International Scientific Conference „Natural Disasters in the 21st Century: Monitoring, Prevention, Mitigation“
Proceedings, ISBN 978-9941-491-52-8, Tbilisi, Georgia, December 20-22, 2021

WATER DEFICIENCY IN EAST GEORGIA AND RECOMMENDATIONS FOR ADAPTATION

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Summary: *The objectives of the study are the assessment of water deficiency and desertification processes risks in East Georgia, planning of measures to reduce the losses and elaboration of adaptation recommendations. The specification of river runoff long-range parameters and features of their anticipated change has serious practical importance for water management calculations in scientific, design and commercial organizations to obtain reliable technical and economic grounding for water management constructions. They will greatly assist both the agrarian experts and designers, ecologists, etc. The implementation of recommended adaptation measures on the basis of river runoff projection will allow to slow down or stop desertification processes and avert the ecological peril. They are highly important and significant for the prevention of hazardous events at the background of progressing climate warming. Their application in practice will assist regional administration and land owners to timely implement corresponding preventive measures for neutralizing expected negative processes, reduction of losses and provision of environmental safety.*

Key Words: *Hazardous events, river runoff, water management.*

Introduction

Water consumption, as a key factor of country's environmental and economic development, has significantly increased in line with the growth of population, expansion of industry and agriculture, resulting in the decline of water resources. This process is substantiated by the global warming which has initiated acute water shortage in a number of regions of the world, causing the hampering of the development in many branches of economy. According to the UN experts` forecast, water consumption to 2025 will increase by 40% and 2/3 of the population may experience water deficiency that will provoke epidemics and mass mortality in underdeveloped countries.

The process of desertification at present is running rather fast than ever in history. The UN has declared desertification as a global problem being related with poverty and environmental changes. About 250 million people are in direct contact with problems of desertification and 1 billion are under its potential threat. More than 100 nations have signed the treaty according to which a global model to combat desertification should be worked out, along with regional models. Therefore, problems of water resources, their projection and rational strategy of water consumption are extremely urgent for today.

Study area and method

Georgia is reach in water resources, but they are distributed very unevenly at the territory. In this respect highly problematic is East Georgia where under the arid climate conditions the productivity of large areas of fertile soils is low without artificial irrigation. Here the 85% of Georgia's irrigated lands are disposed, while 77% of water recourses are concentrated in West Georgia and only 23% - in its Eastern part. At the same time, in contrary to the Western part, the rise in temperature and decrease of atmospheric precipitation is projected in XXI century in East Georgia that eventually will cause the decline of river runoff. This will very negatively affect the water provision of irrigation systems and related productivity of vegetation, efficiency of enterprises and hydropower plants (HPPs) [1].

Besides, as a result of intense droughts and anthropogenic loading the land erosion has been amplified in East Georgia. An area of more than 200 thousand ha is already damaged and 3000 ha are decertified. In this respect most vulnerable regions are: Outer Kakheti, Lower Kartli, Inner Kartli and partly South Georgia. If the necessary measures would not timely be taken here, the slow-down of desertification process in these regions will become more complicated and expensive in the future [2].

Ensuing from this, the assessment of risks to processes of water shortage and desertification at the territory of East Georgia, study of their development conditions regarding the upcoming climate change and anthropogenic impact is extremely topical. Thus, the objectives of the study are the assessment of water deficiency and desertification processes risks in East Georgia, creation of their projection models, planning of measures to reduce the losses and elaboration of adaptation recommendations. For reaching these goals the solving of following problems is necessary:

Provision, systematization and analysis of information sources and observation materials related with processes to be examined, anthropogenic, hydrological and meteorological factors causing them; description of phenomena connected to the studied processes in East Georgia, selection of characteristic region (river basin and section of the river) for the assessment of their development; specification of main features and calculation parameters of events to be studied and factors causing them for the selected region; examination of multi-year dynamics of events and factors to be studied, definition of their expected variability and development scales. Creation of river runoff long-range forecast model for different time intervals aimed at the provision of selected regions irrigation systems and HPPs with necessary data; working out of recommendations for the reduction of losses in case of the development of water shortage and desertification processes.

Under the conditions of limited hydrometeorological information on river runoff and its forming factors, for the projection of river discharge the multi-factor statistical model will be applied, in which from the existing complex of factors the predictors will be selected and the model will be adjusted using mathematical criteria and multi-stage sifting method. For the determination of numerical quality of optimal projection model the expansion of equation system with the gradual inclusion of factors, when the forecast information is reduced, prediction period is increased and accuracy is grown will be used [3, 4].

As e result the projection formulae are obtained containing different information on the river runoff in vegetation period (IV-IX), its separate quarters (IV-VI, VII-IX) and months, based on which the operational forecasts are issued annually both in single and several case regime, when additional information is included specifying the data. The provision of all kinds of mathematical calculations will be realized based upon unified computation principle using special computer program [5, 6].

Discussion

In the current conditions of global economic crisis and unemployment, Georgia's rural population is keeping its livelihood only by harvesting agricultural produce grown on its plots. Hence, it is highly important to guarantee systematic provision of these plots with water for irrigation. In East Georgia the vegetation, water-demand phases do not correlate with rainfall intervals. Therefore to secure harvesting a wide network of irrigation systems was operating here, destroyed since 1992, wind belts were logged out along with elements and registration of runoff at the rivers has been suspended [7].

Currently the revitalization of agriculture has started in Georgia accompanied with the restoration of irrigation systems, new hydropower plants are built. To provide the filling of their reservoirs it is necessary to define more exactly the discharge of rivers, determine their interannual distribution and variability, that has altered in connection with global warming [8].

In terms of agricultural production volume Kakheti is the leading region. However the plant productivity here is highly vulnerable to weather and climate changes. According to computations performed with the modern climate models it has been established that compared to 2010, the mean annual temperature at the territory of Kakheti will increase by 1.1 °C to 2050 and by 3,5 °C to 2100, while the atmospheric precipitation would change slightly (by ± 5%) to 2050, but decrease by 10-20% to 2100. In such conditions the demand on irrigation water will grow [9].

In Kakheti the irrigation water is provided from the river Alazani. Hence, up to now it is highly urgent to assess its irrigation potential. Ensuing from this, the main problem in the project is the specification of r. Alazani's runoff parameters and definition of its expected variations, that will allow to work out concrete recommendations for the correct determination of water consumption regime. The norms of mean annual, vegetation period quarter and separate months runoff are specified.

Kakheti vast fertile valleys are irrigated from river Alazani water with the biggest irrigation system constructed on it (in Georgia) and composed of two – upper and lower Alazani magistral channels. The upper magistral canal takes start from the upper part of the river, near hydrological post in village Birkiani, where natural river runoff used to be measured earlier. 76 thousand hectares of land are attached to it for irrigation. The lower magistral canal begins at presently operating post near village Shaqriani and it irrigates 262 thousand hectares of arable. There bas been ascertained the vegetation period of river according to individual months, quarters, maximum and minimal water discharge, extremes, alteration and other statistical qualities – Table 1.

In order to evaluate the impact of climate warming and man-made factors, dynamics of multi-year fluctuation of maximal and minimal runoff, also different intervals of annual and vegetation period of river Alazani water have been studied. Relevant trends have been developed and equations made reflecting their rectilinear approximation, parameters of which are provided in table 2. Their analysis show that tendencies of the change in river Alazani water runoff vary at different periods. This can be explained by diversity of watery tributaries (flowing into the river before these cross-sections) and their regimes, conditioned by natural conditions in these basins.

Table 1. Features of under discharges (Qm^3/s) of the Alazani river

Estimated Period	IV- IX	IV	V	VI	VII	VIII	IX	IV-VI	VII-IX
r. Alazani – Birkiani F = 282 km^2, H = 2200 m, Q_0 = 13.9 m^3/s									
Average	20.4	16.7	26.8	27.7	22.3	15.4	12.	23.7	16.8
Part, % Q_0	73.0	10.1	16.4	16.4	13.6	9.0	7.5	43.1	30.2
Greatest	32.0	27.6	42.7	57.2	51.1	31.0	26.	39.4	27.1
Least	13.4	8.16	17.8	13.5	12.4	7.98	5.9	15.7	9.48
r. Alazani – Shaqriani F = 2190 km^2, H = 1260 m, Q_0 = 45.7 m^3/s									
Average	62.0	70.3	94.0	80.2	52.4	37.0	37.	81.5	42.3
Part, % Q_0	69.4	12.9	17.3	15.1	9.9	6.9	7.0	45.4	24.0
Greatest	128	120	246	223	112	109	117	176	91.3
Least	36.5	25.0	32.4	31.3	15.8	5.72	9.2	40.4	14.4

Trend equation of descending (drop) tendency of natural runoff (Q m^3/wm) of river Alazani vegetation period is presented as follows:

$$T_Q = - 0{,}0084 N + 20{,}642, \qquad (1)$$

Along with such water deficit in the vegetation period, river Alazani runoff in fall-winter and spring flooding periods is left unused, as water consumption is minimal in this period. This remained water volume is big enough and its accumulation in specific water reservoirs makes it possible to avoid deficit of irrigation water in the vegetation period [10, 11]. In order to economically and rationally manage utilization of the existing water resources of river Alazani in the vegetation period, their forecast is required for different time intervals. River runoff is a complex dynamic process conditioned by multiple factors. But, for forecasting purpose can be used only those that are subject to standard observations and provide operative information.

Table 2. Parameters (a and b) of trends' equations ($T_Q = aN + b$) of river Alazani water discharge periods

Periods of the water discharges	Months	Village Birkiani 1950 – 1996		Village Shaqriani 1933 – 2010	
		a	b	a	b
Annual	I-XII	−0.002	13.98	0.050	43.79
Maximum	max	−1.079	98.42	−1.184	347.8
Minimum	min	0.019	3.731	−0.126	20.44
Vegetation	IV-IX	−0.008	20.642	0.031	60.80
April	IV	0.004	16.64	0.337	57.29
May	V	−0.058	28.23	0.060	90.44
June	VI	−0.009	27.90	−0.015	80.79
July	VII	−0.041	23.30	−0.014	53.00
August	VIII	0.094	13.13	−0.005	37.20
September	IX	0.005	12.60	−0.036	39.01

In our case, existing information on atmospheric precipitations (R mm), air temperature (θ, °C) and water-consistency of snow (W mm) have been used for forecasting of river water runoff (Q m^3/sec) in river Alazani basin and an enlarged forecast model has been developed, in which separate previous period factors are broken down into different period indicators, thus, impact of their dynamics is envisaged for future runoff. For example, precipitations at fall, winter and spring have diverse impact on the vegetation period runoff. So, it is not expedient to imagine their total sum in this forecast model [3, 4].

Based on the available data and correlation analysis, we revealed the most effectively operating previous period factors and developed a multi-factor forecast model by using them. But, many variables in the forecast model reduce sustainability of the equation, that's why, by specific mathematical criteria and multi-pitched screening method, we corrected the model based on the principle: maximal accuracy with minimal factors [5]. Thus, we developed optimal forecast models by taking into account up to 3-4 factors.

In the process of determination of numerical quality of forecast dependencies, two equation systems are discussed by gradual adding of separate factors, when direct and reversed break down of multi-factor equation is done [6]. In order to plan the rational use of existing water resources for the irrigated agriculture, water discharge forecasts of the whole vegetation period (IV - IX) as well as of its separate quarters (IV - VI and VII - IX) is required (table 3).

Table 3. Forecast equations of river Alazani water average discharge (Q, m^3/sec) of the vegetation period (April-September) and its separate quarter; their assessment criteria

Forecast Equations	**Assessment criteria**			
	s / σ	**P %**	**r**	**Э %**
r. Alazani – Birkiani F = 282 km^2, H = 2200 m, Q_0 = 20.4 m^3/s				
$Q_{IV\text{-}IX} = 0.04\ R_I + 0.60\ Q_{III} - 0.75\ \theta_{IV} + 10{,}52$	0.72	61	0.72	61
$Q_{IV\text{-}VI} = 0.03\ R_I + 1.1\ Q_{III} + 0.10\ R_{II} + 11{,}1$	0.65	73	76	68
$Q_{VII\text{-}IX} = 0.21\ Q_{VI} - 1.05\ \theta_{VI} + 25.3$	0.79	60	0.63	65
r. Alazani – Shaqriani F = 2190 km^2, H = 1260 m, Q_0 = 62.0 m^3/s				
$Q_{IV\text{-}IX} = 0.48\ Q_{II} + 0.27\ R_{II} - 0.53\ Q_{III} + 0{,}09\ R_{IV} + 44.5$	0.84	68	0.63	67
$Q_{IV\text{-}VI} = 0.34\ R_{III} - 3.36\ \theta_{III} + 0.12\ W_{III} - 58{,}4$	0.73	71	0.74	63
$Q_{VII\text{-}IX} = 0.13\ Q_V + 0.12\ \theta_{VI} - 0.34\ Q_{VI} + 0.19\ R_{VII} + 22.4$	0.73	75	0.71	69

Comment: s / σ – correlation between the forecasts' error and average square deviation of the runoff; P % – forecast prediction reliability; r – correlation between the actual and forecast meanings; Э % – economic effectiveness of forecasts. Forecasts are permissible, when: (s / σ) < 0.80; P > 60; r > 0.60; Э > 50.

Forecasts of II quarter (IV - VI) are exceptional by their accuracy, which is very important as this is the quarter when biggest spring floods occur in this river and often create danger to the environment and the population. That's why, these forecasts have two-fold designation. The economic effect received using the developed forecasts exceeds by 10-35% the effect received using the forecast discharge norm. Now, we may say that their application in practice with the purpose to serve irrigation systems and channels, gives possibility to rationally use and appropriately plan the existing water resources of river Alazani – this will increase productiveness of agricultural crop.

Conclusion

Based on the forecast calculations, by the end of the 21st century, due to significant temperature growth (up to 5 °C) as well as increased evaporation from the surface of river Alazani basin, river runoff will decrease by 8,5% compared to the second half of the 20th century [9]. Similar conditions are favorable to frequent drought processes in Kakheti region and the desertification process. For mitigation of negative results of the expected droughts, it is required to use river Alazani runoff in an optimal regime without losses. This requires specific measures:

- Rehabilitation and expansion of water systems, cleaning, restoration and reconstruction of irrigation channels;

- Putting the pumping stations in operation for additional supply of channels with water;
- Development and introduction of optimal water distribution/utilization time-tables for water consumers;
- Accumulation of unused water (of fall-winter and spring floods) in small reservoirs for further utilization during the irrigation water deficit in summer [11];
- Creation of a drip irrigation network; this will increase yield and use less water compared to surface irrigation [12];
- Introduction of a pivot irrigation with those equipment that can be used in huge inclinations and complex relief [13];
- Restoration of windbreak lines in agricultural fields and introduction of drought-resistant varieties;
- Planting of trees on slopes of river ravines;
- Introduction of an active impact on clouds, during which, atmospheric precipitations increase and plants get protected from hail [14];
- Raising awareness of population and farmers to moderately and economically use water resources;
- Annual long-term forecast of river Alazani water discharge for separate intervals of vegetation period (quarters, months and decades). As a result of the planned water consumption regime (and taking into account the water prognosis), the right time for river water irrigation will be determined, as well as timeline for putting the pumping stations in operation, using pivot irrigation systems or increasing precipitations by impact on the clouds [15].

Implementation of the mentioned measures will slow down and suspend desertification process, fight against drought, increase crop productivity and improve economic condition of the population.

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