Ecological-hydrological aspects of the delta Volga meadow vegetation dynamics

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Abstract. Many years ecological monitoring results of the Volga delta meadow plant cover are presented in this work. Temperature conditions and territory humidity conditions were distinguished as leading ecological factors. Geographical methods and mathematical statistics methods were used as analysis tools. It was revealed that watersoluble salts amount sharp increase in soils, also their toxicity level and soil salinization type change from chloride-sulfate to sulfate-chloride under aridization degree rapid increase, that influences on plant cover: biomass decrease, foliage cover degree decrease on all deltoid landscape high levels, carexes and gramens participation degree decrease and forbs role increase is noticed. Such processes are blocked and go to the reverse stage under the following sharp water availability conditions increase. The greatest and more rapid changes are observed within special alluvial low level natural boundaries. The main forecast of the Volga delta climate development can be considered general average temperature and air humidity increase with abnormal humid amount increase and abnormal dry years amount decrease.

1. Introduction

Rivers deltas having rich water, soil, biological and other resources, are unique geographical objects, actively involved by the people in the process of ecosystem exploitation. Nowadays the land area of the world deltoid landscapes is 3% from the total dry land area, however natural-territory complexes ecological-economic meaning of such type is enormous [1]. Ecological-hydrological factors influence assessment on the meaningful component of the Volga deltoid landscape – meadow vegetation were made in the present work taking into account high deltoid territory involvement degree into the agriculture and these field importance for sustainable development concept realization.

Deltas can be considered as environment different scales changes indicators and used as model study objects of natural and anthropogenous influence cause-effect relations on such types landscape dynamics. Deltoid landscapes structure understanding and study, revealing interrelations and response reactions of their structural components on environment factors influence can help to reveal functioning regime and landscape dynamics as a whole, make a forecast of its development, give scientific credence of optimal ecosystem exploitation types, protective measures complex development and organize effective management system [2, 3].

2. Materials and Methods

The Volga delta plant cover monitoring was led on 126 points of stationary profile with the size 2×2 and with the purpose of more representative measure of arising changes - on 11 stationary profiles
with area 400 m² situated in the central parts of the islands in delta eastern part, where hydrological regime and plant cover anthropogenous changes expressed in low degree, than in its western part. Vegetation investigation were made according to the common methods. Grassland vegetation classification was conducted in accordance with the J. Braun Blanquet principles aspects, wealth of plants in the fields were defined in the percent of projective cover, with following conversion into points: + < 1%; 1 – 1-5%; 2 – 6-15%; 3 – 16-25%; 4 – 26-50%; 5 > 50%. Higher plants name we give them according to their list «Flora Europaea» [1].

Materials for temperature conditions analysis, quantity and precipitation dynamics and Volga hydrological regimen were data received in Astrakhan center of hydrometeorology and environment monitoring. Mathematical statistics and selection analysis were used when analyzing dynamics. De Martone aridity index, Vysotsky-Ivanov humidity coefficient, standard precipitation index and hydrothermal coefficient according to G.T. Selyaninov, which allowed to reveal territory humidity dynamics as in many years perspective, so vegetation period [4-6].

Territory humidity general trend was defined with the help of many years dynamics calculation of standard precipitation index, that allowed to reveal abnormal amount of dry and humid years dynamics. Index value for separate years were set in the table and colors were assigned to the table cell according to the gradation from red (strong drought) till blue (strong humidity) [6].

3. Results and their Discussion
Modern the Volga delta us a huge water-accumulated plain of the North Pre-Caspian, belong to the water-swamp lands of international meaning, which are under Ramsar convention protection, and have an important environmental forming meaning for the whole this region territory. Nowadays, significant deltoid ecosystem reformation occurs in relation to the climate conditions changes, human economic activity area, mainly, the Volga hydrological regime which is subjected to anthropogenous regulation, that negatively influences on the region social-economical development [3, 7].

3.1. Climate changes
Timeliness and importance of the climate changes are presented in some documents and scientific publications [8-14].

In European part of Russia only semiarid and arid territories of Pre-Caspian lowland, within which the Volga delta intrazonal landscape is located, are characterized by typical arid and continental climate [15].

Fixed many years air temperature changes in the side of its growth in the North-West Pre-Caspian arid conditions define evaporation increase with the daylight surface and territory humidity decrease, that threats to the ecotones of water-ground type existence. Due to this fact, precipitation regime updating is very important aspect, significance of which for this territory type very huge, together with the temperature regime investigations [1].

Average annual air temperature on the Volga delta territory is 10°C, January average temperature is -5…-9°C, July +24…+25°C. Active temperatures sum in average is 3600-3800°. Total radiation is kcal/cm², sunshine duration is till 2400 h/yr, warm period duration is 250 days. Precipitation amount is 180-00 mm per year, fall mainly in warm period. Significant humidity deficit is formed under general year evaporation 1177mm [3, 7].

Data conducted analysis showed that precipitation amount variability in different years is approximately 30%, while temperature regime is characterized by large annual stability and its variability is approximately 10%. More variability of monthly average precipitations and temperatures is observed in warm year months, corresponding to the vegetation period (figure 1).
SPI values analysis let us make a conclusion that on the Volga delta territory small percent of years belong to the periods of relative drought (negative index values), at the same time large years amount is observed in relatively humid years (positive index values) (table 1). These values pointed at the precipitation variability gravity to the side of their large amount relatively average, as far as precipitation amount have a key meaning on the total humidity, then we can speak about large amount of relatively humid years.

**Table 1. Standardized Precipitation Index (SPI) Values.**

| Year | Value | Year | Value | Year | Value | Year | Value | Year | Value |
|------|-------|------|-------|------|-------|------|-------|------|-------|
| 1922 | 0.90  | 1942 | -0.33 | 1962 | -1.34 | 1982 | 1.15  | 2002 | 0.20  |
| 1923 | 0.62  | 1943 | -0.06 | 1963 | 0.92  | 1983 | 0.90  | 2003 | 0.73  |
| 1924 | -0.35 | 1944 | -0.46 | 1964 | 0.29  | 1984 | -0.51 | 2004 | 0.76  |
| 1925 | 0.89  | 1945 | 0.58  | 1965 | 0.68  | 1985 | 0.79  | 2005 | 0.84  |
| 1926 | 0.65  | 1946 | 0.51  | 1966 | 1.18  | 1986 | -0.27 | 2006 | 0.76  |
| 1927 | 0.36  | 1947 | 0.31  | 1967 | 0.89  | 1987 | 0.96  | 2007 | 0.56  |
| 1928 | 1.07  | 1948 | 0.38  | 1968 | -0.19 | 1988 | -0.64 | 2008 | 0.11  |
| 1929 | -0.24 | 1949 | -0.21 | 1969 | 0.51  | 1989 | 1.38  | 2009 | 1.11  |
| 1930 | 0.27  | 1950 | 0.12  | 1970 | -0.24 | 1990 | 0.90  | 2010 | 0.68  |
| 1931 | 0.52  | 1951 | -0.24 | 1971 | 0.94  | 1991 | 0.92  | 2011 | 1.52  |
| 1932 | 0.47  | 1952 | 0.17  | 1972 | -1.15 | 1992 | 1.79  | 2012 | 0.64  |
| 1933 | 1.34  | 1953 | 1.01  | 1973 | 1.01  | 1993 | 1.27  | 2013 | 0.77  |
| 1934 | -0.92 | 1954 | 0.55  | 1974 | 0.06  | 1994 | 0.51  | 2014 | 0.32  |
| 1935 | -0.37 | 1955 | -0.26 | 1975 | 0.19  | 1995 | -0.07 | 2015 | 0.39  |
| 1936 | -0.29 | 1956 | 0.31  | 1976 | -0.01 | 1996 | 1.02  | 2016 | 2.02  |
| 1937 | 0.46  | 1957 | 0.88  | 1977 | 0.24  | 1997 | 1.08  | 2017 | 0.44  |
| 1938 | -0.14 | 1958 | 0.76  | 1978 | 1.45  | 1998 | 1.25  | 2018 | -0.37 |
| 1939 | 0.27  | 1959 | -0.99 | 1979 | 0.52  | 1999 | 1.62  | 2019 | 0.21  |
| 1940 | 0.61  | 1960 | 0.89  | 1980 | 0.47  | 2000 | 0.17  |       |       |
| 1941 | 0.54  | 1961 | 0.27  | 1981 | 0.12  | 2001 | 1.09  |       |       |

Clear trend on relatively humid years increase is observed in the period after 1970, that show existent trend on the total humid territory increase by the effect of precipitation amount. The large...
amount of abnormal dry years is observed in the period of 1922 till 1972, as far as almost abnormal humid years are on the time line since 1973 till 2019. These data show that despite of the linear trend unreliability on the total precipitation amount increase, there is a tendency on abnormal humid years amount increase. We can make a conclusion about existent tendency of climate transition to more warm and humid together with existent trend on average air temperature increase.

3.2. Hydrological changes
Anthropogenous transformations can lead to significant irreversible consequences for deltoid landscapes, their natural-resource potential loss, ecosystem biodiversity decrease etc, affected by observed sweeping climate changes nowadays.
Especially, huge hydrotechnical and water-related activities, carried out in many river systems in XIX-XX, directed on electricity generation and overflowing risk decrease of separate territories, led to serious rivers regime transformations, that led to some negative consequences for river landscapes.

Table 2. Hydrometeorological values according to Astrakhan hydrometeorological station by periods.

| Years    | Average annual air temperature, °C | Average temperature amount for the period with the temperature>10°C | Precipitation average annual amount, мм | Precipitation amount for the period with the temperature>10°C | Spring-summer floods volume |
|----------|-----------------------------------|------------------------------------------------------------------|----------------------------------------|---------------------------------------------------------------|-----------------------------|
| 1972-1981| 10                                | 3601                                                             | 189                                    | 118                                                          | 92                          |
| 1982-1991| 10,2                              | 3714                                                             | 222                                    | 128                                                          | 109                         |
| 1992-2001| 10,3                              | 3612                                                             | 259                                    | 168                                                          | 117                         |
| 2002-2011| 10,8                              | 3886                                                             | 232                                    | 114                                                          | 100                         |
| 2012-2019| 10,8                              | 3862                                                             | 242                                    | 153                                                          | 100                         |

The Volga differs with high water content, which is increased as a result of intermediate inflow from headwater to entry. Average annual volume of the river aqueous runoff in Volgograd hydroelectric power station section is 259 km$^3$, such value decreases till 253 km$^3$ when influx in the Caspian. Water entrance dynamics in the Volga delta is characterized by low stream flow periods (as a rule, in July-March) and spring-summer flood periods (April-June) [1, 3].
Aqueous runoff average annual volumes directional growth for the second quarter was observed from the beginning of monitoring investigations (1978) till the mid of 1990. Part of the spring-summer floods from annual run off in this period was in general approximately 50% (table 2).
Floods in this time period began at the same time that under natural aqueous runoff, but the water rise speed under the mid level meadow overflowing was increased. Also the floods duration and meadow overflowing probability was increased on 5-10 days. If the water fall from the meadows of mid level to the mid of June in the period of 1960-1973, that such meadows were free from water to the end of June in the periods of 1974-1982 and 1983-1999.
Directional decrease as spring-summer floods volumes so their part from annual aqueous run off is observed on the following time line. Average run off volume for the II quarter was 93 km$^3$ for the last investigations period (2012-2019).
Important influence on deltoid landscape ecosystem has not only floods volume, but flood zone and time limits of different level natural boundaries search under the water. Hypsometric topographic low are flooded first of all at the beginning of the high water rise phase, after water storage there is a overtop in them and deltoid territories flooding begins in the central part of the islands, not having direct connection with the river bed.
3.3. Vegetation dynamics

Many years investigations, carried out on 126 model platforms of stationary profile allows to define general vegetation dynamics tendencies.

Increase in phytocoenosis vegetation cover belonged to the group *Phragmitetea* and *Bolboschoenetea* *maritime* in the monitoring beginning period till the beginning of 2000 connected with the Volga delta water cut growth. Volume increase and spring-summer floods duration together with the atmospheric precipitation growth at this period led to watersoluble salts content decrease in soils, that influences on rapid participation decrease in grass stand of vegetation group *Cripsidetea aculeate* salt tolerant types.

Positive aspect for plants groups *Phragmitetea* and *Glycyrrhizetae glabrae* is mowing specific features succession in the Volga delta: cuts are carried out selectively nowadays, before the whole investigated area was mowed down. Nevertheless, water rise level growth for the II quarter and spring-summer floods duration increase in the period till 2005 made possible ground waters level rise, that is favorable factor for vegetation development of these groups.

Aridization process development is observed in the Volga estuarine natural system in 2006-2015, due to the fact of average annual air temperatures growth, atmospheric precipitations amount decrease and aqueous run off for the II quarter reduction. Hydrometeorological changes data influenced on decrease and stabilization of hygrophilous phytocoenosis presence on investigated territory, belonging to the groups *Phragmitetea* and *Bolboschoenetea* *maritime*. Abrupt decrease of *Phragmitetea* group representation happened as a result of directional plants types decrease, belonging to the *Sparganio erecti-Typhetum angustifoliae* association, which was considered as dominant before. Very low floods of 2014 and 2015 led to full this association fall out from grass stand [1].

We consider occurring changes more detailed on the example of stationary area №2. Stationary area №2 (botanic natural monument «Spike rush-quackgrass meadow (Yablonsky)»), vegetation community belong to the ass. *Bolboschoeno-Glycyrrhizetum echinatae* Golub et Mirkin 1986. The area is situated in 3.7 km to the east of Yablonka village within cultural/plain natural boundaries of mid level on the plain meadow with the height under normal water level 1.6 m. Area flooding duration fluctuated from 23 till 84 days in the investigated years.

The greatest top of the grassland reaches on the area under the ecotope flooding during one month period, fluctuation changes in the vegetation composition occurs during flooding duration increase, that first of all refer to gramens, which fall out from the grass stand (figure 2).

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**Figure 2.** Vegetation tops values dynamics on stationary area №2.
Carex representation group increase occurred for the investigated period. (*Bolboschoenus maritimus, Carex riparia, Eleocharis palustris*).

*Typha angustifolia* participation abruptly increased to 1996, connected with the further territory water cut regime increase, water level increase in flows and ground waters rise, also mowing finishing on the area.

Gramens content significantly increased to 2016, mainly, by means of *Phragmites australis* types, returning to the values of 1982-1983, continuous and high flood of 2016 (127 km$^3$) influenced on *Carex representation* group increase (*Scirpus lacustris, Carex melanostachya*), which become dominant. Mixed herbs decreased abruptly, that is connected with the dieaway in shortage of water 2014-2015 which were dominant earlier on the area group *Typha angustifolia*.

4. Conclusion

Climate conditions different scales changes, observed nowadays practically in all our planet’s regions influence landscape dynamics, plant and wildlife state, can lead to the potential loss and ecosystem diversity and become significant threat for the people prosperity and territory sustainable development.

The results of many years ecological monitoring in the Volga delta point out that leading factors as directly so mediately (through soil cover humidity, its saturation with oxygen and soluble mineral substances, soil sanilization type change and its toxicity degree, ground water depth etc) are amount and duration of spring-summer floods in conjunction with precipitation amount for vegetation period under complex influence of human economic activity and its intensity, defining the Volga delta meadow vegetation dynamics direction, biomass values, general projective cover.

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