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Geoinformation Methods for Development of Intensive Animal Husbandry in Catchment Basins of Small Rivers in the Belgorod Region

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Abstract: The article discusses the area of distribution of livestock complexes in Korochansky district of the Belgorod region, as well as in the catchment areas of the rivers (Koren, Korocha, Mokraya Ivitsa and Razumnaya) located on its territory. The quantitative characteristics of manure runoff from livestock complexes in the territory of the studied catchment basins, as well as the specific load of production waste on the catchment area caused by them, are discussed.. The areas of livestock breeding complexes in the basins of the rivers explored were mapped using the high-resolution remote sensing data. Geoprocessing tools helped to figure out the main parameters of the production sites of livestock breeding complexes. This made it possible to calculate the intensity of distributed area loads of livestock waste through the areas of typical production complexes. The obtained indicators served as the basis for modeling the degree of anthropogenic load on the studied catchments. The method of scoring the intensity of the impact of the livestock industry on the river basin structures of the Korochansky district was developed. Based on geoprocessing tools, the maps of anthropogenic load were created. They represent the determined zones of the most significant impact of the livestock industry on the territory of the Korochansky district as well as river catchment basins within this territory. The key assessment factor for territorial distribution of animal waste is to take into account the boundaries of the basin structures. This is due to the fact that livestock wastewater is distributed subject to the relief pattern, and the boundaries of the basins act as barriers to the spread of pollutants.

Keywords: Catchment basins, Small rivers, Intensive animal husbandry, High-resolution space imagery, Pig breeding complexes, Hydroecological situation

The Belgorod Region ranks the first in pig population in the Russian Federation (Expert and Analytical 2020), and the Korocha District is one of the pig breeding development leaders in the Belgorod Region. Having advantageous geographical position, favourable climatic conditions, significant production, economic and human potential as well as experience and traditions of livestock breeding, the Belgorod Region enjoys exceptional opportunities for intensive development of the latter. However, the development of cattle-breeding industry has a significant impact on the natural environment. This is particularly evident in terms of production waste disposal. The impact produced by any livestock-breeding complex on the environmental conditions can be determined by parameters of human-induced atmospheric effects, soil cover, surface and ground waters (Bezuglov 2013, Koronkevich et al 2017). Surface waters, including river waters, are the most accessible type of water resources for economic purposes, but they face the greatest threats in terms of quantitative and qualitative depletion (Gupta et al 2020, Lisetskii 2021). Water bodies are one of the main natural environment elements affected by pollution. Rivers and water runoff can act as sensitive and integral indicators of various natural and economic situations at catchments (Mukharamova et al 2020, Giri 2021, Zhang et al 2021). An integrated approach to the territorial arrangement of catchment areas and the protection of surface waters using geoinformational technologies and remote sensing has already been previously implemented for Belgorod oblast (Lisetskii et al 2014 a, b, Yermolaev et al 2015, Buryak et al 2019).To assess the degree of impact produced by a livestock-breeding complex on the ecological state of water bodies, should know where it located as well as its quantitative characteristics: animal inventory, waste released, waste disposal method, etc. Since such data is confidential, one of the most effective ways for its identification is to interpret high-resolution satellite images of the areas with production site clusters of livestock breeding complexes.

MATERIAL AND METHODS

Study site: In the central part of the Belgorod Region the pig-breeding complexes are predominantly located in the basins of the Koren', Korocha, Mokraya Ivitsa and Razumnaya rivers in the Korocha District. Most of the pig-breeding

complexes are located in the elevated upland areas. The distance between the complexes and the channels of the nearest rivers is within from 1500 to 7000 m. The satellite image of a typical existing pig-breeding complex located on the territory of the Korocha District of the Belgorod Region (the Koren' river basin, Fig. 1).

Using ArcGIS tools, measured the surface areas for the typical production sites of pig-breeding complexes on the high-resolution images (Table 1). Using the official statistical data, calculated the ratio between the area of the swine-production sites and the capacity of the pig-breeding complexes. As a result, with rare exceptions, there are 25 to 30 thousand pigs per 1 conventional typical site of pig-breeding complex in the Korocha District. Figures 2 and 3 show satellite images of cattle and poultry farming units located in the Korocha District of the Belgorod Region.

The lagoons used by cattle breeders for manure management are rectangular in shape, their area is 17,000 to 19,000 m^2 (Fig. 2). Although there are far less cattle breeders on the territory of the Belgorod Region than pig production ones, the related waste can also cause substantial environmental damage to the nearby river basins. Figure 3 shows a satellite image of the poultry farm of Agrofirma Rus JSC located in the settlement of Bekhteevka (the Korocha river basin), the Korocha District, the Belgorod Region. This is the only poultry farm on the territory of the Korocha District. The satellite image shows that the poultry farm is located at a distance of 1,700 meters from the Korocha river bed and has a sizeable poultry stock (772,400 birds). Using satellite images, identified the locations of the production sites of the livestock breeding complexes in the Korocha District of the Belgorod Region. Based on them constructed a map (Fig. 4) and the map showed the site locations of pig-breeding complexes, cattle and poultry farms in the catchment areas of the river basins within the Korocha District. The statistical data on the animal stock available on the territory of the Korocha District as well as in the Koren', Korocha, Mokraya Ivitsa and Razumnaya river basins located within its boundaries is given in Table 2.

The catchment areas are subject to heavy load due to the high concentration of livestock breeding complexes located at small distances from each other as well as because of a large number of livestock heads (especially that of pigs) on the territory of the Korocha District. The level of river basins pollution significantly increases due to the

Fig. 2. Scheme of an agricultural enterprise for breeding large horned cattle on the territory of the Korochansky district Belgorod region. 1 - Premises for the maintenance of cattle, 2-Utility rooms, 3-Lagoons for the liquid fraction of manure

Fig. 1. A typical scheme of a pig-breeding complex on the territory of the Korochansky district of the Belgorod region. 1-Lagoons for the liquid fraction of manure, 2-Valliers for walking animals, 3-Rooms for keeping pigs, 4-Utility rooms

Fig. 3. Scheme of a poultry farm on the territory of the Korochansky district of the Belgorod region. 1-Rooms for raising and keeping birds, 2-Utility rooms, 3-Lagoons for waste

release of a large amount of manure, which is further taken to agricultural fields (Gostischev 2016).

RESULTS AND DISCUSSION

For a typical pig-breeding complex in the Belgorod Region, the manure output was 4.8 kg per day on average for one livestock unit (10 % of the mass), including 0.48 kg of solid waste products (1 % of the mass) and 0.34 kg of volatile waste products (less than 1 %). (Kiselyov Kornilov 2019). For a typical cow house located on the territory of the Belgorod Region, the manure output for one livestock unit is 16.8 kg per day, solid waste is 1.7 kg and volatile waste is 1.1 kg. A typical poultry farm located on the territory of the Belgorod Region produces daily 140 g of droppings, 14 g of solid waste and 9.8 g of volatile waste per livestock unit (Kurepina Kiselyov Kornilov 2019). The waste quantities calculated by us for the pig-breeding complexes located within the catchment basins of the Korocha District mentioned in Table 3.

As a basis for identifying the most polluted areas, the calculated volumes of livestock production waste for each production site within the studied river basins on the territory of the Korocha District were recorded. During the study, used a scoring method to assess the degree of impact made by livestock production on the basin structures of the Korocha District. The method is based on object density analysis performed with the use of ArcGIS tools – "Density of Kernels". The method essentially means that the tool conceptually selects a smooth curved surface for each point. The surface value is maximum at the point location, and reduces with increased distance from the point and reaches zero at a distance equal to the specified radius for search from the point. For each output, raster cell the density value is calculated by adding the values of all kernels at the points where they overlap the raster cell centre. The kernel function is based on the quartet kernel function. The number of point counts is subject to the value specified in the weight field, which have set as waste volume; this makes it possible both to show the load in terms of the number of sites and to take into account the related animal stock. This method distributes phenomena over the surface and identifies the scope of the studied phenomenon for each location and spatially related measurable values. The sites density of the livestock breeding complexes with due account for waste volume at

Table 1. Areas of pig production facilities

River basin	Total area of the site (ha)	Area of production premises (ha)	The area of the lagoon (ha)
Mokraya Ivitsa	6.7	2.9	3.8
Koren	7.0	4.0	3.0
Korocha	7.6	4.6	3.0
Razumnaya	7.4	4.0	3.4
Korochansky district	7.2	3.9	3.3

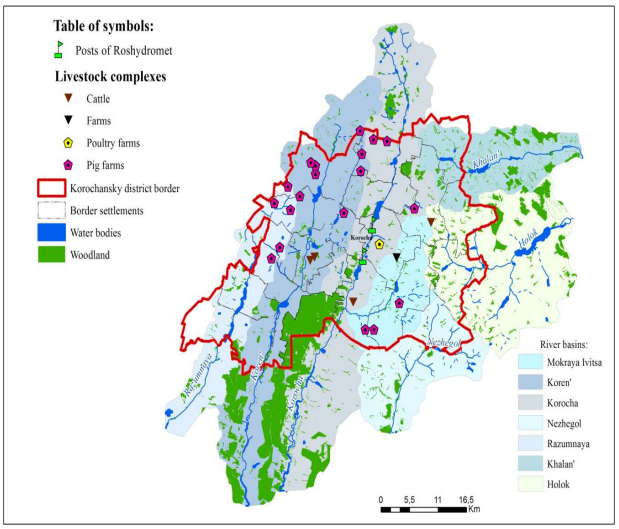

Fig. 4. Placement of livestock breeding grounds on the territory of the catchment basins of the Korochansky district rivers

Table 2. Presence of pigs, cattle and poultry in agricultural enterprises in the territory of the Korochansky district and in the catchment basins of rivers

Location of site	Pig farms, number of heads, units	Large horned cattle, number of heads, units	Poultry farms, number of heads, units
Korochansky district (1 417 km ^{2})	515237	9 171	772400
The site of the catchment area of the Koren river on the territory of the Korochansky district (410, 3 km^2)	168238	4635	–
Site of the catchment area of the Korocha river on the territory of the Korochansky district (325,3 km^2)	85840	1389	772400
Site of the catchment area of the Mokraya Ivitsa river on the territory of the Korochansky district (266 km^2)	153655	2045	–
Site of the catchment area of the Razumnaya river on the territory of the Korochansky district (173 km^2)	105026	–	–

Table 3. Waste output from pig-breeding complexes, cattle and poultry of the Korochansky district (per day, per year)

District, square	Waste	Per day	Per year
Pig-breeding complexes			
Korochansky district (1 417 km^2)	Daily manure waste	2 473 t (1.8 t km^{-2})	902 695 t (637 t km^{-2})
	Solid waste	247,3 t (0.18 t km^{-2})	90 264,5 t (63.7 t km^{-2})
	Volatile waste	175,2 t (0.12 t km^{-2})	63 948 t (45,1 t km^{-2})
Site of the catchment area of the Koren river on the territory of the Korochansky district (410, 3 km^2)	Daily manure waste	808 t day^{-1} (2 t km^{-2})	294 920 t year^{-1} (718,8 t km^{-2})
	Solid waste	80,8 t (0.2 t km^{-2})	29 492 t (71,9 t km^{-2})
	Volatile waste	57.2 t (0.14 t km^{-2})	20 878 t (50.9 t km^{-2})
Site of the catchment area of the Korocha river on the territory of the Korochansky district (325,3 km^2)	Daily manure waste	412 t (1,3 t km^{-2})	150 380 t (462.3 t km^{-2})
	Solid waste	41,2 t (0.13 t km^{-2})	15 038 t (46.2 t km^{-2})
	Volatile waste	29,2 t (0.09 t km^{-2})	10 652 t (32.7 t km^{-2})
Site of the catchment area of the Mokraya Ivitsa river on the territory of the Korochansky district (266 km^2)	Daily manure waste	738 t (2.8 t km^{-2})	269 204 t (1 012 t km^{-2})
	Solid waste	73,8 t (0.28 t km^{-2})	26 920 t (101 t km^{-2})
	Volatile waste	52 t (0.19 t km^{-2})	18 980 t (69.4 t km^{-2})
Site of the catchment area of the Razumnaya river on the territory of the Korochansky district (173 km^2)	Daily manure waste	504 t (2.9 t km^{-2})	183 960 t (1 058.5 t km^{-2})
	Solid waste	50,4 t (0.29 t km^{-2})	18 396 t (105.9 t km^{-2})
	Volatile waste	35,7 t (0.21 t km^{-2})	13 031 t (75.3 t km^{-2})
Cattle			
Korochansky district (1 417 km^2)	Daily manure waste	154,1 t (0,1 t km^{-2})	56 237 t (40 t km^{-2})
	Solid waste	15,6 t (0,01 t km^{-2})	5691 t (4 t km^{-2})
	Volatile waste	10,1 t (0.007 t km^{-2})	3 682 t (2,6 t km^{-2})
Site of the catchment area of the Koren river on the territory of the Korochansky district (410, 3 km^2)	Daily manure waste	78 t (0,2 t km^{-2})	28 422 t (69,3 t km^{-2})
	Solid waste	7,9 t (0.02 t km^{-2})	2 876 t (7 t km^{-2})
	Volatile waste	5.1 t (0.01 t km^{-2})	1 861 t (4,5 t km^{-2})
Site of the catchment area of the Korocha river on the territory of the Korochansky district (325,3 km^2)	Daily manure waste	23,3 t (0,07 t km^{-2})	8 517,3 t (26,2 t km^{-2})
	Solid waste	2,4 t (0,007 t km^{-2})	862 t (2,7 t km^{-2})
	Volatile waste	1,5 t (0.005 t km^{-2})	547,5 t (1,7 t km^{-2})
The site of the catchment area of the Mokraya Ivitsa river on the territory of the Korochansky district (266 km^2)	Daily manure waste	34,4 t (0.13 t km^{-2})	12 556 t (47,2 t km^{-2})
	Solid waste	3,5 t (0,013 t km^{-2})	1 277 t (4,8 t km^{-2})
	Volatile waste	2,3 t (0,008 t km^{-2})	840 t (5,2 t km^{-2})
Poultry			
Korochansky district (1 417 km^2)	Daily manure waste	108,1 t (0,08 t km^{-2})	39 457 t (27,8 t km^{-2})
	Solid waste	10,8 t (0,008 t km^{-2})	3 945 t (2,8 t km^{-2})
	Volatile waste	7,6 t (0.005 t km^{-2})	2 774 t (1,8 t km^{-2})
The site of the catchment area of the Korocha river on the territory of the Korochansky district (325,3 km^2)	Daily manure waste	108,1 t (0,33 t km^{-2})	39 457 t (121,3 t km^{-2})
	Solid waste	10,8 t (0,03 t km^{-2})	3 945 t (12,1 t km^{-2})
	Volatile waste	7,6 t (0.02 t km^{-2})	2 774 t (8,5 t km^{-2})

each site within the Korocha District. The results are presented in the form of a grid, which was classified into six types to identify load scores where 1 point corresponds to the load value of up to 1,000 kg km^{-2} of livestock wastewater (Fig. 5).

The distribution of waste water from the livestock breeding located within the basin structures with due account for the relief aspects on the territory of the Korocha District was obtained by integrating all density distribution grids for livestock farms per each individual basin, which made it possible to take into account the principle of mass transfer within the basin structures (Fig. 6).

The areas of the highest man-induced impact made by the livestock grounds through calculation of the density of the sites for livestock breeding complexes with due account for waste quantity factor was identified. The highest anthropogenic impact is produced on the catchment areas of the Koren', Korocha and Razumnaya rivers in the north-western part of the Korocha District because 12 pig production sites are accumulated there. The level of man-induced load from manure runoff was 6 tons km^{-2} there. The small area in the south of the Korocha District in the Mokraya Ivitsa river basin where there is also a high level of human-induced load made by manure runoff – 6 tons km^{-2}. However, this is due to a significant livestock population – 153,655 pig heads rather than because of the number of production sites

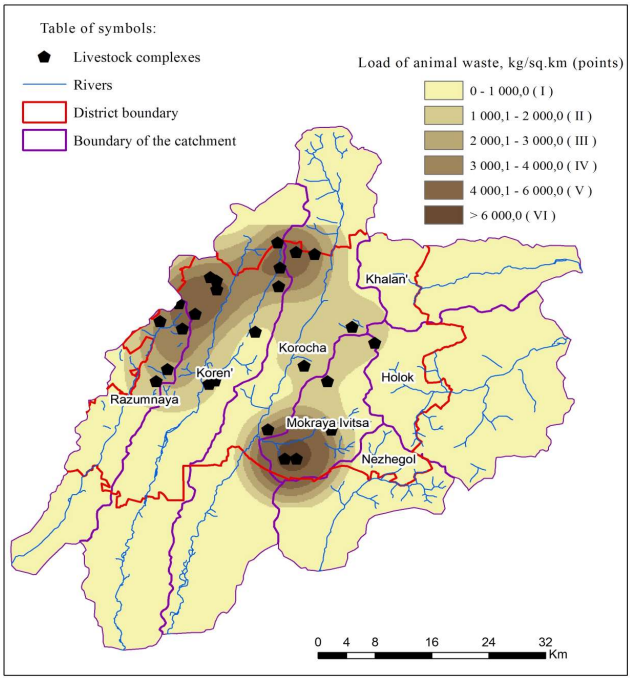

Fig. 5. Load of livestock waste on the territory Korochansky district of the Belgorod region

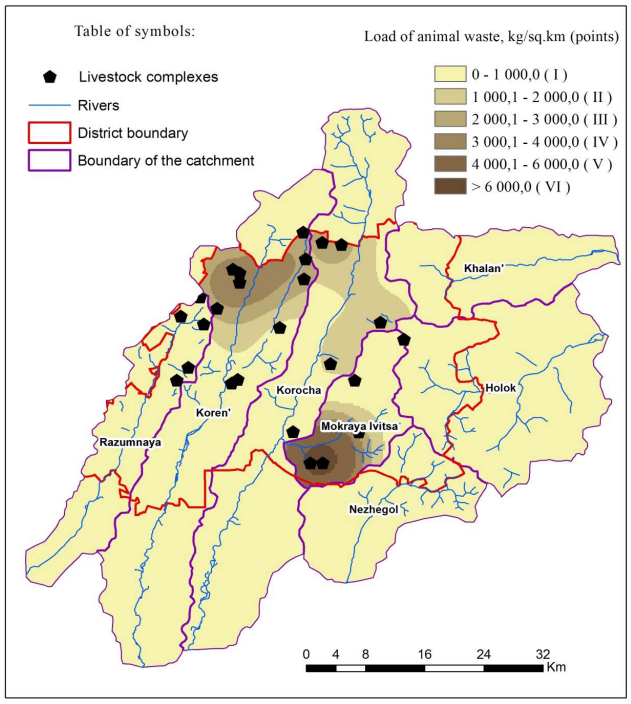

Fig. 6. Load of livestock waste on the basin structures of the Korochansky district of the Belgorod region

of pig-breeding complexes in this area (3 units). Although similar results obtained by comparing the two maps with slight deviations between the Korocha and Koren' river basins. This is due to significant number of production sites of pig-breeding complexes located in the watershed areas of these rivers. In the absence of mass runoff migration factor and taking into account the terrain relief the production sites can give fictitious picture because the Korocha and Koren' river basins are in close proximity and, as a result, the sites are located at a minimum distance from each other within the boundaries of their basins.

CONCLUSION

An intensive development of livestock industry is one of the main factors for worsened hydro-ecological situation in the basins of the Region's small rivers. The main volumes of information related to livestock production are confidential, which makes geo-information research methods to be the basic ones to study this problem. It is advisable to assess the human-induced load from livestock breeding complexes as point-type objects with the use of the density tools of geo-information systems, which take into, account not only their locations and quantity but also volumes of waste produced by each complex. During approbation of methods for assessing the man-made load from livestock breeding complexes it was found that the key assessment factor for territorial distribution

of animal waste is to take into account the boundaries of the basin structures.

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REFERENCES

Barabanov AT, Dolgov SV and Koronkevich NI 2018. The influence of modern climate changes and agricultural activities on spring surface slope runoff in forest-steppe and steppe regions of the Russian plain. *Water Resources* **45**(4): 332-340.

Bezuglov VG 2013. *Ecological situation in livestock complexes, farms, poultry farms and adjacent territories*. VNII Timiryazev Moscow agriculture Academy.

Buryak ZA, Zelenskaya EY, Poletaev AO and Tsybenko VV 2019. System approach to soil protection and ecological arrangement of watersheds at the regional level, Belgorod oblast. *Ecology, Environment and Conservation* **25**(1): 219-228.

Voroshilov YuI, Zhitkov VS, Kovalev NG and Maltsman TS 1984. Modern technology of animal husbandry waste treatment and nature protection. Moscow. *High School,* pp.15-18.

Gostishchev DP 2016. Disposal of wastewater and animal waste in irrigation fields. *Eurasian Union of Scientists* **16**: 7-12.

Expert and Analytical Agribusiness Center. 2020. http://www.ab-centre.ru

Yermolaev OP, Lisetskii FN, Marinina OA and Buryak ZA 2015. Basin and eco-regional approach to optimize the use of water and land resources. *Biosciences Biotechnology Research Asia* **12**: 145-158.

Kiselev VV and Kornilov AG 2019. Geoecological aspects of the development of modern intensive pig breeding in the Belgorod region. *Nauch. Ved. Belgorod. Gos Univ Ser Estestv Nauki* **43**(1): 98-108.

Koronkevich NI, Barabanova EA and Dolgov SV 2017. Hydrology of the anthropogenic direction: formation, methods, results. *Proceedings of the Russian Academy of Sciences. Geographical Series* **2**: 8-23.

Kurepina VA, Kiselev VV and Kornilov AG 2019. Geoecological aspects of the development of modern animal husbandry on the territory of the Alekseevsky and Krasnogvardeysky districts of the Belgorod region. *Nauch. Ved. Belgorod. Gos Univ Ser Estestv Nauki* **43**(4): 425-437.

Lisetskii FN, Buryak JA, Zemlyakova AV and Pichura VI 2014. Basin Organizations Of Nature Use, Belgorod Region. *Biogeosystem Technique* **2**(2):163-173.

Lisetskii FN, Zemlyakova AV, Terekhin EA, Naroznyaya AG, Pavlyuk YV, Ukrainskii PA, Kirilenko ZA, Marinina OA and Samofalova OM 2014. New opportunities of geoplanning in the rural area with the implementing of geoinformational technologies and remote sensing. *Advances in Environmental Biology* **8**(10): 536-539.

Lisetskii FN 2021. Rivers in the focus of natural-anthropogenic situations at catchments. *Geosciences (Switzerland)*, Art. 63 **11**(2): 1-6.

Mukharamova S, Ivanov M and Yermolaev O 2020. Assessment of anthropogenic pressure on the Volga federal district territory using river basin approach. *Geosciences (Switzerland)* **10**(4): 139.

Giri S 2021. Water quality prospective in Twenty First Century: Status of water quality in major river basins, contemporary strategies and impediments: A review. *Environmental Pollution* **271**(116332). 10.1016/j.envpol.2020.116332.

Gupta D, Shukla R, Barya MP, Singh G and Mishra VK 2020. Appraisal of river water quality based on field observations: A case study on Narmada river. *Indian Journal of Ecology* **47**(4): 897-901.

Zhang Y, Lu X, Liu B, Wu D, Fu G, Zhao Y and Sun P 2021. Spatial relationships between ecosystem services and socioecological drivers across a large-scale region: A case study in the Yellow River Basin. *Science of the Total Environment* **766** (142480). 10.1016/j.scitotenv.2020.142480.

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