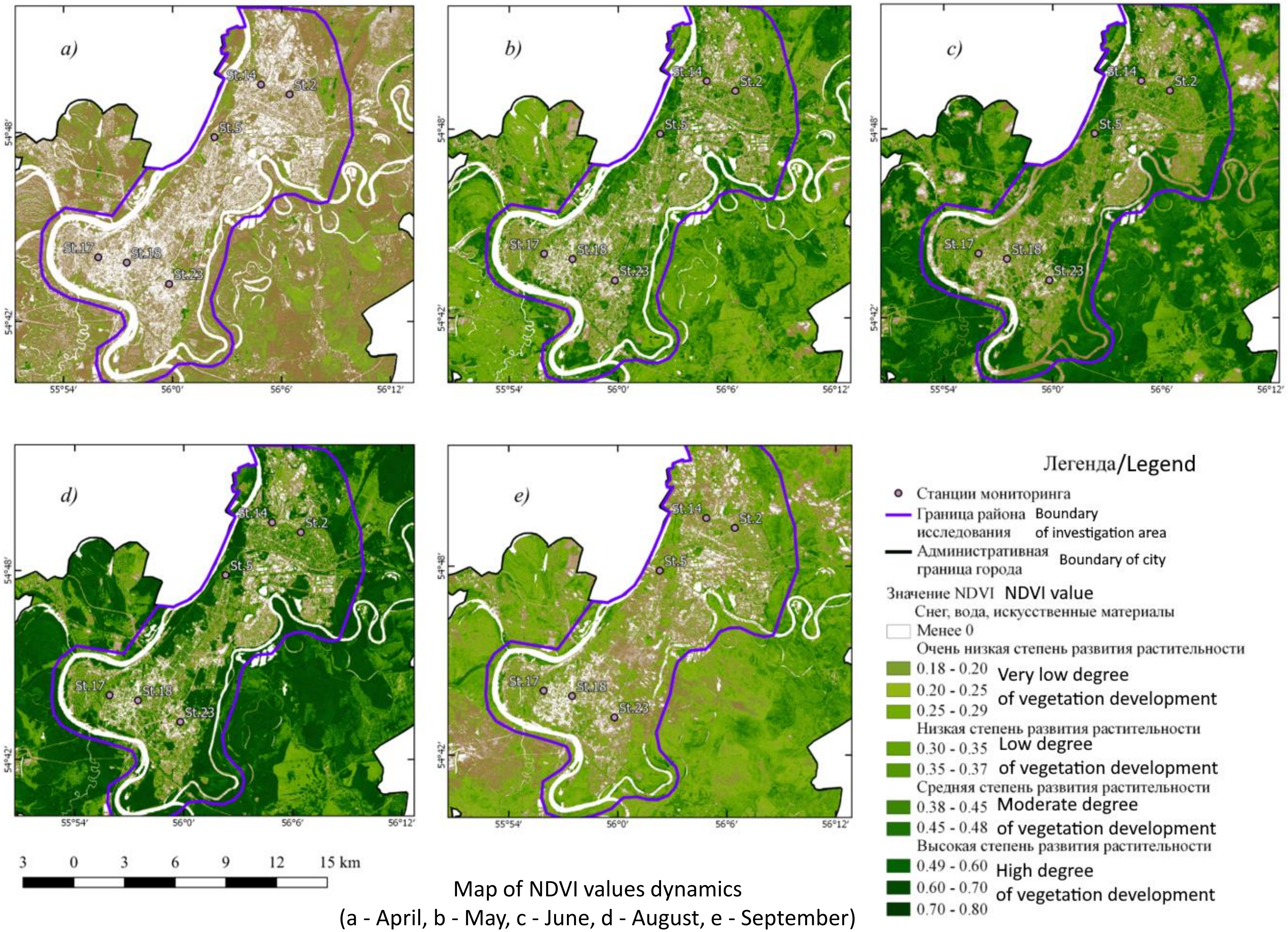
Results of the vegetation cover assessment of the city of Ufa

April - March
NDVI = 0.23
Low degree of vegetation development.

May - August
Max NDVI = 0.67 (Industrial zone)
High degree of vegetation development.
Min NDVI = 0.45 (Residential area)
Medium degree of development.

September - November
NDVI = 0.25.
Low degree of vegetation development.

November - April
NDVI less than 0
No vegetation
(snow, artificial surfaces)



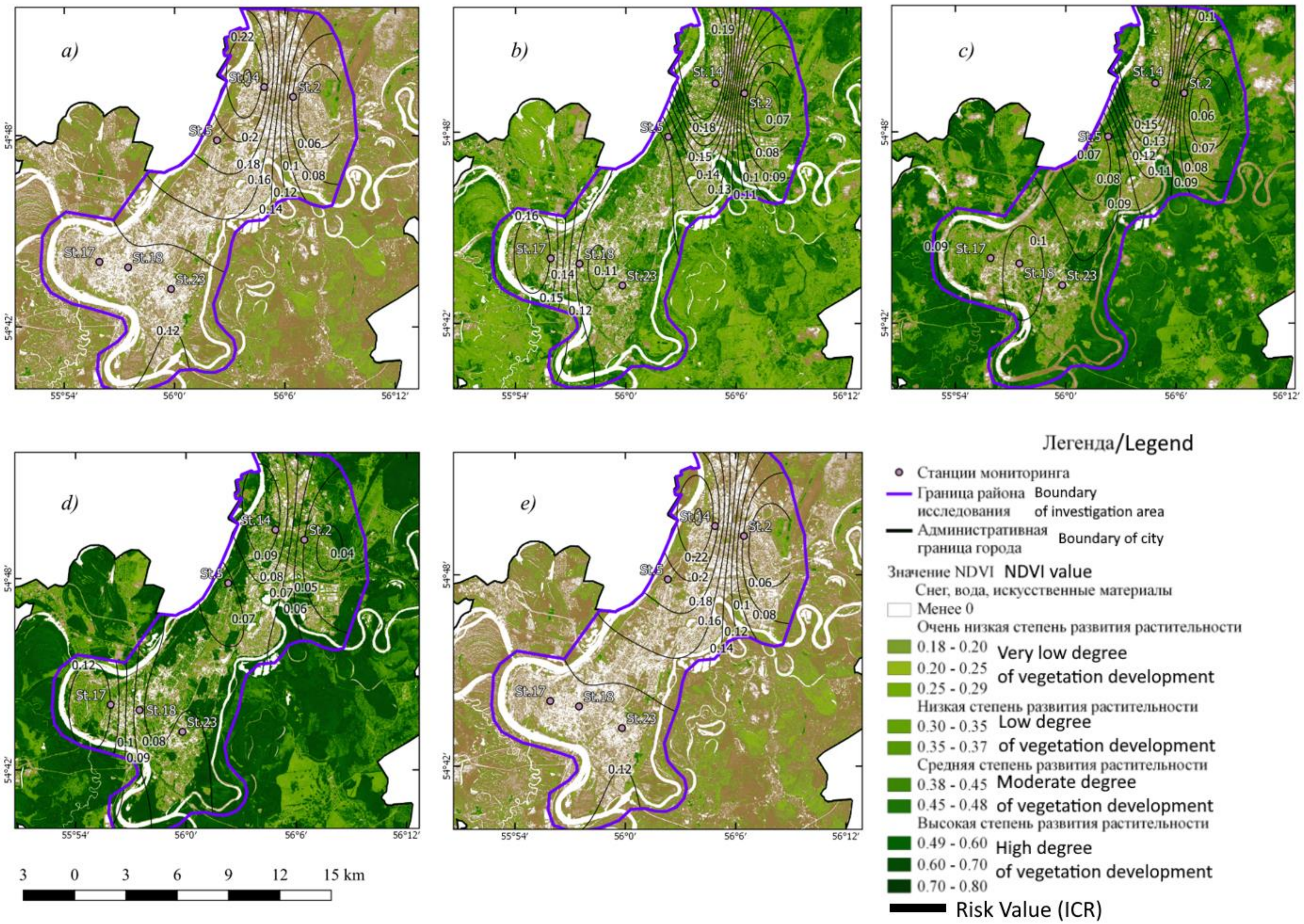
Map of NDVI values dynamics
(a - April, b - May, c - June, d - August, e - September)

Relation of carcinogenic risk to the quality of green spaces

In the early and late months of the growing season (April, September), the distribution of ICR values is more homogeneous than in the months of more active vegetation.

May
Industrial area:
ICR values - decrease
NDVI values - increase
Residential area:
ICR values - do not change
NDVI values - do not change

August
Industrial area:
ICR values (0.06×10^{-7})
NDVI values (0.67)
Residential area:
ICR values (0.14×10^{-7})
NDVI values (0.47)

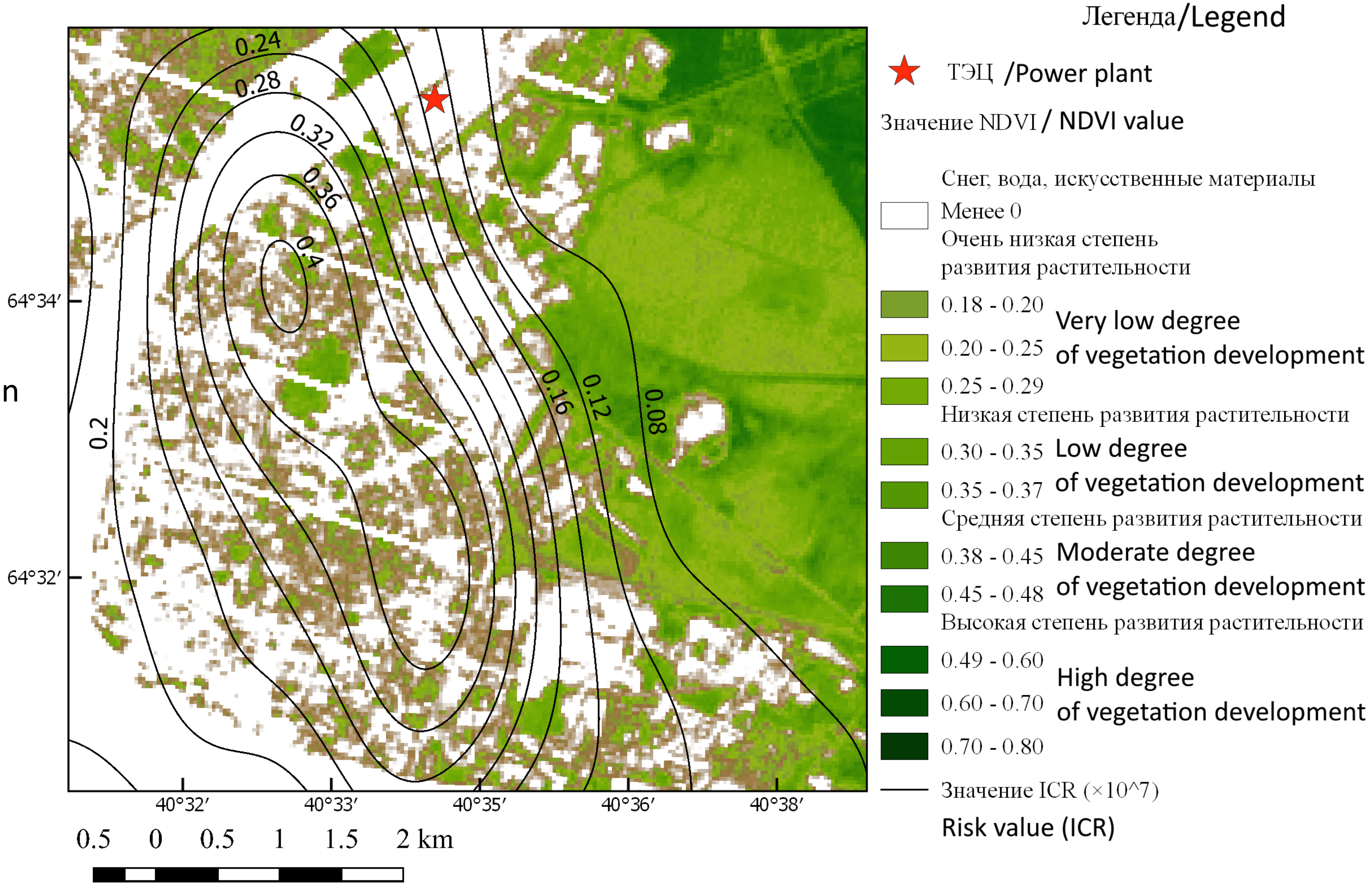


Evaluation of ICR and green space development for the city of Arkhangelsk

Minimum ICR value equal to 8×10^{-9}.
Observed in the area of the city with a large number of green spaces.

Maximum ICR value equal to 4×10^{-8}.
In the city center, the ICR value in particular near the Arkhangelsk thermal power station.

The whole territory of the city is characterized by a low degree of vegetation development with an average NDVI value for the city area equal to 0.34.

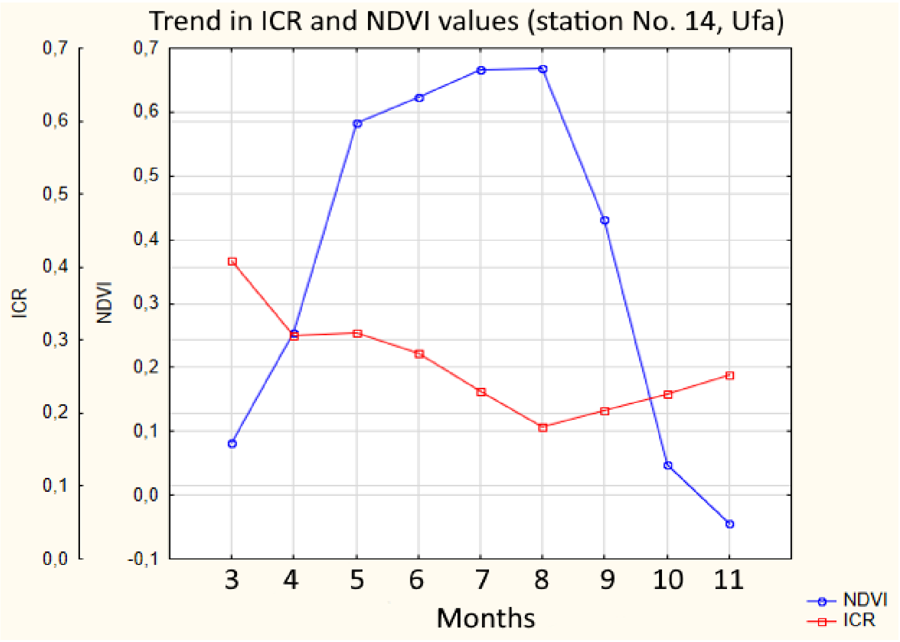


Statistical analysis of the relationship between ICR and NDVI

When analyzing the relative dynamics of NDVI and ICR, the values of the parameters show a clear reverse relationship.

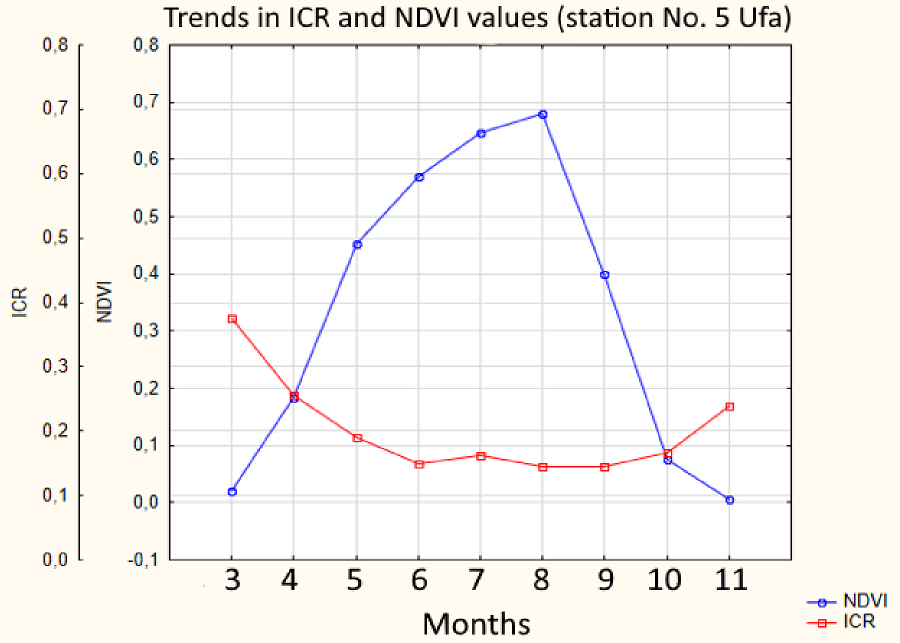
The values of the correlation coefficient r in most cases are negative, which indicates an inverse relationship between NDVI and ICR.

We can conclude that the quantity and quality of green areas in the study area have an impact on the health risk value.



Correlation coefficient r between ICR and NDVI values
(significant correlation coefficients are highlighted)

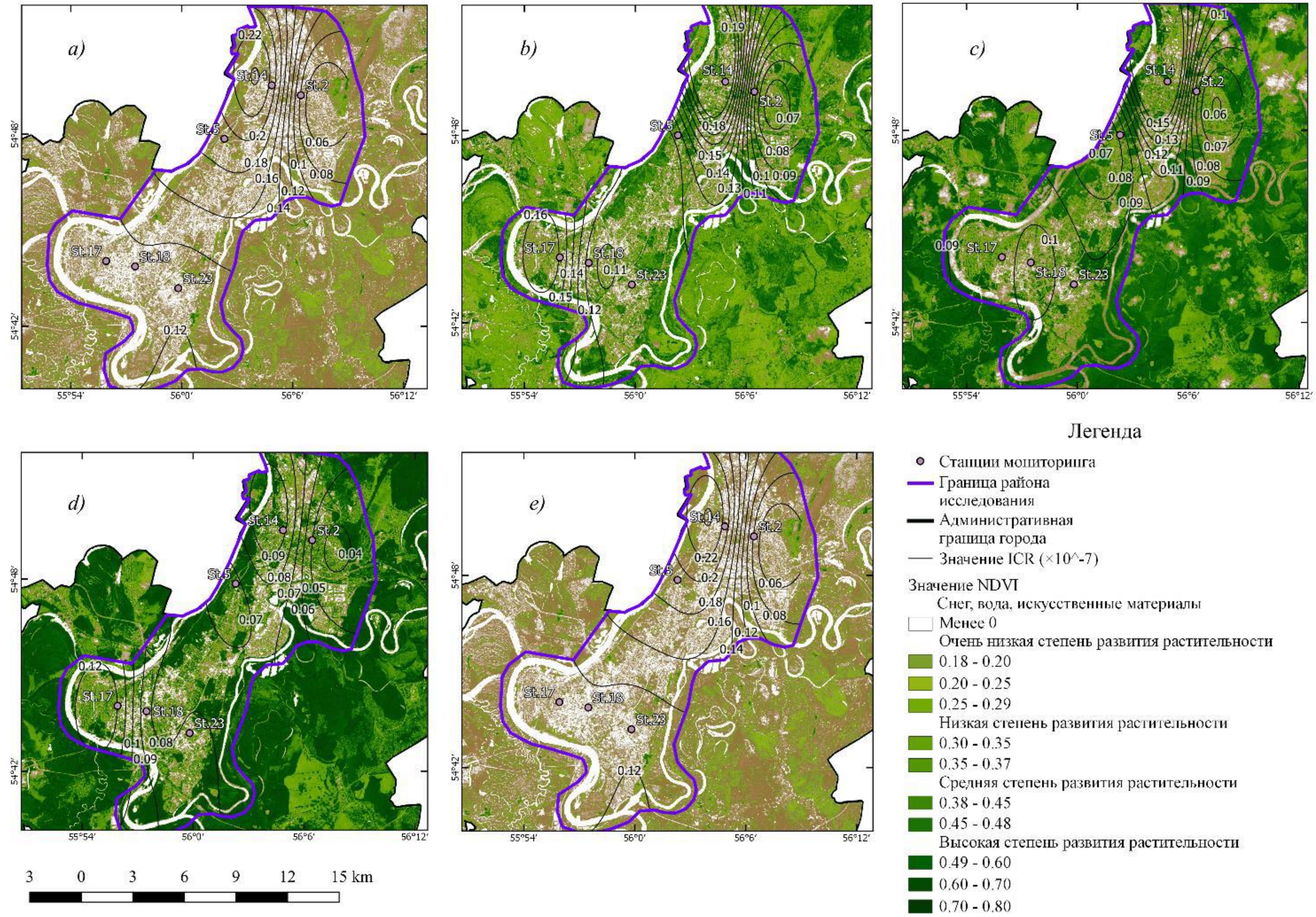
Year	Station 5	Station 17	Station 23	Station 14	Station 18
2012	**-0,75**	**-0,60**	**-0,73**	**-0,67**	**-0,61**
2013	**-0,58**	**-0,59**	**-0,56**	**-0,50**	**-0,61**
2014	**-0,56**	**-0,53**	**-0,22**	**-0,63**	**-0,55**
2015	**-0,61**	**-0,58**	**-0,46**	**-0,62**	**-0,92**
2016	-0,42	0,15	0,11	**-0,60**	0,26



Conclusions

- The growing urbanization rate has resulted in a significant reduction of green space on the territory of the city of St. Petersburg
- The increasing rate of urbanization requires the introduction of local green infrastructure within cities (e.g., green roofs, vertical gardening)
- Using the same methods to assess atmospheric air pollution could be the key to transferring experience in the implementation of green infrastructure between countries
- In planning urban green spaces, public health risk assessment methods should be used to mitigate the impact of air emissions on the health of citizens

Thank you for attention!


a)
b)
c)
d)
e)
St.14
St.2
St.5
St.17
St.18
St.23
54°48′
54°42′
55°54′
56°0′
56°6′
56°12′
Легенда
Станции мониторинга
Граница района исследования
Административная граница города
Значение ICR (×10^-7)
Значение NDVI
Снег, вода, искусственные материалы
Менее 0
Очень низкая степень развития растительности
0.18 - 0.20
0.20 - 0.25
0.25 - 0.29
Низкая степень развития растительности
0.30 - 0.35
0.35 - 0.37
Средняя степень развития растительности
0.38 - 0.45
0.45 - 0.48
Высокая степень развития растительности
0.49 - 0.60
0.60 - 0.70
0.70 - 0.80
3 0 3 6 9 12 15 km

Risk assessment

To assess the permissible individual risks associated with hazardous activities, we use the so-called Ashby criteria.

It shows represent the probabilities of one fatal event (one death) per year.

Rank of risk	The value of individual risk	Degree of acceptability
1	No less $1*10^{-3}$	Risk is unacceptable
2	10^{-4}	Risk is acceptable only in special circumstances.
3	10^{-5}	A detailed justification of eligibility is required.
4	10^{-6}	Risk acceptable without limits

Risk acceptability criteria (by Ashby)