The assessment of the Hukiv basin rivers' (Ukraine) stability level and ecological stress

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Introduction

The Hukiv River is a small river (Figure 1). The current state of the ecological balance of small rivers is largely determined by the degree of riverbed change by economic activity both in the river itself and in its catchment area. The main riverbed changes refer to siltation associated with a significant increase of the washout volume from the catchment area. The maximum ploughing level, which does not lead to the disruption of the normal functioning of the river ecosystem, is 20–30% of the total catchment area.
The upper catchment of the Hukiv River is not ploughed, but in the middle and lower parts the ploughing degree reaches 64%. The latter contributes to the amount of the deposit volume in the Hukiv riverbed that the river is unable to transport and, as a result, an intensive accumulation of sediments in different parts occurs.
The stability of the riverbed is an integral indicator of the riverbed conditions, the development of morphodynamical types, and the intensity of channel deformations. Stability is determined by the ratio of the size of channel-forming sediments and the flow speed. The latter is associated with the mobility of sediments, forming the channel, and the degree of its transformation in the process of interaction with the flow.

Figure 1 The Hukiv river basin.

Results

The vulnerability of riverbeds (potential ecological stress) to anthropogenic activity and adverse natural factors in the years of 2005–2021 based on the calculation of the Lokhtin number (1) and the Maccaveev stability coefficient (2) for the rivers of the Hukiv basin are assesed.

$$L = \frac{d}{I}, (1)$$

where d – average diameter of the channel sediment products in the riverbed part, mm;

I – river slope, ‰.

$$Cs = 1000\frac{d}{BI}, \quad (2)$$

where *d* – average diameter of the channel sediment products in the riverbed part, mm;
B – channel width in the low water period, mm;
I – river slope, ‰.

Table 1. Main channel features in Hukiv River basin. Average values of the stability level, the river flow turbulence level, and the channel flatness in the winter low water period (2005–2021)

№	№ of the observation site	Width (m)	Depth (m)	Speed (m/s)	Diameter of bed deposit (mm)	Water discharge (m^3/s)	River slope (‰)	The Lokhtin number	The stability level according to the	The Maccaveev number	The stability level according to the	The Froude number	The Grishanin criterion	The river channel flatness
1	3	The channel is mostly ice-covered in the section area												
2	2	2,9	0,3	0,26	300	0,226	4,13	72,6		25034		0,023	1,44	9,7
3	1	2	0,1	0,52	80	0,104	4,03	19,9		9950		0,28	0,66	20
4	4	1	0,1	0,35	60	0,035	5,68	10,6		10600		0,13	0.93	10
5	5	3,2	0,5	0,12	0,01	0,192	4,03	0,002		0,62		0,003	0,43	6,4
6	6	2	0,08	0,24	60	0,038	4,03	14,9		7450		0,074	0,84	25
7	7	2	0,42	0,24	0,01	0,202	4,03	0,002		1,0		0,014	1,96	4,8
8	8	4	0,45	0,15	50	0,27	4,03	12,4		3100		0,005	2,17	8,9
9	9	2,5	0,2	0,65	50	0,325	4,03	12,4		4960		0,22	0,78	12,5
10	10	1,2	0,1	0,25	60	0,03	13,9	4,3		3583		0,064	1,09	12
11	11	2,6	0,25	0,24	0,001	0,156	2,55	0,0004		0,15		0,024	1,44	10,4
12	12	3,2	0,5	0,16	50	0,256	2,55	19,6		6125		0,005	2,32	6,4
13	13	2	0.35	0,41	0,35	0,287	4,3	0,08		40		0,049	1,36	5,7
14	14	2,5	0,28	0,25	0,001	0,175	2,27	0,0004		0,16		0,023	1,48	8,9
15	15	2,8	0,2	0,26	0,001	0,146	2,45	0,0004		0,14		0,034	1,21	14
16	16	2	0,2	0,23	0,001	0,092	4,55	0,0002		0,1		0,027	1,39	10

Unstable	
Low stable	
Stable	
Absolutely stable	

Table 2. Main channel features in Hukiv River basin. Average values of the stability level, the river flow turbulence level, and the channel flatness in the spring flood period (2005–2021)

№ п/п	№ of the observation site	Width (m)	Depth (m)	Speed (m/s)	Diameter of the bed deposit (mm)	Discharge (m^3/s)	River slope (‰)	The Lokhtin number	The stability level according to the	The Maccaveev number	The stability level according to the	The Froude number	The Grishanin parameter	The river channel flatness
1	3	8	1,7	0,48	0,005	13,6	3,9	0,0013		0,16		0,014	1,37	4,7
2	2	10	2	0,2	0,01	4	4,13	0,24		24		0,002	3,15	3,8
3	1	8	2,1	0,64	0,001	10,75	4,03	0,0002		0,025		0,02	1,91	5,0
4	4	2	0,4	0,41	0,001	0,33	5,68	0,0002		0,1		0,043	1,48	5,0
5	5	4	1,2	0,64	0,001	3,1	4,03	0,0002		0,05		0,035	1,71	3,3
6	6	3,5	1,1	0,51	0,001	1,96	4,03	0,0002		0,06		0,024	1,9	3,2
7	7	6	1,2	0,5	0,001	3,6	4,03	0,0002		0,03		0,021	1,75	5,0
8	8	3	1,3	0,88	0,005	9,1	4,03	0,001		0,33		0,06	1,00	2,3
9	9	5	1,2	1,06	0,01	6,36	4,03	0,002		0,4		0,1	1,26	4,2

№ п/п	№ of the observation site	Width (m)	Depth (m)	Speed (m/s)	Diameter of the bed deposit (mm)	Discharge (m^3/s)	River slope (‰)	The Lokhtin number	The stability level according to the	The Maccaveev number	The stability level according to the	The Froude number	The Grishanin parameter	The river channel flatness
10	10	1,5	0,4	0,51	0,01	0,31	13.9	0,0007		0,47		0,07	1,4	3,8
11	11	4,5	0,8	0,91	0,001	3,3	2,55	0,0004		0,09		0,11	1,13	5,6
12	12	6	1,1	1,44	0,005	9,5	2,55	0,002		0,33		0,2	0,99	5,5
13	13	3,5	0,8	0,95	0,01	2,66	4,3	0,002		0,57		0,12	1,19	4,4
14	14	The channel is mostly flooded in the section area												
15	15	12	2,5	0,26	0,005	7,8	2,45	0,002		0,17		0,003	2,94	4,8
16	16	4	2,1	0,65	0,001	5,46	4,55	0,0002		0,05		0,02	2,25	1,9

According to the calculations, 43.8% of riverbeds are the areas with a high degree of dangerous channel processes (unstable channels), 37.5% – areas with a low degree (stable channels), 9.35% – areas with an increased and no danger of danger channel processes (low stable and absolutely stable channels, respectively) (Tables 1, 2). Based on the calculations, maps showing the river flow turbulence (the Froude number) (3), energy (the Grishanin parameter) (4), stratification (5), and degrees of stability according to the Lokhtin and Maccaveev number in the winter low water and spring flood periods are presented (**Figure 2*a*–*e***).

$$Fr = \frac{V^2}{gH}, (3)$$

where v – the mean velocity, m/s;

g – acceleration due to gravity, m/s^2

H – the section size, m.

$$M = \frac{H(gB)^{0,25}}{\sqrt{Q}} = const, (4)$$

where *H* – depth, m;

g – acceleration due to gravity, m/s^2;

B – width, m;

Q – discharge, m^3/s.

$$F = \frac{H}{B}, (5)$$

where *H* – depth, m;

B – width, m.

The ecological stress according to the Chalov method, modified and adapted to local natural and anthropogenic conditions (Alekseevskiy et al. 2008) (**Figure 2*f***) for the entire catchment area of the Hukiv basin is assessed:

0 points – in the grids where there is no ecological stress (no temporary watercourses, river tributaries);

1 point – the minimum ecological stress (influence of temporary watercourses);

2 points – low ecological stress (influence of the river and tributaries);

3 points – medium ecological stress (influence of temporary watercourses, rivers, and tributaries);

4 points – high ecological stress (influence of ponds, amplified by the activity of temporary watercourses, tributaries, and the main river).

The following types of ecological stress are characteristic of the Hukiv river basin: 4 points – 0.8%; 3 points – 7.56%; 2 points – 17.5%; 1 point – 28.14%; 0 points – 46%.

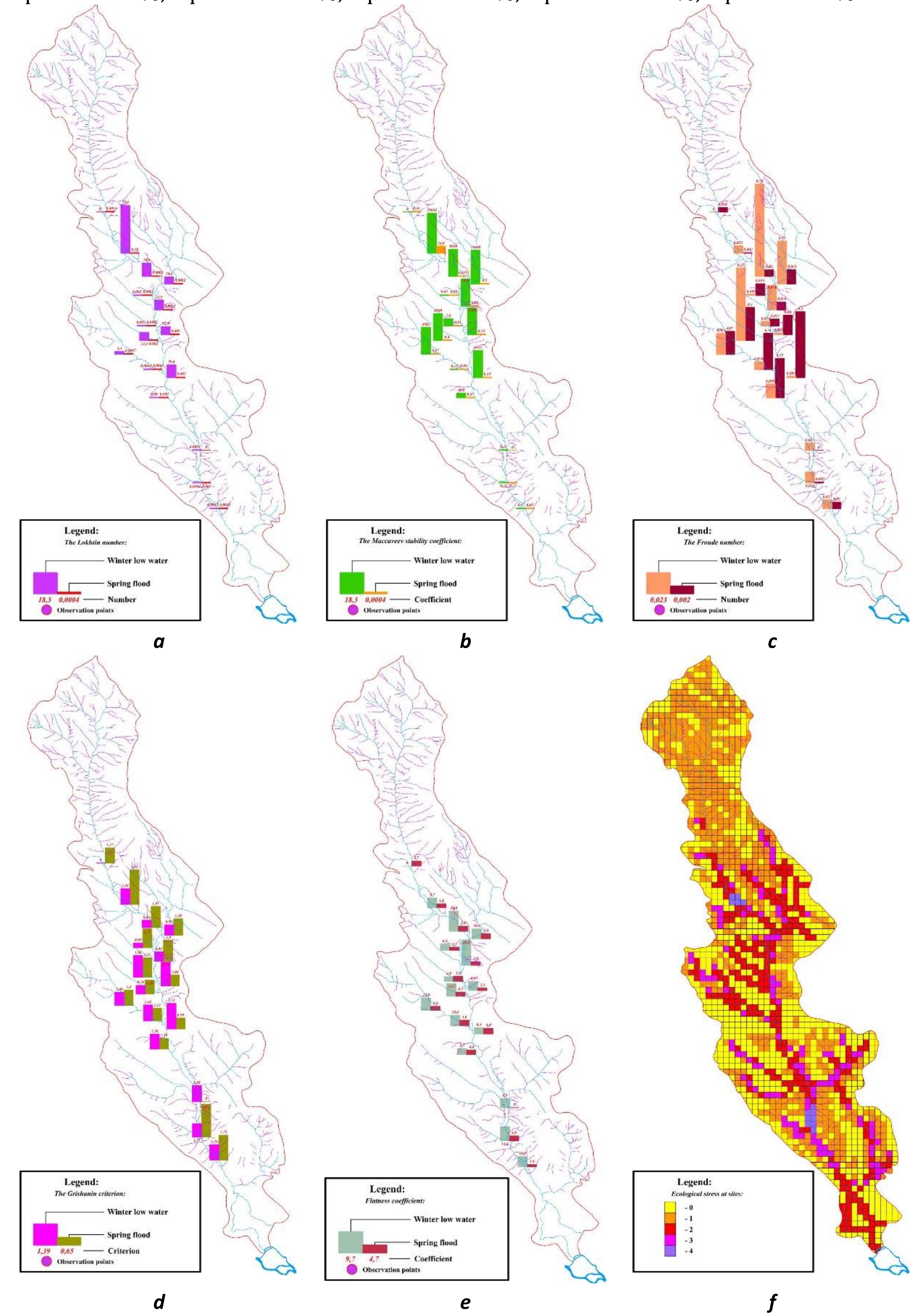

Figure 2 The Lokhtin number (a); the Maccaveev stability coefficient (b); the Froude number (c); the Grishanin criterion (d); Flatness coefficient (e); Ecological stress at sites (f).

Conclusions

In general, our study, based on our own observations and measurements in the period of 2005–2021, reveals low environmental tension in the upper river catchment, associated primarily with minor anthropogenic modifications of riverbeds. In the middle and lower parts, high level of environmental tension is detected due to the irrational use of the river floodplain (plowing, illegal construction). High environmental tension is characteristic of the pond locations which significantly increases siltation and leads to the degradation processes in the Hukiv river and its tributaries.
The riverbed stability is found to serve the indicator of interaction in the system flow – riverbed between active and passive factors including economic activity. Erosion in the catchment is a significant regulator while the erosion growth or attenuation changes the stability of riverbeds.

References

Alekseevskiy N. I., Berkovich K. M., Chalov R. S. 2008. Erosion, sediment transportation and accumulation in rivers. *International Journal of Sediment Research* 23 (2): 93–105.