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LAND RECLAMATION AND TRANSFORMATION OF FLOODPLAIN-CHANNEL COMPLEXES AT THE MIDDLE AMUR LOWLAND

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Due to the specifics of climate, geology and relief of the Russian Far East, extensive land reclamation has been carried out in this region for more than sixty years in order to create the necessary conditions for agricultural production. The purpose of this land reclamation is heavy soils drainage in Primorye and the Amur Region. An extensive network of reclamation systems of open and closed types was created. This paper presents the results of studying the effect of land reclamation on floodplain-channel complexes (FCC) of the Middle Amur Lowland. It was found that construction and subsequent operation of reclamation systems (water receivers, main canals, regulating dehumidifiers) led to general degradation of FCC with full cessation in development of channel and riverine forms at micro- and meso- relief, and their complete silting. The concentration and seasonal dynamics of heavy metals in the soils of meliorated lands, in bottom sediments and water of small rivers and main canals at FCC was estimated. The content of heavy metals in the soils of meliorated lands' decreased in comparison with unaffected environment. At the same time, accumulation of heavy metals took place in the waters and bottom sediments of main canals and water receivers. In addition, the paper presents data on the impact of catastrophic and unfavorable hydrological phenomena (floods, freshets) on the dynamics and state of agrocenoses within the boundaries of FCC.

***Keywords**: floodplain-channel complex, land reclamation, heavy metals, Middle Amur Lowland.*

Introduction

Specific features of natural conditions at the Middle Amur Lowland have determined intensive processes of swamping and over-moistening [1, 4, 8]. Land reclamation has been carried out in this region for more than sixty years in order to create the necessary conditions for agricultural production. A significant part of river basins at the Middle Amur Lowland has been transformed to varying degrees by the reclamation network. The land reclamation systems are represented by water receivers, main canals and drainage grooves. Water receivers are natural watercourses, mainly rivers; less often they are depressions in the relief that do not have a runoff.

Land reclamation as a complex of organizational, economic and technical measures has been widely developed within floodplain-channel complexes (FCC) of the Middle Amur Lowland [5]. FCC is very dynamic and, at the same time, vulnerable natural system that consists of river channels and floodplains as main elements [3]. Man-made impact on some parts of floodplain or riverbed causes a whole chain of processes that substantially alter the components of these geosystems. The purpose of the current study is to assess the effect of land reclamation on the state and dynamics of floodplain-channel complexes at the Middle Amur Lowland.

Historical Reference

The development of land reclamation in the Middle Amur Lowland dates back to the beginning of the 20th century. Studies conducted in 1926 showed that the vast majority of swamped areas could be used for agricultural purposes only after land reclamation. The construction of reclamation channels was carried out with the help of “Sudanese ditch digger”, graders and manual rework. Steam coal operating excavators were used in the construction of canals with a depth of more than 1.5 m. At that time there was one excavator station in Birobidzhan, in which there were 10-15 excavators. By 1938, 5 reclamation systems had been completely drained and commissioned for settlers.

In the early 50-ies of the XX century reclamation stations began to be founded. All expenses for research and design of land reclamation work were covered by the state budget.

Along with construction reclamation divisions, repair and maintenance water management organizations were founded and developed. By 1980, the land reclamation department had a network of repair organizations and production facilities throughout the Middle Amur Lowland. Land reclamation continued in the 70s of XX century at the highest rates. By the mid 80s, the technology of land reclamation included the trenchless laying of polyethylene pipes, with the

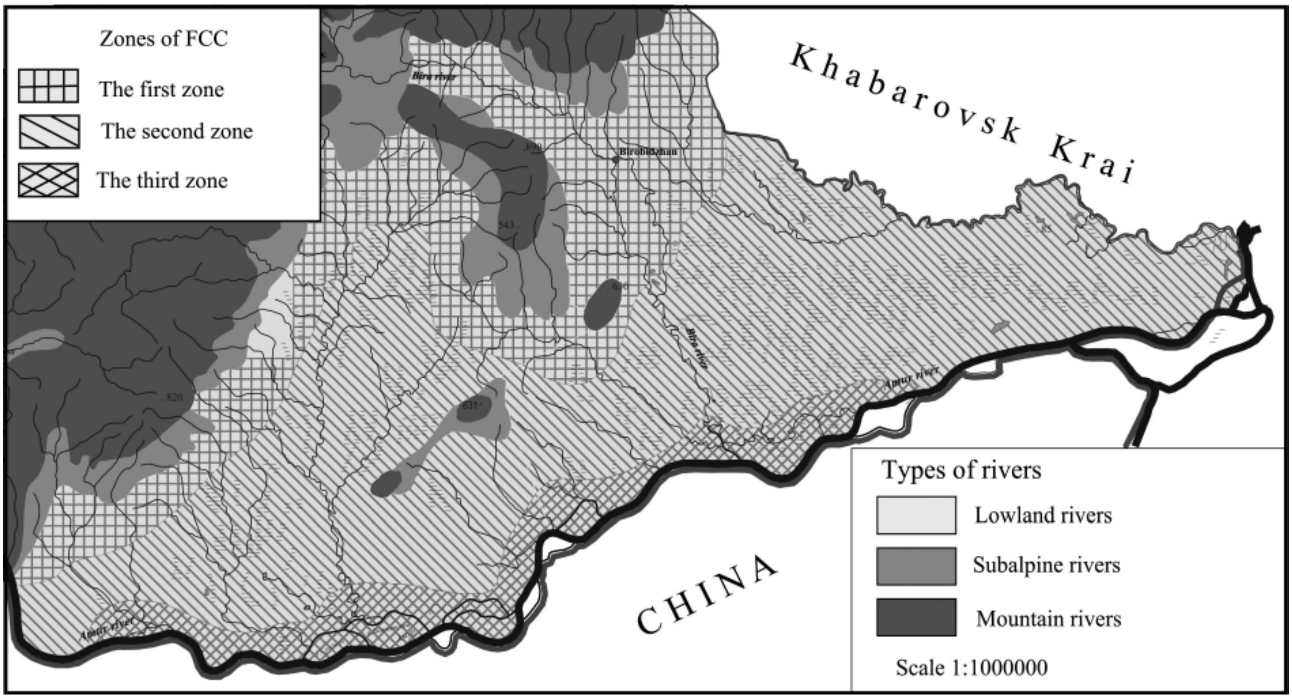

Figure. Zones with characteristic types of FCC at the Middle Amur Lowland [2, 9]

help of which more than 1000 km of drainage channels were laid.

Thus, reclamation measures significantly increased the efficiency of agricultural production in the territory of the Middle Amur Lowland and reducing its dependence on weather conditions. On the other hand, these measures led to the transformation of natural floodplain-channel complexes and determined new vectors for their development and dynamics.

Characteristics of the study area

Most rivers of the Middle Amur Lowland have a length of more than 30 km, characterized by small inclines with an average altitude difference of 45-50 m. The main river flow is directed from the northwest to the southeast. The overall pattern of the river network is feather-like with sections of radial rivers in areas of rock pillars. The river valleys are poorly expressed in the relief, the watersheds are indistinct and the catchments are waterlogged on vast areas.

The study area has monsoon climate of temperate latitudes, largely determined by the annual cycle of changes in the temperature gradient between the ocean and the continent, the prevailing wind direction and the pronounced annual maximum precipitation in summer months. The average annual precipitation is about 600 mm; about 10% of the total amount precipitates in winter and up to 90% – during a warm period [6].

The river water supply is mostly pluvial, accounting for up to 70% of the runoff. The following phases of hydrological regime are identified: spring flood, summer and autumn freshet and winter low water; summer low water usually does not occur.

The formation of spring floods is due to winter snow and precipitation in the form of rain and wet snow. The duration of spring floods is up to 15 days on small rivers and up to 30 days on large and medium rivers.

The second most significant phase of water regime of rivers in the study area is rain floods – single or multi-peak water increase, separated by periods with relatively low levels lasting up to 10 days. The average amount of runoff during the flooding period exceeds 60% of its annual values.

Winter low water is the longest and at the same time low-water phase of the water regime. It is usually observed from November, the moment of freeze-up formation, till April. During this period, small rivers freeze to the bottom, medium and large rivers are characterized by a stable level and a minimum runoff during the year. Debacle occurs almost simultaneously throughout the lowland at the end of the second – the beginning of the third decade of April.

Due to natural conditions, morphodynamic types of river beds and geomorphological types of floodplains, three zones with characteristic types of FCC are detected [2, 9] (Figure).

The first zone is FCC of rectilinear channels of the foothills with predominance of bilateral marshy floodplain composed of pebble-sandy alluvium and distributed fragmentarily, which is characteristic for fairly large rivers (tributaries of the Amur River). Their valleys are box-shaped and are well expressed in relief. Their bottoms are flat and swampy, while the sides are flat and have soft outlines. The mean river fall is 25-60 m per 30 km. Floodplain is swampy and has meadow nature. Sandy and sandy-pebbly soils predominate; loamy, clayey and peat deposits prevail in depressions.

The second zone is FCC of meandering channels with sandy alluvium, developing in loose rocks and with predominantly segmental bar plain. It occupies most of the Middle Amur Lowland. The valleys are poorly expressed in the relief. The watersheds rise above the surrounding territory by 6-8 m, maximum by 12 m. Leveled surfaces with small differences in altitude predominate in river valleys. Elements of river valleys are poorly differentiated, except for FCC. The significant part of river basin is swamped or waterlogged. Mean river fall is 12-15 m per 60-80 km; riverbeds tend to meander. A low floodplain with lot lakes, dry channels of temporary streams and erosion gullies is well expressed.

The third zone is floodplain-channel complexes of braided, spreading channels, composed of fine- and medium-grained sandy alluvium, that develop in loose sediments. These complexes are characterized by a bar-island floodplain. They are common along the left bank of the river Amur, mainly in the lower reaches of large rivers crossing the Middle Amur lowland. These rivers as a rule have gently sloping banks, formed by accumulative sand deposits in the form of extensive shoals. Bends of wide channels are irregular in shape.

Method and Materials

Small rivers at the Middle Amur Lowland, remote from man-made pollution (mining and forest industries and populated localities), which serve as water drains from reclamation systems are investigated (Table). The main approach used is the method of hydrological analogy proposed by V.G. Glushkov and developed by the Soviet hydrologists [3]. The main idea is selection and comparison of the transformed river and non-transformed river (where catchment and floodplain-channel complexes are not affected by agricultural activity).

Field data during period from 2005 to 2017 include hydrological, morphological, morphometric characteristics of FCC; 600 spot samples of water (250), soil (175) and bottom sediments (175); maps, statistical and fund data from ICARP FEB RAS are used.

Analytical equipment exploited was: atomic absorption spectrometer "Thermo Solaar 6M"; the system of microwave decomposition of samples "MARS 6"; spectrophotometer "Shimadzu UV-1800"; planetary monofilament "Pulverisette 6"; water-distiller "DE-4 (TZMOI)"; the vacuum filtering device "PVF - 47/3 N B (PP)"; pH meter "Hanna 211"; laboratory portable ionomer "ANION-4101".

Results and Discussion

Results of the fild visual observations

The fild visual observations demonstrate that in natural conditions the lowland rivers of the Middle Amur Region are characterized by continuous erosion pavement, composed of small and medium well-rounded pebbles, filled with sand of various granularities. Coastal slopes are well expressed. Convex banks are composed of sandy sediments. Concave banks are usually steep and well fixed with vegetation.

Sandy loam and silt-clay deposits, which are up to half a meter in thickness, predominate in the composition of channels of river-water receivers. The banks are marshy, clayey, especially at the confluence of main land reclamation canals, with typical inten-

Table

Characteristics of small rivers affected by land reclamation at the Middle Amur Lowland

River	River length, km	River basin, km^2	Floodplain soil types	Reclamation area, ha (% of basin area)	Length of land reclamation canal, km
Ul'dura	15	160	Podzolic brownified clay and loam	1429 (20)	99
Gryaznushka	32	191		3139 (55)	224
Solonechnaya	52	484	Meadow clay	536 (40)	423
Vertoprashikha	42	281		3942 (30)	272
Osinovka	56	530		9854 (30)	450

sive vegetation in river beds. In the lower reaches of rivers, whose basins area has been changed by more than 35–40%, there is a large amount of undecomposed organic material with a thickness of up to 25 cm in the channels.

Beds of rivers, in the basin of which reclamation works were carried out, acquire smoothed outlines. Elements of floodplain-channel relief are practically not differentiated. In the areas of confluence of tributaries or main canals, extended shallows of irregular shape are formed. The beach is hummocky and strongly waterlogged. At the same time, a trough-like riverbed is characteristic for watercourses flowing in natural conditions. This riverbed has relatively uniform distribution of depths along the width and developed riverbed relief – from ridges and riffles to reach-shoal systems.

When the river basin is changed by more than 45–50% due to reclamation measures, the channel ceases to exist as a single linearly extended negative form of the relief. It is replaced by a system of small elongated reservoirs, which have an oval shape and are united in a single stream only during periods of increased water content (summer-autumn floods).

Field observation data and comparison of terrain plans shows that in river FCC within the reclamation systems and downstream, the horizontal deformation of channels is drastically reduced or almost completely stopped. Thus, under natural conditions during the summer-autumn floods within the bends of rivers an intensive blurring of the concave bank (up to 4.3 m/year) and the development of rectifying ducts (up to 1.2 m/year) are observed. In channels with a developed system of tributaries in the form of land reclamation channels there is only coastal encroachment without visible destruction.

As a whole, land reclamation within the FCC and catchment areas changes significantly the migration of pollutants through soil horizons and their removal to rivers [9].

Results of the spot samples of water, soil and bottom sediments analysis

The results show in spring the concentration of heavy metals in river water reaches: Fe – 2.6 mg dm^3, Mn – 0.9 mg dm^{-3}, Cu – 0.03 mg dm^{-3}, Pb – 0.15 mg dm^{-3}, Zn – 0.03 mg dm^{-3}. By the winter low water the content of water-soluble forms of heavy metals increases depending on the floodplain state. For example, in dry floodplains Fe, Mn, Cu and Pb concentration increases by 1.5-2.5 times; in flooded riverbeds Fe and Mn concentration decreases by 2.5 times, Pb and Zn concentration increases by 1.5 times.

The content of heavy metals in soils of the main land reclamation canals is always higher than in the natural background, but is less than in drainage water.

Water chemical composition in the rivers, draining through reclamation systems, during seasonal water level elevation is effected by increased washout of solid metals from floodplain soils and reducuction of their concentration due to dilution. During floods, the decrease of solid Fe (by 2–4 times), Mn (by 2–90 times) and Zn (by 2 times) in river waters has been recorded; no change in Cu, Ni, and Co have been detected; in some cases Pb accumulation has taken place.

When the water fills the floodplain in the areas of reclamation systems during floods, the amount of suspended matter increases up to 3.5 times in comparison with the background. At the same time, in accordance with requirements for composition and properties of water for drinking-water facilities the concentration of suspended solids should not increase by more than 0.25 mg dm^{-3} in compare with the background.

The concentration of total organic carbon in background spots is 3.5–8.43 mgC dm^{-3}; in rivers with a developed network of reclamation channels its concentration is approximately 1.5 times higher. Organic carbon is mainly encountered in a dissolved form – from 2 to 10 mgC dm^{-3} (92%) and marginally in the form of suspended particles (less than 1 mg C dm^{-3}). Water-soluble organic substances are represented by 60% of humic and fulvic acids; their content in river basins with reclamation systems is approximately 1.5 times higher than in background ones. The concentration of fulvic acids exceeds the humic content by approximately 10 times.

Complex analysis of heavy metals content in the system "floodplain soil – water – bottom sediments" showed the moderate influence of land reclamation in FCC of rivers, whose basins have been transformed to about 15%. In these complexes the content of heavy metals, biogenic and organic substances increases (rarely above the maximum allowable concentrations). There is a slight decrease in the oxygen content and in the rate of the river water flow; surface waters are capable for self-cleaning. The greatest influence of land reclamation is manifested in river basins, which have been changed by reclamation by 20% or more. Heavy metals are intensively removed from the soil, washed away into the surface water with suspended organic material, subsequently sedimenting at the bottom. The above leads to general degradation and swamping of river valleys; their further restoration requires human intervention.

Conclusion

Development of meliorative systems in river basins of the Middle Amur Lowland leads to significant transformation of floodplain-channel complexes, their degradation and simplification, with a cease in forming of micro-, meso- and macro relief. Drainage water discharges from a drained massif through reclamation system, and changes the chemical composition of surface waters in small rivers. The discharged waters are characterized by approximately 2-fold excess of hydrogen index, ammonium nitrogen and chlorides in comparison with the natural environment. Intensive migration (removal) of suspended and organic substances, especially fulvic acids into surface water increases geochemical mobility of heavy metals and lead to worsening of water hydrochemical characteristics.

FCC in small rivers with basins drained by less than 15%, retains the ability for self-cleaning and self-recovery. When the basin is drained by more than 20%, intensive migration (removal) of heavy metals, biogenic and organic substances takes place, leading to degradation of floodplain-channel complexes, the further restoration of which requires anthropogenic interference.

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