Assessment of water resources use efficiency based on the Russian Federation's gross regional product water intensity indicator

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The extended representation of the water management problem that is an important component of the supply of resources is vital in an effective regional economy. This article justifies the importance of such a representation through the lens of the paired strategizing of the water resource system and regional economic development. The authors' purpose is to analyse the rationality of the usage of water resources in conjunction with regional socio-economic development indicators, by applying tools that allow grouping based on the existing trends in water consumption. The article studies the importance of the effective management of the allocation of scarce water resources among users. It also examines the rationality of their usage in the context of optimising resource usage, and the high variations across areas based on the potential of the resource components, as well as the dynamic socio-economic indicators. The theoretical framework of the rational water usage paradigm comprises a set of interrelated concepts and theories, such as the theory of economic growth, as well as theories and concepts of regional development, particularly regional resource management, considering the parameters of current and proposed mesoeconomic policies in combination with the basin approach for the allocation of water resources. It has been shown that the gross regional product (GRP) water intensity indicator is one of the important criteria in assessing the rational usage of territorial water resources. The authors' hypothesis is that regional peculiarities in the tendencies of GRP water intensity indicator changes allow not only to define the current situation pertaining to water use, but also to determine the direction of the control actions to increase its efficiency. In the study, this hypothesis is confirmed. Unlike other existing approaches and models which are oriented chiefly towards the identification of scarce water resource allocation options in accordance with the standards of water use, this article implements an approach to the assessment of the efficiency of water usage as a strategic resource for socio-economic development at the regional level. Based on the analysis of the GRP water intensity indicator and the problematic nature of region grouping from the standpoint of rational water usage, regions are identified. The results can serve as a guide for designing regional development strategies.

Keywords:
GRP water intensity indicator,
rational water usage paradigm,
efficient usage of water resources,
socio-economic development

Introduction

Russia continues to face the pressure of sanctions imposed on it by western countries. It also coped with the global economic crisis and overcame its adverse impacts. Against this backdrop, along with a range of externally and internally determined factors, the role of regions in the realisation of state plans and programmes, including the strategic ones, is continuing to expand in the Russian economy. As E. G. Animitsa notes, 'For large Russia that was always notable for significant variation of its subject territories, the regional aspect of economic, social and other reforms has decisive significance' (Silin et al. 2017, p. 684.).

There are a great number of causes for the peculiarities in the economic processes at the regional level. Firstly, the global economic shocks, significantly affecting the state economy, are usually moderated while switching over to mesoeconomic systems. Secondly, in spite of the fact that the regions are also influenced by cyclical factors, they have a larger potential than the state as a whole, for both finding a way out of the crisis and forming prerequisites for sustainable economic growth. Thirdly, at the regional level, which is more mobile than the macro level, there is a possibility for the efficient management of all kinds of resources, including natural ones, where water resources play a specific role as an integrated element in vital activity. Fourthly, a region is the main coordinating aspect in the purposeful allocation of state efforts to organise effectively resource flows. Therefore, mesolevel water economy systems act as the main control object in the national water economy system. 'Meanwhile, numerous strategies of socio-economic development of the country and its regions that are being designed suffer from fundamental insufficiency – they do not include spatial (3-D) measurements of the productive forces organisation in the foreseeable future' (Silin et al. 2017, p. 684.), the consequence of which is inefficiency of resources supply strategies.

Sufficient and rational water supply to the regional economy promotes adequate functioning of economic processes; realisation of regional plans, programmes, and projects; and stability in the functioning of the regional economic system and its subsystems, both currently and in the future. Rational water supply to the regional economy has a pronounced and purposeful objective. It is an important factor in maintaining the integrity of the system and stability of socio-economic processes. The purpose of this article is to analyse the rationality of the usage of water resources in conjunction with regional socio-economic development indicators, by applying tools that allow grouping according to the existing trends in water consumption.

Efficiency of the usage of regional water resources: problem formulation and research methodology

One of the important characteristics of the historically formed non-uniformity in the Russian Federation's economic territory is the fact that regions are essentially differentiated according to their resource base, as well as the availability of water resources within their boundaries. However, in each of them, sufficient resource security allows for the smooth functioning of the regional economy, and formation of sectoral specialisations as well.

A range of problems in resource security management has the 'special significance of taking into account the country's scales and the high degree of regional distinctions both by resource availability and the level of their economic development in the background of increasing scales for demographic, ecological and social problems in some of them. It causes the necessity to carry out the system research for studying resource security management in the region as the object having the criterion character from the viewpoint of the purposeful orientation for the reproduction processes at the regional level' (Dobrolezha 2011, p. 5.). Moreover, the problems of effective management of water resource allocation (one of its features is scarcity) among consumers, as well as the rationality of their usage, increase the need to optimise resource consumption and examine high area asymmetry for their potential, using indicators of regional socio-economic dynamics. The water strategy of the Russian Federation for the period until 2020 is oriented towards the effective usage of scarce water resources, which is one of the most important tasks and is defined as the 'rationalisation of the water resources usage for different needs'.[1] This

[1] Water Strategy of the Russian Federation for the period until 2020 (approved by the RF Government regulation of 27 August, 2009 № 1235-p)// Ministry Resources and Ecology of the RF/Electronic resource/. http://www.mnr.gov.ru/regulatory/detail.php?ID=128717 (Downloaded: 20.02.2018).

emphasises the actuality of the interconnected nature of the problem of rational water supply for the regional water economy and the dynamics of the regional socio-economic indicators, using tools adaptive to both types of regions and environmental factors.

The theoretical basis of a water user's interest and agreement with the frameworks of the regional water economy system has been formed in the works of many researchers (Stackelberg 1934, Bettrand 1883, Wickham 2005, Szabó 2015, Belyaev et al. 2014, Danilov-Danilyan–Khranovich 2013).

The problems in creating tools to support the decision making process in the water economy of the country and its regions, including strategic decision making, are represented in a great number of works by the experts at the Institute of Water Problems of the Russian Academy of Sciences (Danilov-Danilyan–Khranovich 2013, Levit-Gurevich et al. 2010, Xu–Singh 2004, Loukas et al. 2007, Torregrosa et al. 2010). The models developed by these studies are oriented towards solutions for the task to adjust the society or region that needs the water resources with the possibility of their fulfilment. In a number of studies on this range of problems, including Molina et al. (2009), Chernova et al. (2015), Calizayar et al. (2010), Niua et al. (2016), Zhang–Guo (2016), and Krass (2017), the impact of water resources as a factor of both production and existing practices of their allocation, on the strategic plans of regional development as well as efficiency of water resources used in different sectors (primarily in agribusiness by assessment of the yield) is examined. The tools proposed by the authors do not allow an integrated assessment of the efficiency of regional water resources usage. They also do not allow the integrated assessment of the validity of the degree of the water allocation structure formed as a result of the position of the GRP growth security, based on intensive factors.

Various scientists opine that one of the main criteria for the assessment of the complex functioning of the regional water economy is the GRP water intensity indicator that allows the characterisation of the type and level of the ecological and economic development of the territories involved (Antonova 2013, Fomina 2010). The factors determining the GRP water intensity level, including specific weight of mining and manufacturing industries with high levels of water usage, population, as well as natural and climatic factors, are observed in the works of these economists. However, such substations for the high level of the GRP water intensity in Russia (on an average, 2.4 cubic metres/thousand roubles, but in a number of regions 11–14 cubic metres/thousand roubles) do not explain why this indicator exceeds similar ones in industrially developed countries such as the UK, Denmark, Sweden, and others, by 3 to 5 times.

Thus, the specific characteristics of the regional factors and management conditions explain the distinctions in the character of the regional water resources usage that affect the GRP water intensity indicator, which in turn, is determined by the sectoral structure. Since, as V. V. Gamukin justly notes, 'it is the combination of economies of separate regions that finally makes the main foundation of the national economy' (Gamukin 2017, p. 411.), it is important to understand the features of water use in regional economies, and to reveal the tendencies of its changes. Regional economies have to adapt to external and internal challenges in order to support definite rates of socio-economic development. This results in the search for new technologies for production and economic activities, in connection with the rational usage of water resources.

In our opinion, the high GRP water intensity level of the regions within the Russian Federation does not testify to the high specific weight for mining and manufacturing industries (i.e. non-rational structure of regional production), but to the insufficient efficiency of applied resource-saving technologies or the lack of innovative ones. GRP growth security is facilitated through extensive factors, and not intensive ones. The modern conditions of neo-industrialisation for the national economy, based on the paradigm of high innovation in production, confirm the conclusion.

One should emphasise the methodological significance and practical importance of the dynamic approach to this problem. Existing publications suggest that the rationality of the usage of water resources is usually carried out through the implementation of statutes, according to the state, for a specific period. The methods applied make it possible to reveal the actually formed degree of adequacy of the existing regional methods for the allocation of water resources and their requirements within a concrete period. However, they do not present the possibility of the interrelated prediction of water supply strategies and socio-economic development of the region. According to this approach, water supply management of the regional economy has an exclusively tactical character, since it covers a short period.

It is supposed that in the process of regional strategizing, it is necessary to reveal tendencies of water supply and water resources use in each concrete constituent territory and federal district of the Russian Federation. This will allow the formation and implementation of strategic plans for rational allocation according to the prospects of the socio-economic development of the territory in question. To solve this problem, it is necessary to carry out an analysis of the dynamics revealing the tendencies of changes in the GRP water intensity level in separate regions and in the macro region. Moreover, it is evident that the management of water supply processes and the regional economic development should be goal-oriented in both current and strategic contexts, and include a set of science-based control actions to achieve the rational allocation and effective usage of scarce water resources in the regions.

The rational allocation and effective usage of regional water resources as a control object require heightened attention from the data monitoring system, characterised by the practice formed, as well as by the dynamics of the water supply process in the regional economy. For the unification and systematisation of approaches on part of the management to the processes of allocation and use of scarce water resources, it is necessary to apply mathematical and strategic methods. These methods should enable granting a scientific basis for the main goal-oriented and programme guides for all the regions found in the same qualitatively uniform group, from the perspective of tendencies for changes in the GRP water intensity level, not excluding the differentiated approach for each region. Using such an approach, the principle of rational water supply and effective water conservation is observed. This principle conditions the possibility of the successful functioning and stability of economic players; the uninterrupted operation of production processes; the realisation of regional plans, programmes, and designs; the achievement of regional development balance; and the greatest conformity of the GRP structure to the imperatives of modernisation and innovation.

The arguments given here support the propounding of the following tasks:

– to analyse the dynamics of the GRP water intensity indicator for separate federal districts and other entities of the Russian Federation, affiliated to their composition;
– to reveal the factors determining the changes in the GRP water intensity level;
– to reveal regularities in the changes in the GRP water intensity level for separate constituent territories of the Russian Federation;
– to carry out grouping of the constituent territories in the Russian Federation by tendencies of changes in the GRP water intensity level.

The results of carrying out these tasks, besides the assessment of the general dynamics for the changes in the GRP water intensity indicator of the regional economy, can become determinants for the directions to increase the rationality level of water resources usage, and their purposefulness to realise strategic priorities in the development of concrete territories.

Empirical analysis of the rational usage of regional water resources

Although each region pays a great deal of attention to the level of supply of resources (including water), the various ways of water resources usage can either contribute or not contribute to the growth of GRP. In this study, the GRP water intensity indicator, as mentioned above, is determined by the volume of water use and the tendency of GRP changes. When innovative technologies are applied, even intensive development with careful usage of water resources may result in a decreasing GRP water intensity indicator. Besides, a sharp decrease in the GRP water intensity indicator can testify to the implementation of a water saving innovation in the regional economy.

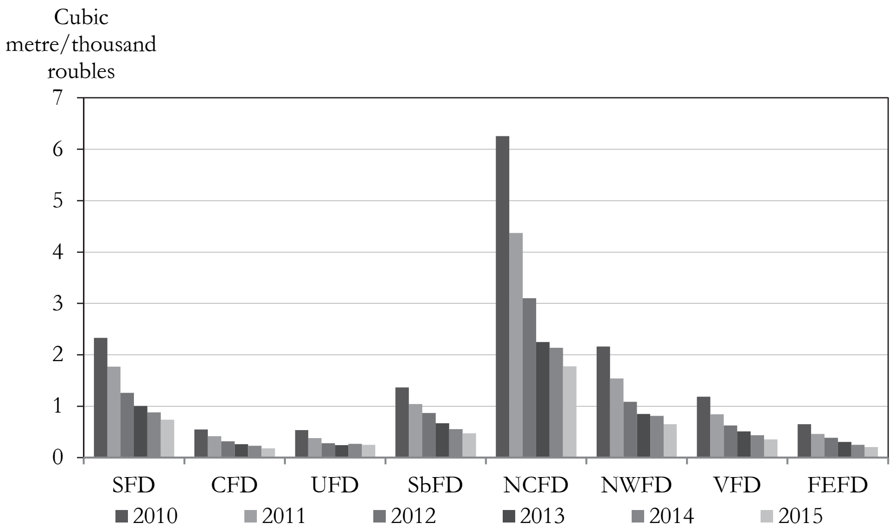
Placing emphasis on the interrelation of the component structure of the regional economy (expressed by the GRP value), and the indicator of the volume of water use allows us the reveal which regions with similar component structures (peculiar macro groups) show comparable and even similar tendencies of changes in the GRP water intensity indicator. It also makes it possible to develop a model that will have a great socio-economic effect and thereby create conditions for the modernisation of the regional economy and to make managerial decisions on its application related to the exploitation of water ecosystems.

In the following, the link between the GRP water intensity level and GRP volume dynamics is analysed based on the Russian Federal State Statistics Service's (Rosstat) 2010–2015 data on fresh water use in the Russian Federation's various entities. The indicator of the volume of water consumption by circulating water systems is, however, not taken into account in the computations since the application of such a technology is impossible or limited in some industrial productions (for example, in the food industry). Conclusions of that kind can be only drawn if data on the structure of sectoral water usage are available. However, this is not the focus of this article.

Decrease in the volume of (fresh) water use (with a given GRP growth) indirectly testifies to the application of water saving technologies. In the period from 2010 to 2015, the GRP water intensity indicator decreased in every constituent territory of the Russian Federation. The largest decrease was in the North-Caucasus Federal District (NCFD) (see Figure 1).

Figure 1

Changes in the GRP water intensity indicators of the Russian federal districts



Note: Here and in the following figures, SFD – Southern Federal District, CFD – Central Federal District, UFD – Ural Federal District, SbFD – Siberian Federal District, NCFD – North Caucasus Federal District, NWFD – North-western Federal District, VFD – Volga Federal District, FEFD – Far Eastern Federal District.

Source: Own calculation based on Rosstat (2016).

In 2015 data, the GRP water intensity level was below one cubic metre/thousand roubles in seven of the federal districts. The only exception was the

NCFD, whose GRP water intensity figure – even if it fell to one third between 2010 and 2015 – was more than double of the GRP water intensity indicators of the other federal districts at the end of the period considered.

To analyse the factors affecting changes in the GRP water intensity level, the following model is used:

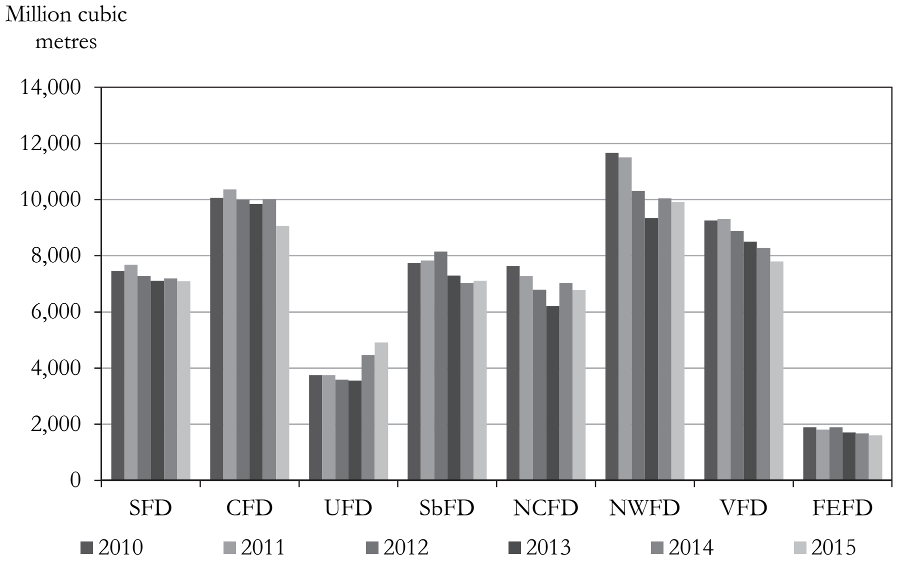
$$W_i = \frac{V_f}{GDP} \ ,$$

where W_i denotes the GRP water intensity level, and V_f stands for the volume of fresh water use.

The analysis has revealed that between 2010 and 2015 the volume of fresh water use was approximately the same, or varied insignificantly in a number of federal districts. They include the Southern Federal District (SFD), the Far Eastern Federal District (FEFD), the Central Federal District (CFD), NCFD, and the Siberian Federal District (SbFD). In the North-western Federal District (NWFD) and the Volga Federal District (VFD), however, this indicator showed a significant decrease (see Figure 2), which, as it was noted above, indirectly testifies to the improvement in the efficiency of fresh water usage, taking these federal districts' GRP growth rates also into account. In the period considered, the volume of fresh water use increased only in the Ural Federal District (UFD), owing to the growing figures of the Tyumen region (the volume of fresh water use has not changed significantly in other constituent territories of the micro region).

Figure 2

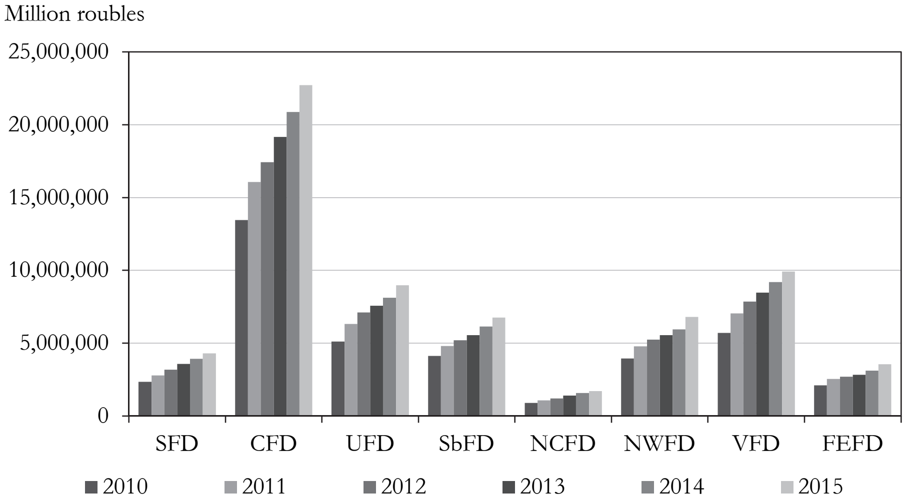
Dynamics of fresh water use in the Russian federal districts



Source: Own calculation based on Rosstat (2016).

Figure 3

Dynamics of GRP changes in the Russian federal districts



Source: Own calculation based on Rosstat (2016).

In the period considered, the GRP growth rates were similar in most of the federal districts, except for CFD whose GRP figures and rates of GRP growth were higher. Besides having the highest GRP water intensity indicator, NCFD does not rank last among the federal districts by the volume of fresh water use, but has the lowest GRP figure. The volume of its fresh water use coincides with that of the SFD and SbFD, but its GRP figures are much lower compared to those of the other federal districts. This testifies to the high water intensity of its regional economy, and possibly, to the irrational management of its water resources.

Our analysis demonstrates that the rates of decline in the fresh water use of the federal districts were significantly lower than their GRP growth rates. In other words, a lower and lower volume of fresh water was needed in each subsequent year for the production of one rouble GRP. Moreover, the GRP water intensity indicator showed a decreasing tendency in the period considered, although the rate of decline became smaller in the last few years. The reasons for this tendency presumably are the following:

– more careful usage of water resources owing to the introduction of new technologies reducing water consumption levels, the introduction of a circulating water supply system, and the decrease in the level of losses;
– expansion of regional production with low water intensity levels.

These reasons, however, can be only proved and concretized by a more detailed analysis of the water consumption levels and GRP water intensity indicators of the regions.

Next, the regions are grouped based on the tendency of their GRP water intensity changes. The results indicate that the GRP water intensity level varies considerably in the regions. Supposing that each group of 'similar' regions forms a separate interval, and the level of GRP water intensity varies evenly within their bounds, Sturges' rule can be used to determine an optimum number of intervals by which the observed range of the random variable is divided when building a histogram. As a great set of indicators are analysed in the present research, and their allocation is close to the standard 1, the reliability of data received is sufficient.

In Table 1, the computation results for the upper bounds of the GRP water intensity intervals are presented that form the basis of a regional grouping. Using Sturges' rule, we could determine seven intervals. As Table 1 shows the boundary values of these intervals were different in the various years and showed a decreasing tendency between 2010 and 2015. The separation of the groups with 'very low', 'low', 'relatively low', 'average', 'relatively high', 'high' and 'very high' levels of GRP water intensity is relative and was performed by taking the maximum and minimum values of the grouping indicators into account in the six years considered.

Table 1

Regional grouping and the upper bounds of the seven GRP water intensity groups (intervals)

Upper bound, cubic metre/thousand roubles						Group (interval)/Level of GRP water intensity
2010	2011	2012	2013	2014	2015	
2.02497182	1.58321951	1.22777915	1.09266440	1.0249131	0.76380529	1/Very low level
3.91970718	3.06065078	2.36348670	2.11253985	1.9856368	1.47679462	2/Low
5.81444254	4.53808206	3.49919424	3.13241529	2.9463605	2.18978395	3/Relatively low
7.70917790	6.01551334	4.63490179	4.15229074	3.9070843	2.90277329	4/Average
9.60391326	7.49294462	5.77060934	5.17216618	4.8678080	3.61576262	5/Relatively high
11.4986486	8.97037590	6.90631689	6.19204162	5.8285317	4.32875195	6/High
13.3933839	10.4478071	8.04202443	7.21191707	6.7892554	5.04174128	7/Very high

Source: Own calculation based on Rosstat (2016).

Table 2 presents the Russian Federation's constituent territories grouped by the tendency of their GRP water intensity indicator changes, and reflects – where it is appropriate – the characteristics of their transition from one group to another.

According to Table 2 and Figure 4, a great part of the Russian Federation's constituent territories was in the same group during the entire research period. However, some constituent territories moved from a group with higher GRP water intensity level into another group with a comparatively lower GRP water intensity level, or vice versa. Nevertheless, several constituent territories remained in the same group of high water intensity level.

The results of the analysis have revealed the 'problematic' entities of the Russian Federation. Among them, there are constituent territories:

– with growing GRP water intensity level (Leningrad region, Adygeya Republic, and the Republic of Kalmykia);
– with constantly high or average GRP water intensity level (Kostromskaya and Twerkaya regions).

For these constituent territories, further research needs to be conducted to find the reasons for their growing/high GRP water intensity level. In some cases, it can be explained by their broadening regional business activities or some structural changes introduced in the regional economy. However, if this tendency continues in the next few years, the water consumption will be likely irrational in these constituent territories.

Table 2

Grouping of the Russian Federation's constituent territories by the tendency of GRP water intensity indicator changes, 2010–2015

Tendency of changes	Constituent territory	Group of constituent territories/Transition between groups
Relatively constant GRP water intensity level	Amur region, Jewish autonomous region, Kamchatka krai, Magadan region, Seaside krai, Republic of Sakha-Yakutia, Sakhalin region, Khabarovsk krai, Chukotka autonomous okrug, Kirov region, Nizhny Novgorod region, Penza region, Republic of Bashkortostan, Republic of Mari El, Republic of Mordovia, Republic of Tatarstan (Tatarstan), Samara region, Saratov region, Udmurtia Republic, Ulyanovsk region, Chuvash Republic – Chuvashia, Arkhangelsk region, Vologda region, Saint Petersburg city, Kaliningrad region, Novgorod region, Republic of Karelia, Komi Republic, Altai krai, Trans-Baikal krai, Irkutsk region, Krasnoyarsk krai, Novosibirsk region, Omsk region, Altai Republic, Tyva Republic, Khakassia Republic, Tomsk region, and Kurgan region	Group 1 – These constituent territories had the lowest GRP water intensity level in the period considered, which was close to 2.0 cubic metres/thousand roubles in 2010 and decreased to 0.8 cubic metres/thousand roubles by 2015.
Relatively constant GRP water intensity level	Perm' krai, Chechen Republic, Kemerovo region, Republic of Buryatia, and Rostov region	Group 2 – The GRP water intensity level of these constituent territories was sufficiently low in the period considered; it did not exceed 4.0 cubic metres/thousand roubles in 2010 and decreased to 1.5 cubic metres/thousand roubles by 2015.

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Tendency of changes	Constituent territory	Group of constituent territories/Transition between groups
Relatively constant GRP water intensity level	Tver' region	Group 3 – The GRP water intensity level of this constituent territory was average in the period considered; it did not exceed 6.0 cubic metres/thousand roubles in 2010 and decreased to 2.2 cubic metres/thousand roubles by 2015.
	Kostroma region	Group 7 – The GRP water intensity level of this constituent territory was very high in the period considered; it almost reached 14.0 cubic metres/thousand roubles in 2010 and decreased to 5.0 cubic metres/thousand roubles by 2015.
Decreasing GRP water intensity level	Orenburg region, Pskov region, Republic of Severnaya Osetia-Alania, Krasnodar krai, Kabardino-Balkar Republic, Republic of Ingushetia, and Astrakhan' region	Transition to 'neighbouring' groups (not more than two transitions in the period considered)
	Stavropol' krai and Republic of Dagestan	Transitions to 'non-neighbouring' groups (not more than two transitions in the period considered)
Growing GRP water intensity level	Republic of Adygeya and Leningrad region	Transition to 'neighbouring' groups (not more than two transitions in the period considered)
	Republic of Kalmykia	Transitions to 'non-neighbouring' groups (not more than two transitions in the period considered)

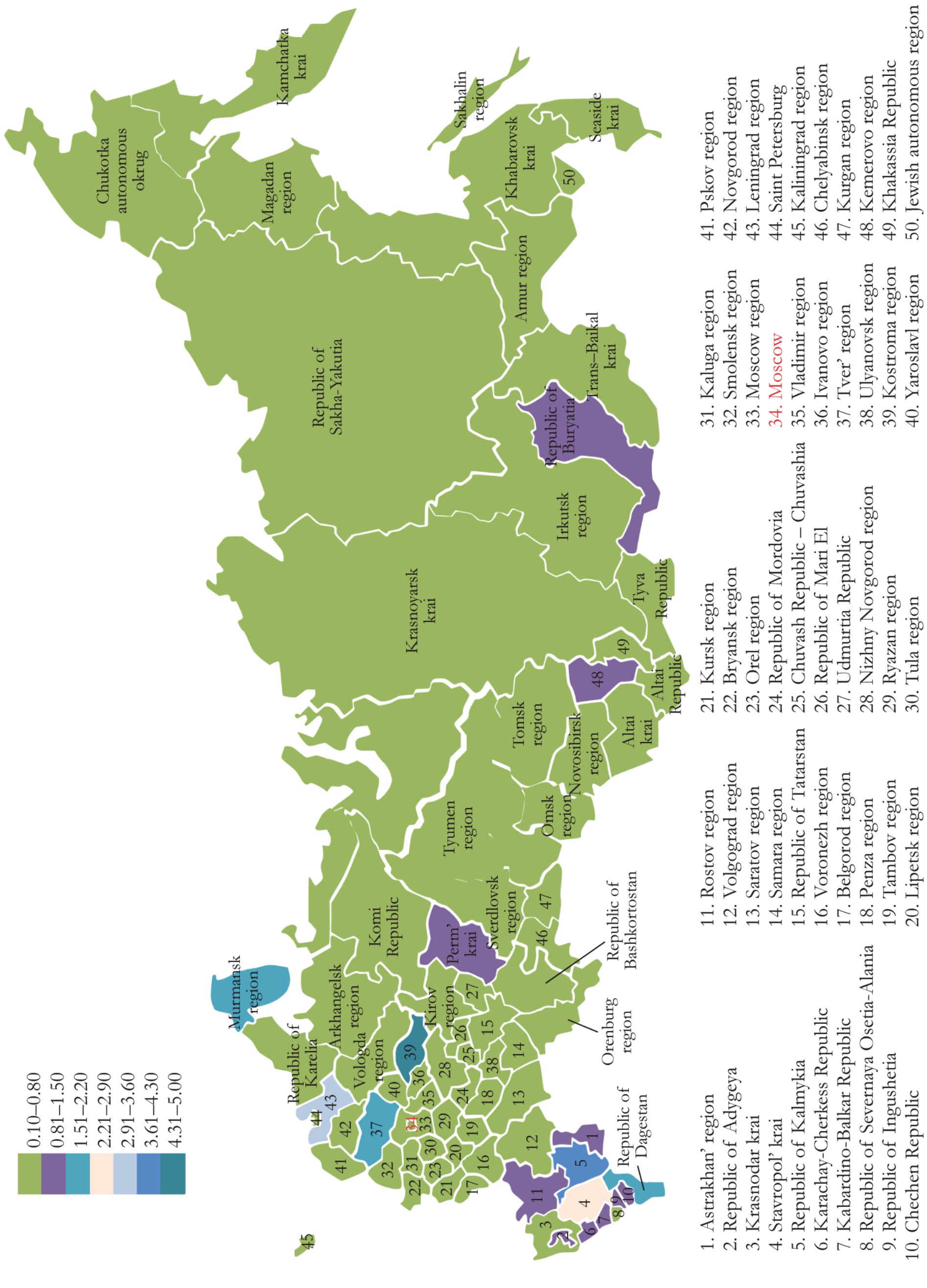
Note: Krai and okrug are two types of administrative divisions in the Russian Federation.

The results demonstrate that the situation in the Republic of Kalmykia (that is characterised by a growing GRP water intensity level and very low indicators of fresh water use) and the Kostroma region (whose volume of fresh water consumption is high, but its GRP figures are low) deserve special attention.

The regional authorities that are responsible for the realisation of water supply policy may consider studying regional experiences with decreasing GRP water intensity levels, particularly those of Stavropol' krai and the Republic of Dagestan, where, against the background of relatively constant water consumption levels, GRP growth is observed.

Figure 4

Map of the Russian Federation's constituent territories grouped by GRP water intensity, 2015



Conclusions

This study of the efficiency problems in the regional economy and its supply of resources, including the support tools for adopting and realising managerial decisions in the field of water usage, has made it possible to draw a reasonable conclusion on the necessity to develop assessment methods to study the rationality of the usage of water resources in conjunction with regional socio-economic development indicators. The verification of the proposed tools showed that in the macro regions of the Russian Federation, a decrease in the GRP water intensity indicators was observed, conditioned by the growth of the volumes of GRP while maintaining fresh water usage volumes. This decrease in the GRP water intensity is due to the introduction of new technologies to secure higher levels of rationality in the usage of water resources based on the circulating water use system and reducing the water losses incurred. One possible reason for the situation is the change in the sectoral GRP structure in favour of lesser water intensity.

To conduct computations of this kind in both current and strategic perspectives, it is necessary to create an effectively functioning system for the steady monitoring of information, to carry out analyses of the situation in the fields of allocation and utilisation of water resources.

A confirmation of the hypothesis on the conjunction of the GRP water intensity indicators and the dynamics of the regional socio-economic development, results in the important conclusion that it is necessary to adjust water resources management tools applied by the basin authorities and the regional management for the development of territories. These conditions are propounding new tasks that determine the directions of the authors' further scientific investigations oriented on research of the sectoral structure for water consumption and the GRP water intensity to reveal and identify factors, as well as to develop mechanisms to adjust the interests of water consumption entities to the position of conjunction for the 'basin' and 'region' approaches.

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