ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Satbayev University

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

5 (449)

SEPTEMBER – OCTOBER 2021

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*
Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.
Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF
KAZAKHSTAN **SERIES OF GEOLOGY AND TECHNICAL SCIENCES**
ISSN 2224-5278
Volume 5, Number 449 (2021), 77-83 ***https://doi.org/10.32014/2021.2518-170X.101***

UDC 556.18: 338.46

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APPLIED MODEL OF ENVIRONMENTAL SERVICES - DEVELOPMENT OF ECOLOGICAL AND ECONOMIC DRAINAGE SYSTEM OF TRANSBOUNDARY RIVER BASINS (on the example of the Talas river basin).

Abstract. Based on the climatic index of biological productivity of landscapes according to D.I. Shashko developed a mathematical model of the bioclimatic potential of the catchment area of a transboundary river basin with its complex arrangement in the form of a coefficient of ecological services. Given coefficient characterizes the potential for increasing the biological productivity index of landscapes, allowing the formation of ecological water demand and average long-term disposable water resources in the context of administrative districts for the provision of services for the reclamation of agricultural lands Basin of the transboundary Talas River. At the same time, within the framework of geomorphological schematization, determine the «export-import» of environmental services of water resources at the interstate level with equity participation, ensuring the creation of highly productive and environmentally sustainable hydro-agrolandscape systems in order to increase food security of the population living in the region.

A mathematical model has been developed to substantiate the maximum permissible area of land reclamation, taking into account the water resources of transboundary river basins formed as a result of environmental services, where the relationship between the biological water requirements of the vegetation and soil cover of agricultural lands of the hydro-agrolandscape was used as a theoretical basis, it made it possible to determine maximum possible areas of irrigated land in the context of geomorphological schematization of the catchment area of the Talas river basin.

Key words: climate, index, productivity, potential, river, ecology, service, model, water, resource.

Introduction. The processes taking place in nature, society and the world economy are interconnected and have a mutual influence on each other. Human life takes place in the «economy-ecology-society» system and the study of the economic subsystem is impossible without considering its connections with other subsystems, especially in the basins of transboundary rivers. This implies the need to develop analysis tools - models for the development of a natural-technogenic system, that is, an integrated arrangement of river basins, taking into account the role of natural capital and environmental services of natural systems and human anthropogenic activities, allowing to identify new and substantiate known patterns of rivers flowing in the basin.

Solving environmental problems of river basins is one of the priority areas of socio-economic development of any modern state using the water resources of transboundary rivers to ensure water security and sustainable development [1; 2; 3; 4; 5; 6].

The situation on the market for environmental services in transboundary river basins is changing under the influence of demand, which in turn depends on the general economic situation, environmental conditions and is subject to the regulatory influence of the state. The successful development of the market for environmental services in river basins, its scale and content depend on the state's impact on nature-users in order to comply with environmental requirements.

Object of study - natural and natural-man-made systems of the catchment area of the transboundary Talas river basin [7].

Research goal - consists in identifying the features of the influence of natural capital and environmental services of components of natural systems and anthropogenic human activities in the complex arrangement of a transboundary river basin, ensuring a reasonable, fair and equitable use of natural resources for sustainable development and ensuring food security.

Methodological base of the research served as dialectical, abstract-logical methods, methods of analysis, synthesis, analogy, comparison, grouping, and also used the systemic, empirical and evolutionary approaches.

Research results. Natural capital - reserves consisting of life-supporting systems (life support systems), biodiversity, renewable and non-renewable resources used by man or of industrial interest to him [1; 2; 3; 4; 5; 6]. In river basins, natural capital is considered not only natural raw materials for production, but also so-called environmental services [7].

Consequently, an increase in «natural capital»(ППС) to «potential natural capital» (РПС), that is $\Delta РПС = РПС - ППС$ it can be carried out at the expense of ecological services of water resources of river basins, which are related to a regulated and controlled factor, and light and heat supply is not regulated and is not controlled, mankind adapts to these factors. Therefore, for the redistribution of ecological services of water resources in the catchment area of river basins, a methodological substantiation of integral criteria is required, which allows the rational, equitable and fair use of «natural capital»(ППС). To develop integral criteria that allow for a balanced redistribution of ecological services in the catchment area of river basins, one can use the ratio of the natural climatic index of biological productivity of individual landscape classes or catena (facies) [8]:

$$Б_{кфi} = K_{p(ky)} \cdot (\sum t > 10^oC / \sum t > 10^oC_o)$$

where $\sum t > 10^oC$ - the sum of the average daily air temperatures above +10°C, reflecting the flow of solar energy and heat supply of landscapes; $\sum t > 10^oC_o$ -the sum of the average daily air temperatures above +10°C, equal to the initial zone of formation of the river basin runoff, equal to 1000°C; $K_{p(ky)}$- coefficient depending on the coefficient of annual moisture - K_y) [8] to the average climatic index of biological productivity of all landscape classes $Б^{ср}_{кфi} = \sum_{i=1}^{n} Б_{кфi}/n$, that is, the coefficient of ecological services of the catchment area of river basins, ensuring the balancing of the biological productivity of hydro-agrolandscapes in the conditions of anthropogenic activity$K_{бкi} = 1 - (Б_{кфi}/Б^{ср}_{кфi})$ и $\sum_{i=1}^{n} K_{бкi} = 0 \rightarrow const$[9].

On the basis of the proposed methodological approach, the coefficient of ecological services for the catchment area of the Talas River basin was determined (Table 1).

Table 1- Integral coefficient of ecological services of the Talas river basin

Physico-geographicalzoning		Weather station	Environmental service ratio	
landscape class	facies		$Б^{ср}_{кфi}$	$K_{бкi}$
Mountain	Eluvial	Aktash	187.5	- 0,4159
Foothill	Transeluvial	Talas	141.5	- 0,0687
Foothill plain	Super aquatic	Taraz	139.4	- 0,0527
Plain	Aquatic	Bilikkol	149.1	- 0,1259
		Baikadam	107.3	0,1897
		Kamkalykol	69.7	0,4736
$Б^{ср}_{кфi}$ and $\sum_{i=1}^{n} K_{бкi}$			132,42	0,0

As can be seen from Table 1, the mountain (eluvial), foothill (transeluvial) and foothill plain (superaqual) zones of the catchment area of the Talas River basin can export the natural capital of the Kyrgyz Republic in the form of a water resource to increase the biological productivity of soil and vegetation covers of the plain (aquatic) zone, that is, by importing water resources, which will ensure the balanced functioning of the natural and man-made complex based on the creation of highly productive hydro-agrolandscapes in the territory of the Republic of Kazakhstan.

For an equitable, reasonable and fair distribution of the average long-term disposable water resources of transboundary rivers, it is possible to use the coefficient of available land resources ($(K_{зpi})$) of the catchment of the river basin in the context of facies, which is determined by the formula:

$$W_{бкi} = K_{зpi} \cdot (W_{oi} - \Delta W_{сэi}),$$

where W_{oi} – volume of water resources of river basins, km^3; $W_{сэi}$- volume of guaranteed sanitary and ecological water resources of river basins, ensuring the ecological sustainability of the natural system in the lower reaches.

At the same time, the volume of water resources (Wi) or the provision of environmental services in order to increase the «natural capital»(ППС) to «potential natural capital» (РПС) from the standpoint of the biological productivity of vegetation and soil covers of individual landscape classes or facies of river basin catchments is determined by the formula: $W_{бк(э-и)i} = К_{бкi} \cdot W_{бкi}$.

The average long-term volume of water resources (Woi) of the catchment area of the transboundary river Talas is1,84 km^{3}of which0,552 km^{3}is the volume of guaranteed sanitary and ecological water resources of river basins $W_{сэi}$),ensuring the ecological sustainability of the natural system in the lower reaches, that is, the average long-term volume of available water resources($W_{rai} = W_{oi} - W_{сэi}$)) is 1,288 km^3.

On the basis of the average long-term volume of available water resources($W_{rai} = W_{oi} - W_{сэi}$)) and the ratio of available land resources ($К_{эpi}$) the average long-term available water resources for the administrative districts of the catchment area of the Talas transboundary river basin were determined (Table 2).

Table 2 - Average long-term disposable water resources of the administrative areas of the catchment area of the transboundary Talas river basin

Landscape class andfacies	Administrative districts	Natural resources			Environmental services, km^3	
		land		aquatic, km^3	export	import
		km^2	%			
Mountain (Eluvial)	Talas	5280.0	7.394	0.095	-0.0395	-
Foothill (Transeluvial)	Kara-Burinsk	3207.0	12.808	0.165	-0.0113	-
	Bakai-Atinsk	9145.6	4.491	0.058	-0.0040	-
	Manas	2670.0	3.739	0.048	-0.0032	-
Foothill plain (Super aquatic)	Zhambul	3200.0	4.480	0.057	-0.0030	-
	Bayzak	4400.0	6.162	0.079	-0.0099	-
Plain (Aquatic)	Talas	12200.0	17.086	0.220	-	0.0227
	Sarysu	31300.0	43.840	0.564	-	0.0482
Along the Talas river basin		71402.6	100	1.288	0.0709	0.0709

It should be noted that the ecological runoff of the Talas river basin was determined using the analogy method, since both the Shu and Talas rivers are located in the Shu-Talas water basin and belong to the rivers of glacial-snow supply, according to S.R. Ibatullin, Zh.S. Mustafayev and K.B. Koybagarova basin of the Shu river, which are accepted as analogues, ecological runoff is 36% of hydrological runoff on a temporal and spatial scale [10].

Consequently, the presented information and analytical materials based on predictive calculations [7] made it possible, on the basis of available water resources providing environmental services, to determine the maximum possible area of irrigated land in the context of geomorphological schematization of the Talas river basin catchment area (Table 3).

Table 3- The maximum possible area of irrigated land in the context of geomorphological schematization of the catchment area of the Talas river basin

Landscape class andfacies	Administrative districts	Показатели экологических услуг			
		Available water resources for irrigation (W_{rai}),km^3	Specific water demand rate ((q_{pi}^{max})), m^3/cper 1 ha	Synchronous coefficient ($К_{ас}$)	Maximum possible irrigated area ($F_{пдо}$), thousand ha
Mountain (Eluvial)	Talas	0.035	0.44	1.067	72.1
Foothill (Transeluvial)	Kara-Burinsk	0.061	0.52	1.150	114.7
	Bakai-Atinsk	0.022	0.52	1.150	41.4
	Manas	0.018	0.52	1.150	33.8
Foothill plain (Super aquatic)	Zhambul	0.021	0.56	1.179	37.6
	Bayzak	0.029	0.56	1.179	51.9

Plain (Aquatic)	Talas	0.082	0.76	1.063	97.5
	Sarysu	0.209	0.76	1.063	248.5
Along the Talas river basin			-	-	697.5

As can be seen from Table 3, the maximum possible area of irrigated lands with an extremely efficient use of the ecological service of water resources of the Talas River basin is only 697.5 thousand hectares, of which 351.5 thousand hectares in the interstate section belong to the Kyrgyz Republic and 346.0 thousand hectares to the Republic of Kazakhstan.

In this case, the volume of water resources ($\Delta W_{ra(э-и)i}$) for the provision of environmental services in the «export-import» system of the catchment area of the transboundary river basin is determined by the formula: $\Delta W_{ra(э-и)i} = К_{бкі} \cdot W_{rai}$, where $К_{бкі}$ – coefficient of environmental services of natural resources.

Thus, if the Kyrgyz Republic, on the basis of the principles of balanced use of natural resources, exports environmental services of water resources, and the Republic of Kazakhstan accepts environmental services of water resources from the territory of the Kyrgyz Republic, it is possible to ensure the efficient use of energy services of natural systems by increasing the area of irrigated land in the lower reaches of the basin. the Talas river (table 4).

Table 4 - Forecasting «increase-decrease» in the area of irrigated land in the context of geomorphological schematization of the catchment area of the transboundary Talas river basin

Administrative districts	W_{rai}, км^3	$К_{бкі}$	Environmental services of water resources, km^3		Expected area of irrigated land, thousand ha	
			export	import	-	+
Mountain class of landscapes (eluvial facies)						
Talas	0.035	-0.4159	-0.0145	-	23.9	-
Foothill subclass of landscapes (transeluvial facies)						
Kara-Burinsk	0.061	-0.0687	-0.0041	-	7.70	-
Bakai-Atinsk	0.022	-0.0687	-0.0051	-	9.60	-
Manas	0.018	-0.0687	-0.0012	-	2.25	-
Foothill plain subclass of landscapes (super-aquatic facies)						
Zhambul	0.021	-0.0527	-0.0011	-	1.37	
Bayzak	0.029	-0.0527	-0.0016	-	2.36	
Plain landscape class (aquatic facies)						
Talas	0.082	0.1897	-	0.0155	-	13.43
Sarysu	0.209	0.4736	-	0.0990	-	117.70

As can be seen from Table 4, within the framework of a reasonable, equitable and fair use of water resources of the transboundary Talas River, it is possible to reduce anthropogenic pressures on the mountainous class of landscapes (eluvial facies) and submontane subclass of landscapes (transeluvial facies) based on the export of ecological services of available water resources, which ensure their environmental sustainability, and using the import of environmental services of water resources, it is possible to increase the area of irrigated land to 131.13 thousand hectares, which allows creating highly productive agro-industrial complexes that ensure food security in the region. With a reasonable, equitable and fair use of water resources in the basin of the transboundary Talas River, taking into account energy resources in the context of geomorphological schematization, it is possible not only to ensure a balanced use of water resources within the framework of their «export-import» based on heat and moisture supply of the natural system, but and to design highly efficient hydro-agrolandscapes.

Conclusions: Based on the climatic index of biological productivity of landscapes according to D.I. Shashko developed a mathematical model of the bioclimatic potential of the catchment area of a transboundary river basin with its integrated arrangement in the form of a coefficient of environmental services, which characterizes the potential for increasing the biological productivity index of landscapes and allows one to determine the ecological water demand and average long-term disposable water resources in the context of administrative districts for the provision of services for the reclamation of agricultural lands and within the framework of geomorphological schematization there are opportunities for «export-import» of environmental

services of water resources at the interstate level with equity participation, ensuring the creation of highly productive and environmentally sustainable hydro-agrolandscape systems in order to increase food security in the region.

A mathematical model has been developed to substantiate the maximum permissible area of land reclamation, taking into account the water resources of transboundary river basins formed as a result of environmental services, where the relationship between the biological water requirements of vegetation and soil cover of agricultural lands of the hydro-agrolandscape and its resistance to anthropogenic influences is used as a theoretical basis; as well as the degree of regulation of the flow of the basin of transboundary rivers, which made it possible, on the basis of available water resources, to determine the maximum possible areas of irrigated lands in the context of geomorphological schematization of the catchment area of the Talas river basin.

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ЭКОЛОГИЯЛЫҚ ҚЫЗМЕТТІҢ ҚОЛДАНБАЛЫ ҮЛГІСІ – ТРАНСШЕКАРАЛЫҚ ӨЗЕНДЕРДІҢ СУЖИНАУ АЛАБЫНЫҢ ЭКОЛОГИЯЛЫҚ-ЭКОНОМИКАЛЫҚ ДАМУ ЖҮЙЕСІ
(мысалға Талас өзенінің сужинау алабы)

Аннотация. Д.И. Шашконың ландшафттардың биологиялық өнімділігінің климаттық белгісінің негізінде, трансшекаралық өзендердің сужинау алабының кешенді үйлесіру кезінде биоклиматтық әлеуетін бағалауға арналған математикалық үлгісі, ландшафттардың биологиялық өнімділік белгісін жоғарылатудың әлеуетін сипаттайтын экологиялық қызметтік көрсеткіш түрінде құрылған. Бұл көрсеткіш ландшафттардың биологиялық өнімділігінің климаттық белгісін жоғарлатудың әлеуеттік мүмкіншілігін сипаттай отырып, трансшекаралық Талас өзенінің сужинау алабының әкімшілік аудандардың жағдайындағы ауылшаруашылық жерлерін мелиорациялау кезіндегі көрсетілетін қызметтер бойынша, экологиялық түрғыда суды тұтыну және орташа ұзақ мерзімді қолданбалы су ресурстарынанықтауға мүмкіндік береді. Сонымен бірге, геоморфологиялық желілеу шеңберінде су ресурстарының экологиялық қызметінің «экпорт-импорт» бөлігіне мемлекетаралық деңгейде үлестік қатынасу арқылы, аймақтың тұрғындарының азық-түлік қауіпсіздігін жоғарлату мақсатында жоғарғы өнімді және экологиялық орнықты гидроагроландшафттық жүйелерін құруды қамтамасыз етуге болады.

Трансшекаралық өзендердің сужинау аймағының су ресурстарының экологиялық қызметінің нәтижесінде қалыптасатын суғармалы егістік жердің шектелген-мүмкіншілік ауданын негіздеуге арналған математикалық үлгісі құрылған және оның теориялық негізі ретінде гидроландшафттардың ауылшаруашылық жерлеріндегі өсімдік және топырақ жамылғысының биологиялық суды тұтыну мөлшері және климаттың арасындағы байланыстың теңдеу пайдаланылған, ал ол Талас өзенінің сужинау алабының аймағын геоморфологиялық желілеу аясында және қалыптасқан су ресурстары бойынша суғармалы егістік жердің жоғарғымүмкіншілік ауданын анықтауға жағдай туғызады.

Түйінді сөздер: климат, белгі, өнімділік, әлеует, су жинау, экология, қызмет, үлгі, су, ресурс.

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ПРИКЛАДНАЯ МОДЕЛЬ ЭКОЛОГИЧЕСКОЙ УСЛУГИ –РАЗВИТИЯ ЭКОЛОГО-ЭКОНОМИЧЕСКОЙ СИСТЕМЫ ВОДОСБОРА БАССЕЙНА ТРАНСГРАНИЧНЫХ РЕК (на примере бассейна реки Талас)

Аннотация. На основе климатического индекса биологической продуктивности ландшафтов по Д.И. Шашко разработана математическая модель биоклиматического потенциала водосбора бассейна трансграничной реки при его комплексном обустройстве в виде коэффициента экологических услуг. Данный коэффициентхарактеризует потенциальную возможность повышения индекса биологической продуктивности ландшафтов, что позволяет определить экологическую водо потребностьи средне-многолетние располагаемые водные ресурсы в разрезе административных районов для оказания услуг по мелиорации сельскохозяйственных земель бассейна трансграничной реки Талас. При этомв рамках геоморфологической схематизации разработанная модель позволяет определить «экспорт-импорт» экологических услуг водных ресурсов на межгосударственном уровне с долевым участием, обеспечивающие создание высокопродуктивных и экологически устойчивых гидроагроландшафтных систем с целью повышения продовольственной безопасности населения, проживающего в данном регионе.

Разработана математическая модель для обоснования предельно - допустимой площади мелиорации земель с учетом формирующийся в результате экологических услуг водных ресурсов трансграничных речных бассейнов, где в качестве теоретического базиса использована взаимосвязь между биологическими водопотребностями растительного и почвенного покровов сельскохозяйственных угодий гидроагроландшафта, что дало возможность на базе располагаемых водных ресурсов определить максимально-возможные площади орошаемых земель в разрезе геоморфологической схематизации территории водосбора бассейна реки Талас.

Ключевые слова: климат, индекс, продуктивность, потенциал, река, экология, услуга, модель, вода, ресурс.

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ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Редакторы: *М.С. Ахметова, А. Ботанқызы, Д.С. Аленов, Р.Ж. Мрзабаева*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 15.08.2021.
Формат 60x881/8. Бумага офсетная. Печать – ризограф.
4,6 п.л. Тираж 300. Заказ 4.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19