Landscape-geomorphological features of natural-territorial complexes of the Middle Don Valley (on the example of Volgograd region)

I S Dedova* ORCID0000-0002-2768-9421, T N Burul** ORCID0000-0002-6750-3919

Department of Geography, Geocology and Methods of Teaching Geography, Volgograd State Social-Pedagogical University, Volgograd, Russian Federation

E-mail: *itrofimova@yandex.ru, **busmit@mail.ru

Abstract. The article is dedicated to the assessment of the relationship of the geomorphological elements of the valley of the middle course of the Don in Volgograd region with intrazonal floodplain landscapes and zonal landscapes of floodplain terraces. The purpose of the study is to develop geographical ideas about the regional features of the formation of the considered landscapes. Objectives of the study are geomorphological analysis, which determines the landscape diversity development; assessment of the soil-landscape relation of the zonal steppe geosystems and intrazonal floodplain geosystems, caused by close genetic interconnection; substantiation of landscape structure diversity within the geomorphological units of the Middle Don valley. The study is based on a standard methodology of the landscape-morphological analysis of the territory. Based on the results of the research, described is the landscape structure of the Middle Don Valley, which is characterized by a variety of NTC on a different geomorphological basis. Proved is that the floodplain of the Don in Volgograd Region has distinct geomorphological elements: riverbed floodplain, central and near-terrace floodplains. The above-floodplain terraces are distinguished by the development of 4 generations. The conducted field studies allowed us to establish a close relationship between the local landscape units and the geomorphological conditions of the Middle Don Valley. Floodplain and above-floodplain-terrace types of localities were identified. They are characterized by mottled morphology within their borders highlighted in riverine tracts, the Central area is divided into the floodplain.

1. Introduction

Volgograd region is located within the cereal-forb dry steppe subzone, but, at the same time, the intrazonal landscapes exist in the valleys of large and medium-size rivers. The largest area is occupied by floodplain-valley landscapes of the middle part of the Don, prevailing among other intrazonal landscapes (4.85% of the area). However, the uniqueness of the Don valley landscapes is in the geochemical conjugation between natural-territorial complexes (NTCs) of the floodplain and above-floodplain terraces. These bonds form the landscape-morphological diversity of the territory and determine the appearance of different NTCs: from psammophytic cereal-forb steppes with a sparse cover on above-floodplain terraces to old-growth floodplain forests. Besides, the Don floodplain is one of the amazing natural formations, a kind of oasis in the dry steppe zone of Volgograd region [1]. Its position in the valley of a picturesque river is an attractive factor for the development of spontaneous tourism, and also determines its entry into the structure of a special nature reserve of the regional level
- the natural park "Donskoy". The study of the properties and morphology of the natural-territorial complexes is topical because these areas have been partially studied. Earlier we studied the NTCs of the lakes of the Don floodplain and estimated their geocological state, which is reflected in several publications [2, 3]. The individual structural components of the NTCs of the above-floodplain terraces of the r. Don was considered in the works of regional and metropolitan scientists: A.G. Gael, L.F. Smirnova, V.A. Brylev (the study of the geological and geomorphological components of the floodplain terraces) [4, 5], N.O. Ryabinina (development of the systematics of the NTC of Volgograd region) [6], V.A. Sagalaev (the study of the vegetation) [7]. A.S. Rulev (2011) has determined the taxonomic position of the floodplain NTCs, he distinguishes floodplain ecological-dynamic rows – meadow and shrub-broadleaf; he refers our territory to the group of subarid and arid floodplains [8]. There are still no works, considering the NTCs of the floodplain and above-floodplain terraces of the Middle Don valley in the landscape paragenetic unity. In this article, we have attempted such an analysis, and have tried to assess the location of various NTCs on the geomorphological elements of the floodplain and above-floodplain terraces with different flood regimes.

2. Materials and Methods
The middle part of the valley of the Don in Volgograd region has a considerable length (more than 530 km), within this territory there are unique valley complexes of above-floodplain terraces and floodplains, that differ from the zonal dry steppe NTCs. Landscapes of the Archedino-Donskoy, Golubinsky, and Tsimlyanskiy sands are very interesting, ones are represented by accumulations of ancient fluvioglacial sands with exotic aeolian landforms and the NTC of sparse psammophytic steppes [9], as well as NTC of riverbed floodplains with old-growth forests. Geological and geomorphological factors have a primary significance in the formation of the landscape diversity of the valley NTC. In the Don floodplain, high waters create a wide variety of water stream regimes, which determine the differentiation of the hydrogenic plain into several landscape-geomorphological systems, which differ in the flooding regime, differentiation of alluvium, absolute height, and soil-plant conditions. The above-floodplain terraces are characterized by the NTC’s differentiation, based on the geological and geomorphological conditions, as well as on the groundwater level.

The length of the territory led to the rationale as research key areas of the floodplain and terraces located within the boundaries of the natural Park Donskoy, and Golubinski sandy array. In the field seasons (2014, 2017-2018) routes were laid for landscape survey in the following directions: Panshino – riverbed the Don; Kachalinskaya - riverbed the Don; Peskovatka - riverbed the Don. The selected routes allow to research different types of the NTCs; at the same time, the ones are very convenient for considering the co-evolution of local geosystems of the floodplain and above-floodplain terraces. The research included the standard methods: describing soil profiles and geobotanical sites using the rating scale of an abundance of Drude, making the landscape profiles. The result of the research is formulated to the concept of the landscape-geomorphological structure of the valley landscapes on the example of key territories of Volgograd region.

3. The results
Geomorphological factors determine the diversity of the landscape structure of the Middle Don valley. Valley NTCs topologically differentiate into the floodplain and above-floodplain terraces ones.

3.1. Floodplain NTCs
The Don floodplain is divided into tracts of near-channel, central, and near-terrace floodplains. NTCs of the floodplain lake basins and bayou lakes with damp meadows and willow thickets are interesting. During the field season 2015-2019, we studied the NTCs of the Don floodplain in the vicinity of Kachalinskaya, Panshino, Donskoy.

3.1.1. Tracts of a near-channel floodplain. There are the NTCs of the riverbed shafts and sandy beaches, ridges, and inter-ridge depressions. The average height of the riverbed floodplain is + 36 ... +
38 m. The relief of this part of the floodplain is excelled by good differentiation - the relative height of the ridges above the bottoms of inter-ridge depressions, hollows, and bayous is 2.3-2.6 m. The tops of the ridges are forested (Populus alba L., Populus nigra L., Quercus robur L., Populus tremula L., Salix alba L., Fraxinus excelsior L.) on alluvial forest soils with various texture. The following vegetation associations are characteristic for the Don floodplain: simple floodplain oak forests, lily-nettle-blackberry formations (Quercetum – Rubiosum - Urticaosum+Convalliumosum); willow forests (Salicesetum - Carexosum), black poplar grove (Poplarsetum – Rubiosum), white poplar grove (Poplarsetum – Rubiosum), alder forests (Alderetum - Carexosum) and aspen forests (Poplarsetum - Rubiosum). Willow thickets include Salix caprea L. and develop on sandy soils in elevated river channel parts of the floodplain. This is a pioneering forest formation, replacing willows shrub. The most characteristic associations of these light-colored forests are the willow thickets (Salicesetum - Bromusosum). The black poplar groves are also widespread on alluvial slightly saline soils, in contrast, willows. The blackberry-poplar formations (Poplarsetum - Rubiosum) with an extremely thin vegetation cover were most developed on forest alluvial saturated soils (figure 1).

![Figure 1](image-url)  
**Figure 1.** Landscape structure of the Middle Don Valley (in the direction Panshino – the Don).

Floodplain terrain type:  
Tracts of riverine floodplain: A facies of black poplar of the floodplain (Pópulus sp., Pópulus trémula) on floodplain-forest loamy soils; B facies of the black poplar of the floodplain blackberry with aspen-willow undergrowth (Populus sp., Populus tremula, Rubus caesius L., Salix alba) on floodplain forest silt-humus soils.  
Tracts of the central floodplain: C facies of mesophytic grass-sedge-cereal meadow on floodplain meadow soils; D facies of a meadow of hygrophytic sedge on alluvial meadow soils.  
Tracts of the near-terrace floodplain: E. facies of the hemixerophytic grass-cereal meadow on meadow saline sandy loam soils; The terrain of the sandy accumulative plain of the Don above-floodplain terrace.  
Tracts of sandhills: G facies of the steppe of mixed grass-cereal psammophytic on sod sandy loam shallow soils.  
Tracts of inter hills hollows: H facies of the steppe of mixed-grass-cereal psammophytic on sandy undeveloped soils; J facies of poplar-aspen forest (Populus sp., Populus tremula) on dark-colored forest sandy loam soils.  
Tracts of the ancient alluvial sandy low-hilly plain: I facies of man-made pine forest (Pinus sylvestris L., Salix alba) on fixed sands.

Symbols: 1. Quartz alluvial sands, the lower horizon of the Upper Pleistocene; 2. Quartz sands, mixed-grained alluvial, the upper horizon of the Upper Pleistocene; 3. Floodplain deposits (sandy loam, dark-colored loam), Holocene; 4. Lake silts and clays with an admixture of peat; 5. Pine forests; 6. Willow-shelyuga (Salix acutifolia Willd); 7. Psammophytic cereal; 8. Sedge meadows (species of Carex sp.); 9. Black poplar grove; 10. The brambles; 11. Grasses of the psammophyte steppes; 12. Herbs of the floodplain meadows.
White poplar grove presents as small inclusions among black poplar grove and willow forests, that are growing on the riverbed parts of floodplains, where appear the signs of salinity. Aspen forests are found in closed depressions with elevated groundwater level (1–1.5 m) [12].

The forest is the main provider of organic matter for the riverbed floodplain, which is represented by thin leaf litter (2-4 cm) with a weight of 1-2.2 kg / m². The riverbed floodplain is separated from the modern riverbed of the Don by a natural levee 8-11 m wide and a bayou to 2 m deep and 30-32 m wide [3].

The NTCs of sandy beaches on modern alluvial sands and sandy loams are devoid of soils and have a cover of pioneer vegetation. Shrub formations in the near-channel parts of floodplains are formed by different species of willows - *Salix triandra* L., *S. purpurea* L., *S. acutifolia*, *S. cinerea* L. The natural levees, composed of sands of the channel facies, are distinguished by the development of the NTCs of semi-sandy and sandy meadows on sandy loamy meadow sod soils. The plant formation is reed grass-bluegrass-sedge meadow with vegetation cover of *Calamagrostis arundinacea* (L.) Roth, *Poa palustris* L., *Carex sp.*

3.1.2. Tracts of the central floodplain. The central floodplain is characterized by a decrease in absolute height to +36 m on the crests and relative height to 1-1.5 m. Its average width increases from 3.5 km, the minimum width in the vicinity of the Donskoy to 1.5 km (partial processing by the upstream of the Tsimlyansk reservoir). It is characterized by the development of hygrophytic and mesophytic meadows with a high density of herbage on alluvial meadow soils with heavy texture.

The NTC of hygrophytic meadows on alluvial meadow-boggy clay soils is characterized by the 3 predominant plant formations: *Phalaroides arundinacea* L., *Beckmannia eruciformis* Host, and *Carex sp.*. Canary meadows are located in depressions between ridge depressions, that are more than 1 m below the level of meadows with medium moisture. The Bekmania formation occupies less humid ecotopes. Beckmania is often mixed with meadow foxtail (*Alopecurus pratensis* L.), wheatgrass (*Elytrigia repens* (L.) Desv. ex Nevski), various sedge species, and marsh grass (*Eleocharis sp.* L.). There are mint (*Mentha arvensis* L.) and grub (*Rorippa sp.* Scop.). Sedge meadows (*Carex cespitosa* L., *C. cineria* L., *C. elongata* L., etc.) occupy a significant area of the Don floodplain meadows [12].

Mesophytic meadows are located on alluvial meadow soils. *Alopecurus pratensis*, *Bromus inermis* Leyss, *Poa pratensis* L. and various mixed communities (bluegrass-fox-tailed, etc.) are typical of these landscapes. Mesophilic meadow forbs develop abundantly. Typical of them are *Galium aparine* L., *G. verum* L., *Valeriana officinalis* L., *Lotus corniculatus* L., *Pentanema britanicum* (L.). D.Gut.Larr. et al, *Jacobaea vulgaris* Gaertn, *Veronica longifolia* L. The secondary background is formed by leguminous herbs from *Lathyrus pratensis* L., *Vicia cracca* L., *Mellilotus officinalis* (L.) Lam., *M. albus* Medik, *Glycyrrhiza glabra* L., etc. The species diversity of the meadow communities is quite rich – 26-32 species per 100 m2 and belongs to the Middle Don subtype [12].

There is the NTC of the floodplain lakes coasts in the central floodplain. Near-water vegetation of the shores grows on alluvial meadow-boggy soils and is represented by the NTC of sedge-forb meadows with *Carex sp.*, *Phragmites australis* (Cav.) Trin. ex Steud, *Typha latifolia* L., *Schoenoplectus lacustris* L. Common species of near-water forbs include *Ranunculus repens* L., *Persicaria hydropiper* (L.) Delarbre, *Rumex maritimus* L., *Butomus umbellatus* L., *Lythrum salicaria* L., *Oenanthe aquatica* (L.) Poir, *Alisma plantago-aquatica* L., etc. Some lakes are characterized by coastal woody vegetation of alder (*Alnus glutinosa* (L.) Gaertn), willow (*Salix caprea – S. alba*), poplar (*Populus sp.*).

3.1.3. The above-terrace floodplain. The above-terrace floodplain has a width of 150-200 m, it is marked by the steppe formation of vegetation (the appearance of steppe grasses and shrubs in the grass stand) and increases the absolute height above +38 m. Its average absolute height is +38 m (Kachalinskaya) ... + 40 m (Donskoy). The main source of matter for both generations of the floodplain is both floodwaters and grassy litter, the latter is periodically destroyed here. Therefore, its average thickness is 4 cm, and its weight is less than 0.5 kg / m². A complex geochemical environment
is noted here: an additional source of the chemicals transit from the above-floodplain terraces are steppe gullies, and the ledge of the first above-floodplain terrace is a local geochemical barrier [3], that is proved by chemical analysis of soil extracts. This is indicated by the chemical analysis of soil extracts of the floodplain and above-floodplain terrace types of terrain. The obtained results, using the literature data of A.G. Gael, L.F. Smirnova (1970) and V.M. Kretinin (2006), are summarized in the table 1.

Table 1. Chemical properties of soils of floodplain and above-floodplain-terrace type of localities (compiled on the basis of data obtained by the authors and data from sources [4, 12])

| Soil type                        | Geographic location                                      | Humusness, % soil horizon A | pH of the water extract | Content of CO₂, % total of the volume of the entire profile | Absorbed cations, % total of the volume of the entire profile |
|----------------------------------|--------------------------------------------------------|----------------------------|-------------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| Alluvial meadow-steppe saturated clay soil | The near-terrace floodplain, in vicinity of Kachalinskaya | 2.6                        | 7.6-8.5                 | 14.0                                                        | 115.2                                                       |
| Alluvial forest layered loamy soil | Riverbed floodplain, 30 m from river’s edge, in vicinity of Sady Pridonya | 2.38                       | 7.6-8.0                 | 5.6                                                         | 55.22                                                       |
| Sod sandy underdeveloped soil    | The top of the aeolian hill, in vicinity of Panshino, northern part of Golubinskiy massif | 0.59                       | 5.9-6.9                 | not revealed                                               | not revealed                                               |
| Chestnut light loamy soil        | Upper reaches of the Nizhnegerasimovskaya ravine, in vicinity of Donskoy | 3.0                        | 6.4-7.2                 | 11.47                                                      | 50.73                                                       |

The near-terrace floodplain is marked by the development of the formation of steppe fescue-wheatgrass meadows on alluvial meadow soils with varying degrees of salinity. Transitional communities of fescue-wheatgrass (Festuca valesiaca Schleich. ex Gaudin; Agropyron pectiniforme (L.) Gaertn) and wheatgrass-fescue with an admixture of Elytrigia repens are dominated in the vegetation cover. Forbs are formed by a mixture of steppe species (Artemisia austriaca Jacq. Medicago falcate L., Salvia pratensis L., Potentilla anserine L., etc.) and meadow species. The moderately steppe meadows are 0.7–1.5 m higher than the mesophytic meadows. The strongly steppe meadows are 1.5–3 m above the level of the mesophytic meadows of the central floodplain. Artemisia vulgaris L. and Cirsium vulgare (Savi) Ten. are indicators of saline steppe meadows [12].

Thus, the NTCs of the Don floodplain differ in development in conditions of seasonal flooding and are characterized by the existence of NTCs of floodplain forests and meadows with varying degrees of moisture. The landscape structure is defined by the tracts of the riverbed, central, and near-terrace floodplains. NTCs in the floodplain lake basins and oxbow lakes damp meadows and willow thickets are particularly distinguished.

3.2. The NTCs of the above-floodplain terraces

The NTCs of the above-floodplain terraces were analyzed based on field studies within the boundaries of the Golubinsky sands. Here, the formation of tracts, sub-tracts and facies is noted in the conditions of fluvioglacial sand outcrops, as well as relatively shallow occurrence of the aquifer. The background is the tracts of psammophytic herbs-cereal-wormwood sparse steppe on chestnut sandy loam and sandy soils [2].
3.2.1. The NTCs of aeolian hills and dunes. The vegetation cover of aeolian hills and dunes is characterized by the predominance of Festuca beckeri (Hack.) Trautv., Agropyron tanaicticum Gaertn., Helichrysum arenarium (L.) Moench, Eryngium campestr L., Artemisia arenaria L., growing on chestnut sandy loam underdeveloped soils and humus sands. These facies are combined with the NTCs of depressions and inter-mound depressions with hygrophytic reed-sedge meadows on soddy-humus sandy loam soils (noted for inter-ridge depressions of the near-floodplain part of the sands). Phragmites australis, Carex arenaria, Carex melanostachya M. Bib. ex Willd. are typical for vegetation cover of these facies. NTC of poplar-willow forests in the central part of the sandy massif on dark-colored forest sandy loam soils are also registered here. These forests have undergrowth from Populus tremula, Elaeagnus orientalis L., Rosa canina L. The herbaceous cover here includes Carex arenaria, Chenopodium album L., Artemisia austriaca, Linum perenne L., Festuca beckeri.

3.2.2. The tracts of dunes and dune chains. The tracts of dunes and dune chains are formed by facies of psammophytic herbs-cereal-wormwood steppe on humus and loose sands. We registered these forms in the southern part of the Golubinsky sandy massif. The vegetation cover is represented by Festuca beckeri, Stipa pennata L., Agropyron tanaicticum, Leymus racemosus (Lam.) Tzvelev, Carex colchica J. Gay, Kochia prostrista Roth, Artemisia arenaria, Thymus pallasianus Heirn. Braun and other species.

3.2.3. Relict tracts of deflationary hollows. The unique NTC of the considered territory of the Golubinsky sands is a relict tract of deflationary depressions with groves of birch-aspen forests and oak forests in combination with grass cover, forb-grass-sagebrush steppe-psammophyte on meadow-brown sandy loam and sandy soils, combined in loose sand.

Their formation is associated with the glacial epochs of the past [13], and in modern climatic conditions, the existence of these NTCs is associated with the shallow groundwater table. The main forest-forming species are Betula pubescens Ehrh., Populus tremula, Quercus robur.

3.2.4. The NTCs of the ravines, cutting through the Don above-floodplain terraces. Also very interesting are the NTC beams, that cut through the Don above-floodplain terraces. For the upper parts of the gully slopes, the facies of psammophytic wormwood-grass sparse steppes on sod-sandy soils are registered. The herbaceous cover here is represented by Artemisia arenaria, Festuca beckeri, Avena strigose Schreb, Helichrysum arenarium, Elytrigia repens, Thymus pallasianus, Leymus racemosus. They are combined with sub-tracts of moistened ravines and small steppe rivers, which are represented by an aspen-poplar old-growth forest on dark gray alluvial sandy loam soils [15]. The main forest-forming associations are Poplarsetum – Rubiosum, Poplarsetum – Rubiosum, Poplarsetum - Carexosum, Salicesetum - Carexosum.

3.2.5. The ravine-dry valleys NTC. The ravine-dry valleys NTC, that filled with sandy loamy-loamy proluvium, is characterized by sodding of the slopes and the development of NTC of dry fescue-white wormwood steppe on light chestnut saline loamy soils. The herbaceous cover is characterized by the presence of the following species: Agropyron pectiniforme L., Stipa capillata L., Bromus tectorum L., Achillea leptophylla Kotschy, i.e. the facies of the bottoms of erosional systems are identical to facies on the gully watersheds, which are located within the boundaries of the second above-floodplain terrace and overlap with cover loam.

4. Conclusions

4.1. The analyzed natural-territorial complexes of the Middle Don are represented by two types of terrain: floodplain and above floodplain-terraced
They are distinguished by the absolute height marks, the flood regime, soil and vegetation conditions, and location of the groundwater table. The local climate determines the development of valley complexes in the temperate arid climate of the southern European steppes. They are characterized by mosaics, the presence of endemic species, a combination of vegetation formations of the steppe, floodplain meadows and forest, evolving in paragenetic unity.

4.2. For the first time, geographical ideas about regional features and the landscape structure of the Middle Don valley are formulated

It was found, that floodplain NTCs are characterized by the development of tracts within the boundaries of the near-channel, central and near-terrace floodplains. Spatial structure is characterized by a linear and consistent change from the riverbed to the terraces above the natural complexes: riparian forest of the riparian floodplain – hygro- and mesophyte meadows of the Central part, differ in the duration of flooding – steppe meadows of the above-floodplain terrace. For the Don floodplain forests, the predominance of sedge, white-field, and aspen forests is noted. In the near-channel parts of the Don floodplain, shrub formations are formed by different types of willows. The hygrophytic meadows of the central floodplain, developed in wet depressions, are represented by the meadows of *Beckmannia eruciformis*, *Phalaris arundinacea* and species of the genus *Carex* sp. The features of the Don floodplain are the predominance of old-age sedge forests, the species diversity of fox-tailed, non-stemmed, bluegrass mesophytic meadows prevailing in the central floodplain, and at the same time the limited distribution of oak forests, which makes the latter unique natural communities. The landscape structure of the coasts of floodplain lakes is also very interesting, represented by a combination of hygrophytic meadows, sedge-mixed grass, reed, cattail, reed with thickets of willows, alders, black poplar.

4.3. The terrace-near-floodplain is characterized by more significant indicators of absolute heights, as well as an admixture of steppe species in meadow formations

The predominant meadows with *Festuca valesiaca*, *Agropyron pectiniforme*, *Elytrigia repens* with elements of steppe grasses.

4.4. The main landscape structure of the above-floodplain terraces is formed by the extrazonal NTCs of the psammophytic steppe

The above-floodplain terraces are characterized by a variegated texture of sediments, which varies from loamy on the second above-floodplain terrace to sandy on the third terrace (Golubinskie sands). This determines the development of the upper groundwater table, the formation of the soil profile, the appearance of the endemcity of the plant world. The main landscape background is formed by the extrazonal NTCs of the psammophytic grass-cereals-wormwood sparse steppe, which alternate with relic tracts of birch-aspen outliers and oak forests in deflationary basins.

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