MINISTRY OF AGRICULTURE AND MELIORATION
OF THE KYRGYZ REPUBLIC

DEPARTMENT OF WATER MANAGEMENT
AND MELIORATION

NATIONAL POLICY DIALOGUE ON
INTEGRATED WATER RESOURCES MANAGEMENT
IN KYRGYZSTAN

MODERN IRRIGATION TECHNOLOGIES AND POSSIBILITY OF THEIR APPLICATION IN KYRGYZSTAN

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Acronyms and abbreviations

ARIIARW	All-USSR Research Institute for Integrated Automation of Reclamation Works
CNiP	Construction codes and performance requirements
CoE	Coefficient of Efficiency
DWMM	Department of Water Management and Melioration, under the Ministry of Agriculture and Melioration of KR
EUWI	European Union Water Initiative
FAO	Food and Agricultural Organization of the United Nations
GEF	Global Environmental Facility
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit, GmbH
ICID	International Commission on Irrigation and Drainage
IFAS	International Fund for saving the Aral Sea
IWRM	Integrated Water Resources Management
IWRMP	"Improvement of Water Resources Management" Project, WB
KGS	Kyrgyzstani som
KIA	Kyrgys Institute of Agriculture
KR	Kyrgyz Republic
KRII	Kyrgyz Research Institute of Irrigation
LSG	Local self-government
MAM	Ministry of Agriculture and Melioration of the KR
MDG	Millennium Development Goals
MO&M	Management, Operation and Maintenance
MTS	Machinery Test Station
NPD	National Policy Dialogue
NSC KR	National Statistical Committee of the KR
OECD	Organization for Economic Cooperation and Development
PIS	Payment for irrigation water supply services
SDC	Swiss Developemnet and Cooperation Agency
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UWUA	Union of Water Users Association
WB	World Bank
WUA	Water Users Association

Foreword

This report was prepared as part of the EU Water Initiative National Policy Dialogue (EUWI NPD) on Integrated Water Resources Management in Kyrgyzstan with funding from EU and with technical support from the UN Economic Commission for Europe (UNECE).

The basis for work was the order of the Government of Kyrgyzstan on the need to implement a set of measures aimed at improving irrigation technologies and introduction of effective methods of crop irrigation, including drip irrigation.

Report provides an overview of the current state of agriculture and irrigation sectors of Kyrgyzstan, the analysis of experience in application of different irrigation methods in the Republic. These sections were prepared by Kirill Valentini on the basis of synthesis of materials, contained in reports of the National Experts Valery Gutnick, Amanjol Atakanov, Payazidin Zhooshev, and Gulmira Adzhygulova. Section containing a summary of international experience of development of advanced technologies of agricultural crops irrigation has been prepared by Yakov Lev, the international consultant hired by UNECE. Recommendations for introduction of advanced irrigation technologies in Kyrgyzstan were developed jointly by the National Experts and international Consultants. Erkin Orolbaev has coordinated the work of Project experts and consultants. Peep Mardiste has carried out general oversight of the Project on behalf of the UNECE.

It is expected that the main conclusions of the report can be used in planning of activities on introduction of advanced technologies of agricultural crops irrigation in Kyrgyzstan.

Figure 1. Map of Kyrgyzstan

Source: UN cartographical section, 2009.

I. Summary of current situation in Kyrgyzstan

1. Geography and climate

The Kyrgyz Republic (Kyrgyzstan, KR) is located in the north-east of Central Asia. Its territory covers an area of more than 0.199 million km². The length of the territory from west to east is 900 km, and from the north to south is 450 km. Kyrgyzstan has common borders with the Republic of Kazakhstan, the People's Republic China, the Republic of Tajikistan, and the Republic of Uzbekistan (Figure 1).

Kyrgyzstan has mostly mountainous landscape. The average altitude of the country' territory is 2,750 m above the sea level with the highest point at 7,439 m (Pobeda Peak), and the lowest is 394 m (in the south-west of the country). Mountain ranges cover about a quarter of the territory and extend by parallel chains mainly in the latitudinal direction. About 94% of the country is located at the marks higher than 1,000 m above the sea level and only 20% of territories are the areas with relatively comfortable living conditions. In this zone resides the most part of population, as well as the economic activity is mainly concentrated.

The location of Kyrgyzstan in the center of Eurasia, its remoteness from the oceans and seas, as well as the neighborhood of deserts predetermines formation of continental arid climate with clearly defined seasons of the year. Most of the territory of the Republic is located in a temperate climate zone, and only the southern areas are in a subtropical climate zone. Average temperatures: in January from -1°C to -8°C in the valleys and up to -27°C in the highlands; in July from +20°C to +27°C in the valleys and up to +5°C in the highlands. Annual precipitation ranges from 180 mm in the East to 1,000 mm in the South-west of the country.

2. Population and workforce

According to data of the National Statistics Committee (NSC KR) as of October 2014 the population of Kyrgyzstan is 5,863 million people. The population density is about 29 people / km². Approximately 66% of the population resides in rural areas. Economically active population in rural areas is 1.6 million people, from which 1.5 million or 94% employed. From the total size of employed population the share of people engaged in enterprises and institutions is 31%. The 21.5% of total employed population is workin in farms, and 14.5% is working for individual enterprises. 147.7 thousand people are working on the personal subsidiary plots. The rural population resides in 440 rural communities, including 1,871 villages.

The employment rate of the population of Kyrgyzstan as a whole is about 60%. The total number of officially registered unemployed people in the country is 210 thousand people, including 102.9 thousand people in rural areas. According to the data of the Ministry of Labour, Migration and Youth of the Kyrgyz Republic, for today, the number of employees in the foreign labor market amounts to 591.6 thousand people, or 25.9% of the total number of employees. In total, according to the book "On the migration statistics in Kyrgyzstan" (April 2014), for the period from 1991 to 2013 external migration of the population of the Kyrgyz Republic amounted to 0.73 million people, from them 81% - persons of working age. The main directions of migration flows are the Russian Federation and Kazakhstan. In recent years the character of outflow of Kyrgyz citizens, including native population, more and more becomes not labor migration, but rather irretrievable export of population. The impact of migration processes on macroeconomic indicators of Kyrgyzstan is confirmed by the statistics: of the total income of country population 30% are remittances from migrants.

Estimates of the NSC KR ("Kyrgyzstan in Figures", 2014) and the World Bank as of the end of 2014 show that for today 37-38% of the population live below the poverty line, including 72% of the rural population. According to data for January-October 2014, the average salary in Kyrgyzstan was 11.984 thousand KGS (excluding small businesses); while in agriculture it does not exceed 3.347 thousand KGS. For comparison: the minimum consumer basket for the third quarter of 2014 in Kyrgyzstan was 4.958 thousand KGS, while the subsistence level was 5.011 thousand KGS[1]. It should be noted that in the Governmental Decree as of 14.08.2014, No 469 "On the forecast of socio-economic development of the Kyrgyz Republic for 2015 and 2016-2017", there was provided for an annual growth of nominal GDP by 6-7% and the gradual increase of real income of population from 1.2 to 4.7% per year. The growth rate of production in the agricultural sector was expected on the level of 2-3% per year. These indicators are to be achieved under the following favorable external impact factors:

- Political stability in the regions and countries – the main trade partners of the Kyrgyz Republic;
- Gradual strengthening of the global economy with projected growth to 4%;
- Projected economic growth in the neighboring states - Russia (2%), Kazakhstan (7.1%), and China (7.3%);
- Moderate growth of inflation in the countries – the main trade partners of the Kyrgyz Republic: in Russia (4.5-5.5%), Kazakhstan (6.0-8.0%), and China (3.0%);
- Development of foreign economic cooperation in the framework of the Shanghai Cooperation Organization (SCO) and the Eurasian Economic Community;
- Projected stabilization of world oil prices at the level of US $100-105 per barrel;
- Strengthening the global trends of investments in innovative technologies.

However, a number of well-known political events that occurred in the world during 2014, has led to a significant change of the previously established global economic trends, and had a negative impact on the socio-economic development of the Central Asia countries, including Kyrgyzstan. In this connection, it is appropriate to expect that the previously worked out short-term forecasts of the Kyrgyz Republic development, including the expected volume of investments for development of the national agricultural sector, will be reviewed on the basis of more moderate performance indicators.

3. Land resources

According to official data of the Department of cadastre and registration of rights in real estate of the Kyrgyz Republic, the total area of land within the State borders of the Republic is 19,995 million hectares.

Distribution of land resources according to the collection of the National Statistical Committee of the Kyrgyz Republic "Kyrgyzstan in Figures" (2014) is shown in Figure 2.

[1] Note: In accordance with the structure of a subsistence level, approved by the Government Decree No 694 as of 06.11.2009, the share of food products is 65%, non-food products - 16%, services - 17%, and tax - 2%.

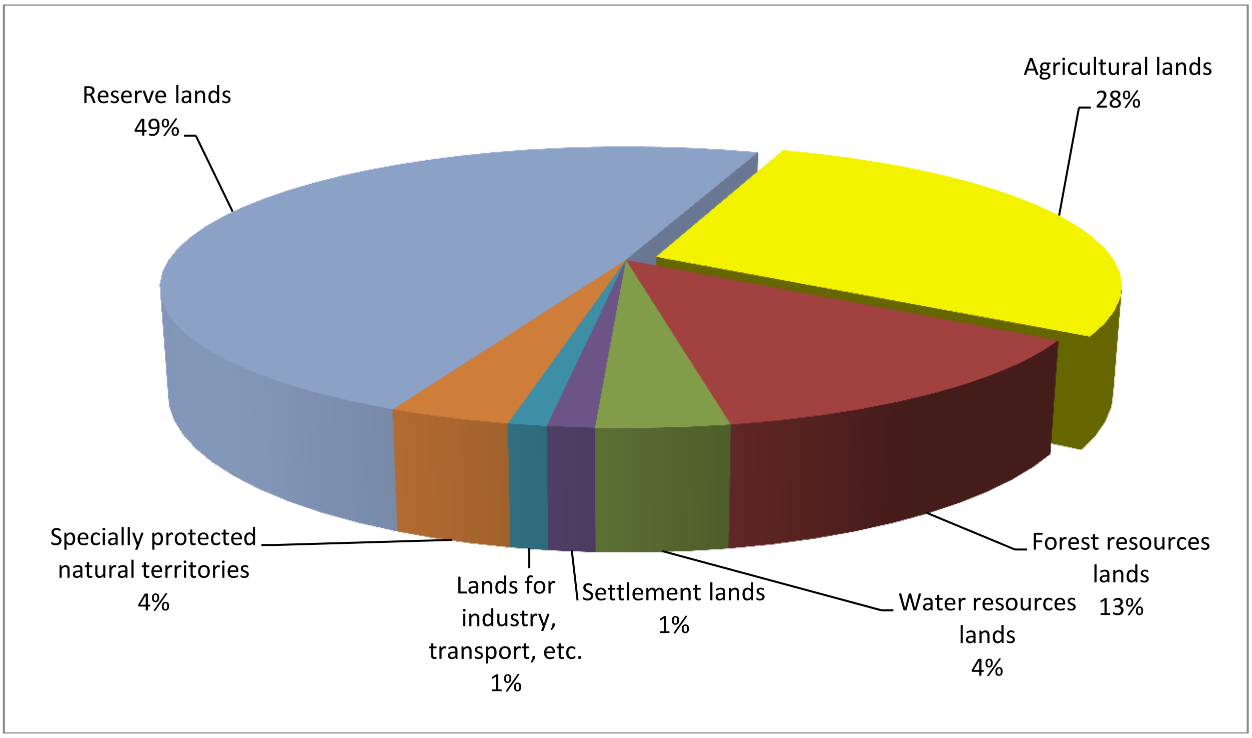

Figure 2. Distribution of land resources of the Kyrgyz Republic by land categories

Of the total area of agricultural land, 1.064 million hectares is owned privately and 4.611 million hectares is owned by the State. The total area of land belonging to different categories of land in the Republic and suitable for agricultural development is about 10.8 million hectares, of which about 9 million hectares can potentially be used as pasture and about 1.5 million hectares as and arable land. Pasture resources and natural hayfields occupy about 50% of the total country territory, or about 90% of all agricultural lands. Actually, in Kyrgyzstan about 1.28 million hectares of arable land is developed or 7% of the total area. However, according to the data of collection of the National Statistical Committee of the Kyrgyz Republic “On the state of agriculture in the Kyrgyz Republic in 2009-2013”, in 2013 all cultivated arable area occupied by crops amounted to 1,170.4 thousand hectares, being slightly increased by 0.3 percent compared to 2009. The average size of arable land in peasant (farmer) facilities in Kyrgyzstan is only 2.7 hectares, including 1.9 hectares of irrigated arable land.

The modern structure of assignment of the arable land to business entities is shown in Figure 3.

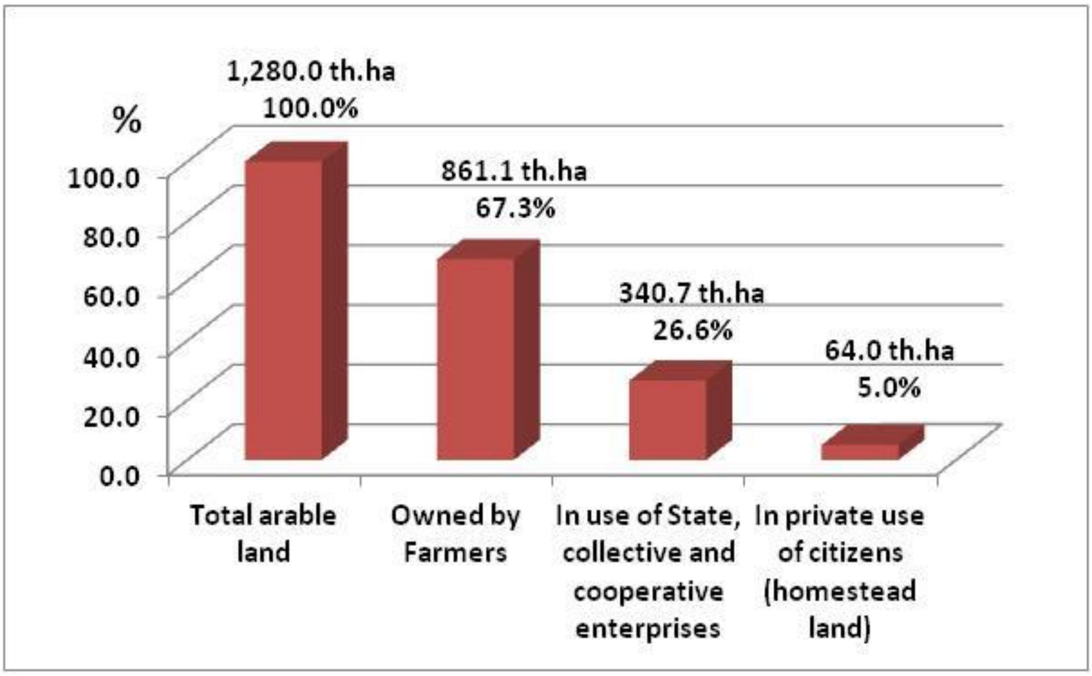

Figure 3. Distribution of arable land among business entities in agriculture (in thousands hectares and %)

To date, 1.035 million hectares of irrigated land is developed in Kyrgyzstan. It means that more than 70% of total area of currently used arable land depends on irrigation. Irrigated lands give more than 90% of agriculture products, and relate to the strategic natural resources of the Republic. According to the various expert estimates, in perspective in Kyrgyzstan the area of irrigated lands can be increased to 1.5-2.3 million hectares. However, the design of these predictions, as a rule, does not provide justification for possible attraction of additional water resources of about 2-6 km³ /year for irrigation of these lands. Therefore, the "National Strategy for Sustainable Development of the Kyrgyz Republic for 2013-2017 years" approved by the Presidential Decree as of 21.01.2013, provides for a very limited development of new irrigated areas of about 50 thousand hectares in the short term perspective. However, the possibility of realization even of this goal currently seems highly questionable, based on the deterioration of the macroeconomic situation in the country.

Crop productivity sector significantly depends on the quality of land resources. The continuing trend of land degradation currently is a serious socio-economic and environmental problem in the Republic. According to the State Register of the Kyrgyz Republic, by the end of 2013, the differentiation of degraded agricultural lands was as follows: saline soil -1,180.8 thousand hectares; alkaline soil - 471.2; swamp lands - 118.6; stone lands – 4,021.2; wind erodibility – 5,689.8; water erodibility – 5,626.8 thousand hectares. At present, of the total area of irrigated lands, 220.0 thousand hectares are saline in a varying degree; 81.8 are alkaline; 33.1 are swamped; 196.1 are stony; 651.1 are wind erodible; 764.8 thousand hectares are water erodible. It is already practically impossible to get any harvest on the saline and alkaline lands. Within the country territory, the area of irrigated lands in submontane zones, which are exposed to wind and water erosion, is more than 700 thousand hectares. In general, at present in the Republic of the total area of irrigated lands 864.5 thousand hectares are in good condition; 61.8 thousand hectares are in satisfactory condition; 96.7 thousand hectares are in unsatisfactory condition, including due to close groundwater occurence - 38.0 thousand hectares; salinization of soil - 51.4 thousand hectares; and in a complex of both close groundwater occurence and salinization - 7.3 thousand hectares. Area of disadvantaged soil-reclamation lands is 96.7 thousand hectares; 23.4 thousand hectares of irrigated land are prone to overgrowing with reeds; in total 215 settlements are impounded.

The main indicator of soil fertility – humus - continues to decrease as a result of erosion and non-application of appropriate doses of organic fertilizers. Removal of humus from arable horizon by plants, according to various estimates, is between from 20 to 45%. Actual loss of crop yield on exhausted, waterlogged, saline and alkaline soils ranges from 10-20 to 70-80%.

4. Water resources

In the aggregate of current estimates, the total amount of water resources of Kyrgyzstan (Figure 4) is about 2,458 km³, including 650 km³ of water in glaciers; 1,745 km³ in the lakes, as well as 13 km³ of potential groundwater resources, and from 44.5 to 51.9 km³ of Annual River flow. Kyrgyzstan ranks the second place in Central Asia by the specific indicators of reserves of water resources per capita.

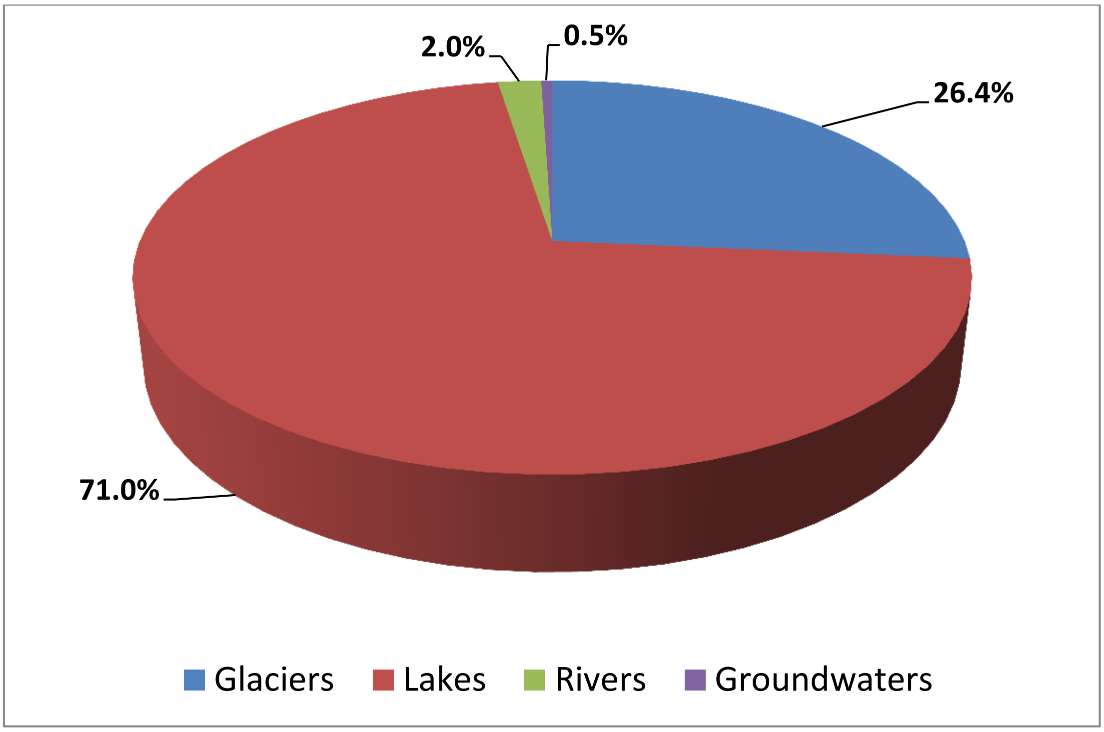

Figure 4. Water resources of Kyrgyzstan

The total area of glaciers is more than 8 thousand km² or 4.2% of the country territory. In recent decades the fresh water resources in the mountain glaciers are permanently reducing due to the global warming processes. The most significant storage of fresh and slightly saline water resources is concentrated in the lakes, mostly in the Issyk-Kul Lake. On the territory of the Republic there are more than 3,500 rivers that belong to the large water basins of the Syr Darya, Amu Darya, Chu, Talas, Ili, Tarim Rivers, and the Issyk-Kul Lake. Although the vast majority of surface waters are formed on the territory of the country, for the domestic water consumption needs is used no more than a quarter of river flow annually; the rest of flow ingresses to the territory of the neighboring States. Average perennial volumes of return waters are weakly studied and estimated approximately as 3 km³ / year. Volumes of collector-drainage waters are estimated as insignificant and do not exceed 1.3 km³/year. The annual volume of wastewaters is 0.71-1.02 km³/year (excluding wastewater discharges from decentralized wastewater systems in rural areas). On the country territory 106 deposits of fresh groundwaters were revealed, and 20 of them are used for household-drinking and industrial water supply. At present 44 underground water deposits are studied in detail, which have potential reserves of fresh water of 11 km³/year and useful groundwater storage of 5.3 km³ / year, including by industrial categories - 2.2 km³/ year. In general, except for local areas in the southern regions, the Republic is provided with drinking water storage for the long term perspective.

Surface water resources are distributed unevenly over the territory of the Republic. In the south of Kyrgyzstan – in Osh, Jalal-Abad and Batken Oblasts – 28.5 km³ of waters are concentrated; in the Issyk-Kul Oblast - 11.7 km³; in Naryn - 13.9 km³; in Talas - 17.5 km³; and in Chui - 4.6 km³ of waters are concentrated. Up to 90-92% of the water resources demand of the Republic is met at the expense of surface waters; including in the Issyk-Kul Oblast - 95.6%; in Naryn - 98.1%; in Osh, Jalal-Abad and Batken - 89.1%; in Talas - 97.7%; and in Chui Oblast - 93.4%.

At the average, the total volume of annual consumption of water resources in the Republic is estimated on the level of 10-12 km³ / year. However, after 2010 the total volume of water intake, according to official statistics, has decreased to 8.10 km³ / year. Groundwater use has also decreased from 1.0 to 0.2-0.3 km³ per year. This was due to not only the reduction of volume of surface water runoff because of the climate change, but also because of slowing the pace of development of water-using industries and, to a large extent, because of degradation of the monitoring system of water management in the country.

The structure of domestic water consumption in Kyrgyzstan remains sufficiently stable for many years and does not involve significant changes in the medium term perspective. At the average, about 90-93% of the water volume is annually used for the needs of irrigated agriculture; about 6% - for water supply to the population and industrial production demands. Forestry, fisheries, energy, and other water-using sectors of economy, together with service industries use about 1% of the total domestic water consumption.

In recent years, everywhere there is an increase of water losses at all levels of communication, from the point of water intake to the end water users. Basically, this is due to the deterioration of technical condition of waterworks infrastructure and disordered water use. The ratio between the amount of total water consumption and water intake from natural water sources, which characterizes the efficiency of water use, has changed from 0.8 in 1991 to 0.6-0.7 in 2005-2013. Loss of water in irrigation systems, in the aggregate of various data and expert estimates, is about 40% of the total water intake[2]. For comparison, similar current figures in Uzbekistan are 33%, in Turkmenistan - 34%, in Kazakhstan – from 30 to 60%. The total average annual loss of water in the country is estimated at about 2.4 km³ / year, but these figures seem to be not sufficiently reliable and are significantly underestimated.

In general, the current quality of water resources in Kyrgyzstan is assessed as satisfactory. No trends of significant deterioration of water quality were observed over the past decade. However, water resources in the basins of the Chu River and rivers in southern regions of the Republic are most subjected to contamination. There are regularly registered local pollutions of surface and ground waters near major settlements. The main sources of water pollution are agriculture and industry enterprises, municipal sewerage systems and domestic wastes of population. Potential threat to water resources is represented by mining dumps

[2] Resolution of the Government of the Kyrgyz Republic “On approval of priority lines of adaptation to climate change in the Kyrgyz Republic until 2017”.

located in the debris cones and in high-water beds, where radioactive, cyanogen-contained substances and salts of heavy metals are utilized.

Significant factors that negatively affect the quality of water resources are disordered economic activity in water protection zones and belts of surface water bodies, as well as the poor state of sanitary protection zones of groundwater deposits.

II. Characteristic of current state of the agrarian sector of Kyrgyzstan

1. Role and input of agrarian sector in the National Economy

At present the agrarian sector of Kyrgyzstan continues to maintain a leading position among the sectors of national economy, although its relative contribution to the gross domestic product of the country has significantly decreased in recent years. Thus, according to preliminary data of express information of the NSC KR "Socio-economic development of the Kyrgyz Republic in 2014", in general, so far there is a positive evolution of the gross domestic product (GDP), which is actually increased by 3.5% compared with 2013. The share of different industries in the total GDP of the country is as follows (Figure 5):

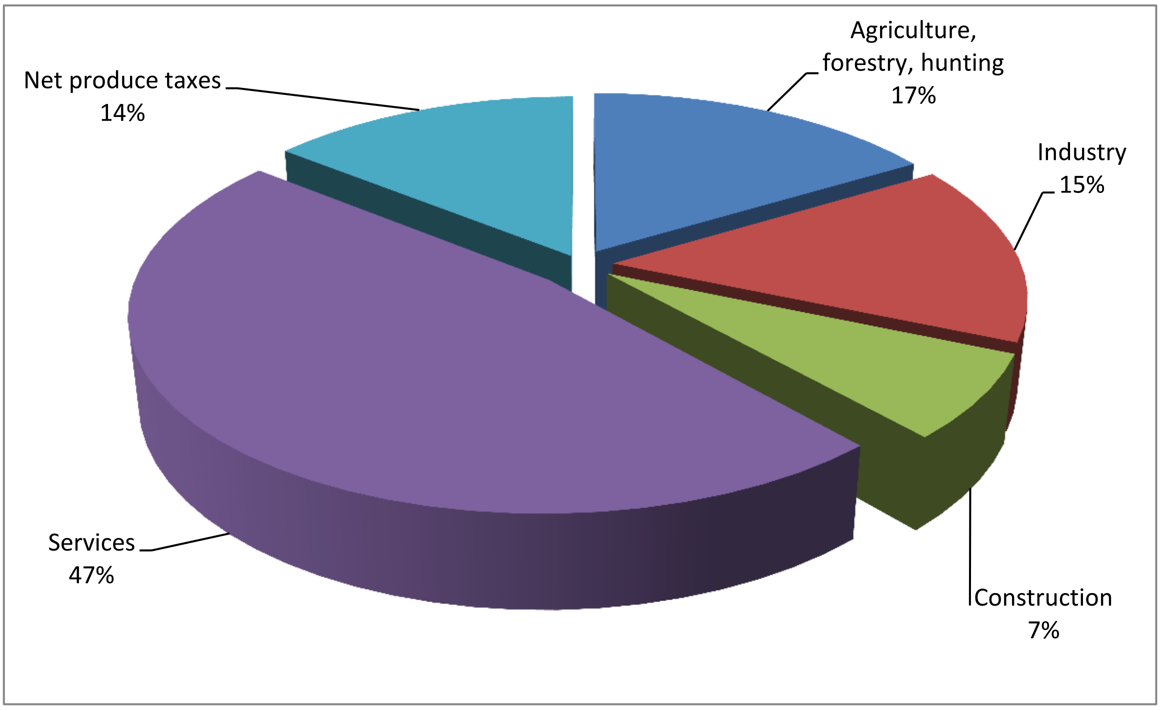

Figure 5. Structure of GDP of KR at the beginning of 2015 (in %)

It should be emphasized that the specific contribution of agriculture in total volume of GDP in recent years has steadily decreased and eventually dropped from 53.1% in 2000 to 16.4% in 2014. Only for the period of January-November 2014 it was noted a further decline of gross agricultural production by 0.8%, primarily due to reduction in crop production by 4.6% compared with 2013. At the same time, the relative contribution of each of the key industry sub-sectors in total production slightly changed in recent years and, according to data of the National Statistical Committee of the Kyrgyz Republic ("Kyrgyzstan in Figures", 2014.), has formed as follows (Figure 6):

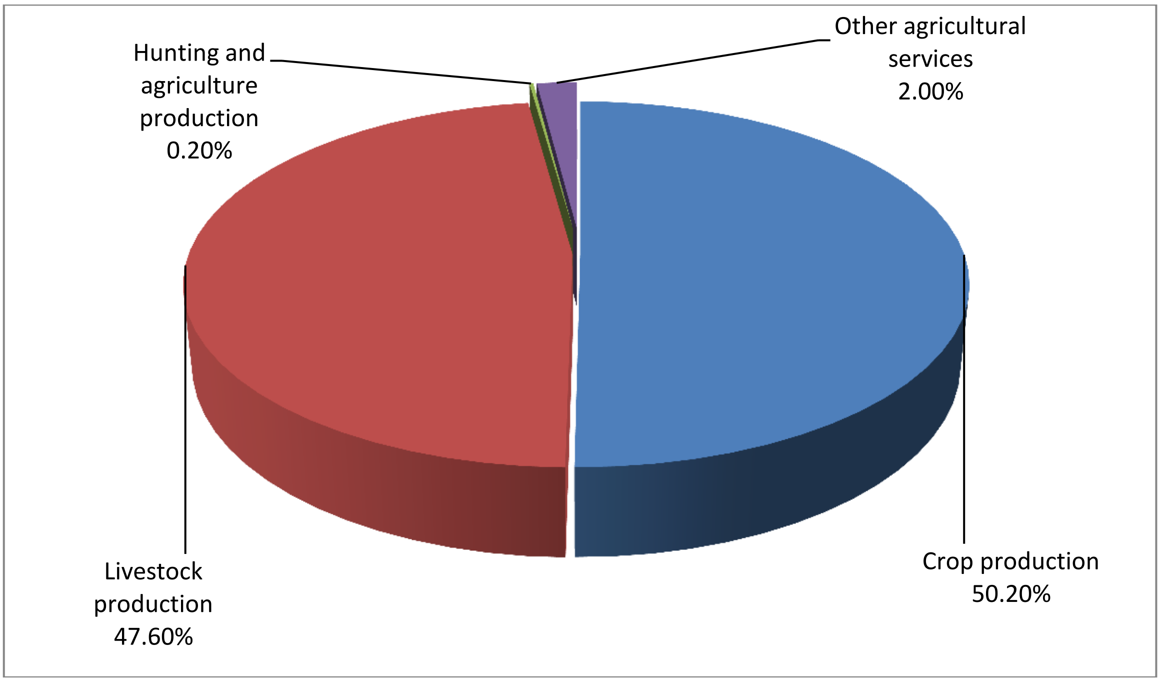

Figure 6. Structure of farming industry in KR in 2014 (% of total cost of produce)

In recent years the signs of stagnation of farming industry in the Kyrgyz Republic have been clearly manifested, especially in the sub-sector of crop production, which led to increased risks in the area of national food security, as the saturation of domestic market with foodstuffs is increasingly dependent on import. To substantiate this conclusion, it should be primarily noted, that at present in Kyrgyzstan about half of the estimated basket of goods (48.1%) are food products, and in accordance with the approved structure of the subsistence level, the share of foodstuffs is slightly higher than 65%. (For comparison, in economically developed countries, on average, the share of foodstuffs in the basket of goods is about 13%).

Summarizing the official statistics data of the NSC KR and evaluation of a number of independent experts, it is possible to conclude that in the period from 2011 to 2014 domestic food market nearly for 50% is formed at the expense of imports (on extreme estimates - up to 65%!), while provision of internal market with its own production by key positions were as follows:

- Grain and grain products 60-63%;
- Meat 57.8-74%;
- Vegetable oil 20-34%;
- Sugar 10-13%;
- Eggs 38-40%;
- Fruit and berries 22-24%.

In general, according to the statistical reporting of the Ministry of agriculture and melioration of the KR for 2013, the share of imported food industry products (including raw materials) has amounted to 14.2% of total import volume, while the cost of imported agricultural and food products exceeded the cost of corresponding export to 3.8 times.

However, despite the multiple increasing of import volume, the real level of food consumption in Kyrgyzstan remains at about 75% of the standards recommended by the Food and Agricultural Organization (FAO) and 25% of Kyrgyzstan's population is systematically undernourished. There are serious imbalances in the structure of food consumption, where the share of carbohydrates and fat clearly predominate, while proportion of proteins is insufficient, in particular, meat and dairy products. For example, at present the population' demand for meat is satisfied for 40%; for milk - 66%; for eggs - 19%; and for fish - only for 2%. At the same time, it should be noted that production of livestock products to a large extent depends on quality of forage resources, and hence on the effectiveness of crop production sub-sector on the basis of irrigated agriculture.

Returning to the above statistics, it is possible to foresee reasonable doubts on the reliability of some these data, for example, about the provision of market at the expense of domestic production of fruit and berries only at the level of 22-24%. While it are exactly these products of Kyrgyzstan that traditionally always were in high demand, and at present the country's population consumes only about a quarter of the volume of these products produced in the Republic. This situation is explained, first of all, by the weak development of logistics infrastructure and sustainable markets in Kyrgyzstan. As a result, according to data of the Ministry of Economy of the Kyrgyz Republic, at present only 12% of the volume of grown agricultural products is processed in the country and its total losses during collection, transportation and storage are estimated at least for 30-40%. Against this background, the regular statements in the news like: *"... at present our farmers and peasants lose most of their harvest of fruit and vegetables, and it just rots on the fields! ... At present the markets of Kyrgyzstan are full with imported tangerines, grapes, apples, bananas and other fruit from China, Uzbekistan and even Morocco and Argentina, while our gardeners and farmers can barely make ends meet ... Farmers are doomed to a miserable existence, but the domestic market is filled with the foreign fruit of unknown quality, Iranian tomatoes, Turkish beans, Chinese kuksi, etc."*, seems very appropriate.

Steady increase of the wholesale and retail prices for food products is the consequence of weak saturation of the consumer market with home-produced goods. In addition, the price movement is under considerable pressure of key factors such as impact of the global markets, seasonal fluctuations in supply and demand, rising prices for fuel and lubricants (FaL), inflation, and (especially at the end of 2014) the sharp depreciation of the Kyrgyz Som[3] and the Russian Ruble against the US dollar. In general, over the previous five years, the wholesale prices for major agricultural products in Kyrgyzstan increased on average for one and a half time (see Table 1).

Table 1. Average producer prices for the main types of agricultural products sold for the period 2009-2013 (KGS / tonne)

Name of product types	**Years**				
	2009	**2010**	**2011**	**2012**	**2013**
Grain	13,676	11,807	17,903	19,450	21,538
Potatoes	11,651	9,858	14,342	10,799	16,152
Fruit and berries	26,230	30,191	33,283	31,426	33,802
Livestock and poultry in live weight	82,471	87,672	132,081	146,275	140,486
Raw milk	14,461	13,170	15,461	18,040	19,651
Eggs (for 1,000 pieces)	5,082	4,607	5,254	5,974	6,846

[3] By the beginning of 2015, $1 US was approximately 61.00 KGS

Wool	26,749	24,464	36,523	44,952	34,002

Source: Collection of the National Statistical Committee of the KR "Agriculture of the Kyrgyz Republic", 2014.

However, preliminary reporting data of the NSC KR demonstrate even sharper rise in prices of all products for about 20-25% in 2014. At the same time, for the period of January-November 2014, as compared to December 2013, a higher increase was in food prices - 11.6%, including the prices of bread and cereals - 12%; of vegetables - 25.8%; and of fruit - 19.2%. In the short term perspective, it is difficult to expect a change in the prevailing current pricing trends for the food products. Moreover, according to estimates of the National Bank of the Kyrgyz Republic, in 2015 the annual average inflation is projected at the level of 11.5%, and the International Monetary Fund (IMF) estimates the further rise in prices in Kyrgyzstan for about 9.1%.

Based on the data from previous review, it is appropriate to conclude that the current problems of the agricultural sector of the Kyrgyz Republic are systemic in nature, so planning of measures to overcome them should be calculated for a long period and will require mobilization of significant investments and coordinated efforts of all stakeholders.

2. Review of current state of the crop production subsector

The specificity of this review, related to assessment of the possibility of introducing advanced technologies of irrigated agriculture in the Kyrgyz Republic will require more in-depth analysis of the current structure of crop production, since the use of various irrigation methods significantly depends on the composition of growing crops. First of all, it should be noted that the climatic conditions of Kyrgyzstan objectively determine the priority development of crop production based on irrigated agriculture, since, on average, crop yields in the irrigated areas of the Kyrgyz Republic are 2-3 times higher, and the income of farmers and peasants is higher more than 3 times compared with the corresponding figures for dry-farming lands. It should also be taken into account that the present structure of crops has undergone radical changes, as compared with indicators in the 1990s. In particular, in the past, the agrarian sector was mainly specialized in production of sugar beet, cotton, tobacco, potato seeds, alfalfa, and hybrid corn, at the same time having met the majority of Republic' demand in fruit, vegetables and fodder crops. Analysis of these data suggests that in the structure of sown areas in the past five years, the share of cereals, potatoes, and vegetable and melon crops has changed slightly, while the share of industrial crops slightly decreased from 7.9% to 7.1%, and the share of fodder crops, in contrast, increased from 24.3% to 26.3%. In general, at present in the crop structure the cereal and fodder crops are dominated - more than 80% of the total sown area (Figure 7). The total increase of the sown areas occupied by crops was only 0.3%, compared with 2009.

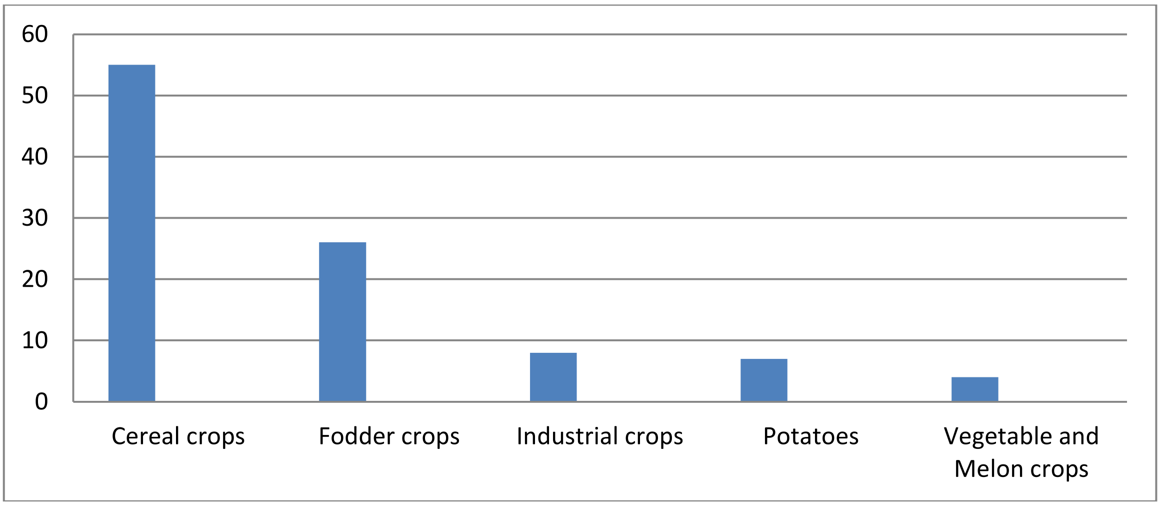

Figure 7. Structure of sown areas of main crops in KR for 2013 (in % from total area)

As for trends in change of the key crops yield, according to the statistics for the previous five years, on average, these figures practically have not changed (Table 2). A noticeable increase of the yield was recorded only for sugar beet grown annually on limited areas (6-8 thousand hectares). Moreover, according to preliminary data of MaM KR, in 2014 the yields of some crops grown on irrigated lands even decreased due to the lack of irrigation water and the purely economical reasons.

Table 2. Average indicators of major crops yields in farms of all types for 2009-2013 (centner / hectare)

Name of indicators	*Years*				
	2009	*2010*	*2011*	*2012*	*2013*
Grain crops (weight after reprocessing)	*29.3*	*25.3*	*25.2*	*23.4*	*28.8*
Wheat	*26.3*	*21.7*	*21.4*	*16.8*	*23.7*
Barley	*23.4*	*18.9*	*19.2*	*14.5*	*21.1*
Corn for grain	*60.0*	*59.3*	*59.0*	*60.2*	*60.8*
Rice	*30.7*	*30.5*	*29.9*	*31.7*	*33.9*
Sugar beet (industrial)	*110.9*	*165.7*	*197.1*	*192.3*	*191.6*
Raw cotton (valid weight)	*29.1*	*27.9*	*27.2*	*27.4*	*29.3*
Tobacco (valid weight)	*24.8*	*24.5*	*24.2*	*21.8*	*21.0*
Oil-yielding crops	10.8	10.7	10.4	10.7	11.0
Potatoes	159	158	161	159	163.3
Vegetables	178	180	182	181.1	186.8
Food watermelons, melons and gourds	204	213	213	216.8	220.2
Fruit and berries	45.4	43.3	47.2	48.1	48
Grapes	20.2	7.5	11	14.3	13.9

Source: data of the National Statistical Committee of the KR “Kyrgyzstan in Figures”, 2014.

The absence of tangible positive results in recent years, both in terms of involvement of new irrigated lands into the agricultural use and increase of crop capacity and gross crops yield, demonstrates the clear signs of stagnation of production in irrigated agriculture sector of the Kyrgyz Republic and in the agrarian sector as a whole. On the basis of generalization of numerous publications, reflecting the views of officials and independent experts, we can identify some reasons of appearance and conservation of the situation in recent years, which more often is referred to as a systemic crisis. In particular, the root causes often ranked as:

- Unsatisfactory results of land relations reform in the Kyrgyz Republic;
- Unstable (often used terms such as “misery” or “critical”) economic situation of the majority of the entities of the agrarian sector;
- The poor state of institutional mechanisms, management and marketing;
- Low levels of dataware and qualification of the entities of the agrarian sector.

It is appropriate to recognize that most likely, some of numerous reasons are direct consequence of the above mentioned causes. This statement can be explained by a few obvious facts. For example, due to incomplete land and agrarian reform, as noted above, the average size of arable land in a typical farm is only 2.7 hectares, including irrigated arable land - 1.9 hectares. Production of marketable agricultural products on the plots of such a small area, as a rule, is not profitable. In such circumstances, most of the farms and peasant entities are forced to work in the mode of subsistence production, providing only vital needs of their families. As a result, only 3-5% of households, mainly the largest ones, have the ability to successfully develop commercial farming with the use of innovative technologies. The members of remaining farms are forced to engage in various agricultural unions (associations, cooperatives, and others) or radically change the occupation and farm out their lands. Since in Kyrgyzstan the stable secondary market of lands has not been established yet, still there are regularly observed the facts of spontaneous redistribution of the rights of cropland ownership.

The second root cause - is the extremely weak economic capacity of the majority of entities of the agrarian sector, which, as a rule, closely linked to other above listed causes, as it is often caused by land scarcity, insufficient level of training and practical experience, lack of awareness in the field of advanced technologies, etc . However, in the first place, it is caused by lack of financial resources of agricultural producers to develop their agribusiness. In general, demand of the agricultural sector of Kyrgyzstan in investments is estimated of about 72 billion KGS. But, if take into account that the cost-effective farms cover their costs from own funds, then the real need for additional investments, according to estimates for 2013, is at least 30 billion KGS. Due to the limited capacity of the State budget of the Kyrgyz Republic, the Government provides very limited support for rural producers - at the level of 2.5% of the value of agricultural produce. For comparison - in the USA this figure is about 25%, in Russian Federation - about 8-9%, and in some countries of the European Union it reaches 50%.

It should also be noted the overly tight credit conditions due to high inflation rates and other reasons of the majority of national commercial banks (interest rate up to 25-30% per annum and date of repayment the loans is not longer than one year). But since 2013, the Kyrgyz Government approved the project “Financing of agriculture” aimed at providing preferential credit resources to agricultural producers. For these purposes in 2013-2014 it was allocated per 350-400 million KGS from the State budget as subsidies to commercial banks for lending at an interest rate of 9-10% per annum and with the date of repayment up to 24 months. However, this initiative is able to cover only a small fraction of the annual credit financial needs. Others forms and sources of financing of agricultural production - mortgage and futures crediting and insurance funds are not developed in Kyrgyzstan. As a result, crop sub-sector entities cannot provide for their needs in fuel and lubricants, mineral and organic fertilizers, weed and pest killers, and quality seeds of high yielders, not to mention the purchase of new types of agricultural machinery and equipment for irrigation, although without the use of these components it is impossible to achieve efficient irrigation farming. Moreover, in current conditions it is not realistic the implementation of resource-intensive projects related to major repairs and new construction of stationary irrigation canals and structures, land grading and improvement of soil fertility at the expense of own resources of the farms.

The negative impact of these factors on the state of agricultural sector of the Kyrgyz Republic is further exacerbated due to the lack of a fully functioning market infrastructure and sustainable relations at all levels of the production chain “production - procurement -

processing - realization – consumption”. Due to poor management and marketing systems, at present the bulk of agricultural products are consumed by the farmers and peasants themselves. They sell the surplus on the market and send for processing only small proportion of the products. While part of the products often cannot be sold in the local markets, and its transportation to other regions is usually associated with excessive costs. In such circumstances, the obvious way to solve the problem could be organization of long-term storage and deep processing of agricultural raw produce at the enterprises located in the vicinity of its producers. However, currently the very limited capacity of processing industry in Kyrgyzstan does not allow effective implementation of this line of activity. If take into account that the level of surplus value of agricultural products, having passed through the deep processing, is much higher compared to the initial cost of harvest, then it becomes obvious the current levels of lost profits both for the farmers and the country as a whole.

In addition, insufficient development of market infrastructure and marketing systems is characterized by:

- The lack of developed organizational and material base for the maintenance and servicing of entities of the agrarian sector;
- The lack of an extensive network of sustainable supply of entities of the agrarian sector with seeds, fertilizers, weed and pest killers, fuel and lubricants, et al, at affordable prices;
- The lack of an extensive network of leasing centers that provide rent of agricultural and irrigation machinery, vehicles and spare parts and consumables.

The assumption about insufficient current level of awareness and skills of the rural population of the Kyrgyz Republic is proved by the following arguments. First of all, it should be noted that after the transfer of land to private ownership in the early 1990s, many people in rural areas, although having previously practisized irrigated agriculture on small homestead plots, quite unexpectedly for themselves have became farmers, and therefore faced with new challenges regarding to expansion of production scale, need to develop new industrial and economic relations, management practices, ignorance of the elementary basics of marketing, etc.

Naturally, not all of them were ready for it, so now the majority of farmers and peasants prefer to grow familiar crops which do not require the use of high-tech technologies. As a result, at present more than a half of sown area is occupied by the least-cost cereal crops, profitability of which is relatively small. This fully applies to fodder crops too. Of particular concern is the fact that on the basis of annual market price fluctuations for one or another agricultural produce, many producers are beginning to grow the same crops, having not sufficient understanding of the need to diversify production (crop rotation and alternation). As a rule, this practice leads to soil depletion and loss of soil fertility, as well as to the emergence of seasonal shortage of irrigation water, because the monotony of crops will require a one-time irrigation on large irrigated areas.

In general, the current level of information, training and consulting services for the rural population of the Kyrgyz Republic can be assessed as unsatisfactory, because it covers only 20-30% of the farmers, and primarily within the framework of international projects.

III. Characteristic of current state of the irrigation sector of Kyrgyzstan

1. Composition of infrastructure and entities of water relationships in the irrigation sector

Irrigation systems of Kyrgyzstan are traditionally divided into two categories: inter-farm and on-farm. Inter-farm irrigation systems are generally operated by the regional (basin, rayon)

State water management enterprises under the Department of Water Management and Melioration (DWMM) under the Ministry of Agriculture and Melioration of the Kyrgyz Republic (MAM KR). On-farm systems are owned and operated by independent entities of agriculture and water use, or by local self-governments (LSG). Dynamics of change of the number of farming and water using entities for 2009-2013 is presented in Table 3.

Table 3. Dynamics of change of the number of farming - water using entities for 2009-2013

Name of agriculture entities	**Years**				
	2009	**2010**	**2011**	**2012**	**2013**
Total, including:	**320,205**	**332,170**	**345,113**	**357,227**	**383,436**
State farms	71	64	65	60	56
Collective farms	781	509	556	525	497
Peasant farms and sole proprietors	318,815	331,059	344,492	356,642	382,883
Collective organizations and enterprises	538	538	538	538	538
Personal subsidiary plots of citizens	726,632	726,632	726,632	726,632	726,632
Gardening and dacha cooperatives	405	405	405	405	405
Forestry enterprises	71	71	71	71	71
Fishery enterprises	13	13	13	13	13

Source: Collection of the NSC KR "Agriculture of the Kyrgyz Republic", 2014.

As of December 2014, about 74% of the irrigated areas of the Republic and the corresponding on-farm infrastructure are served by Water Users Associations (WUAs). By the pace of creation and development of WUAs, at present Kyrgyzstan takes a leading position in Central Asia. WUAs development indicators for the period 2008-2014 are presented in Table 4.

Table 4. Indicators of development of WUAs

Oblast	**2008**		**2014**	
	Number of WUAs	**Served irrigated area, thousand hectares**	**Number of WUAs**	**Served irrigated area, thousand hectares**
Batken	32	43.0	32	48.1
Osh	86	89.5	89	100.5
Dzhalal - Abad	69	92.3	67	96
Issyk - Kul	59	87.4	63	111.9
Naryn	48	46.0	48	68.2
Talas	66	97.0	69	92.3
Chui	104	175.3	107	215.9
Total for the Republic	**464**	**630.5**	**475**	**732.9**

Source: Statistical data of the Central division for support and development of WUAs (CDS WUA) within the DWMM for 2014.

In recent years, in Kyrgyzstan there are actively implemented measures on formation of consolidated public associations of water users through the creation of WUA Unions (UWUA) based on hydrographic principle, that is, depending on the origins to particular sources of irrigation. For today, 35 UWUAs were created, including 7 UWUAs at the stage of registration, and 28 UWUAs have been legally registered covering 189.4 thousand hectares of irrigated land. Of the total number in 2014, 13 UWUAs have worked actively, including 11 UWUAs engaged in the operation and maintenance (O&M) of the irrigation infrastructure and 2 UWUAs have functioned as coordination bodies. Also in the Republic 35 public Water Councils were established, which activities cover 229.4 thousand hectares of irrigated land.

Work of Water Councils mainly aimed at resolving conflicts between water suppliers and water user entities, time matching of water intake and water supply schedules, as well as consideration of issues of operation and maintenance of infrastructure.

Current characteristic (according to 2014) of on-farm infrastructure owned by the WUAs by regions and in the Republic as a whole is presented in Table 5.

Table 5. Characteristic of on-farm infrastructure

Oblast	**Irrigated area, hectares**	**Main canal, km**	**Total on-farm irrigation network, km**	**Including on the balance of WUA**	**Collector-drainage network, km**		**Hydraulic structures, pieces**	**Hydrometric stations, pieces**	**BSR and BDR, pieces**
					Open	**Closed**			
Batken	48,134	33.2	1,828.4	1,828.4	64.22	55.0	3,119	70	3
Osh	100,519	31.91	3,045.6	2,981.2	182.22	0	1,877	315	11
Dzhalal-Abad	96,047	157.3	3,457.4	3,286.4	157	9,5	1,103	179	1
Issyk-Kul	111,948	35.81	2,884.9	2,117.3	32.35	0	1,543	101	32
Naryn	68,160	0	2,484.9	1,722.2	0	0	1,264	99	35
Talas	92,281	0	2,067.0	1,905.3	66.7	73.23	999	82	76
Chui	215,865	47.71	5,994.8	3,620.8	345.4	525.5	8,047	46	96
Total for the Republic	**732,944**	**305.9**	**21,763**	**17,462**	**847.9**	**663**	**17,952**	**892**	**254**

Source: Statistical data of the Central division for support and development of WUAs (CDS WUA) within the DWMM for 2014.

2. Characteristic of previous investments in irrigation sector

In general, according to closely matching assessments of DWMM' experts, as well as international experts of World Bank Projects "Improvement of Water Resources Management" (IWRMP) and "On-Farm Irrigation" (OFIP-2), the current technical condition of both inter-farm and on-farm irrigation and collector-drainage network should be characterized as not enough satisfactory by most of indicators. Basically, this is due to the fact that after 1991 current and rehabilitation repairs of irrigation facilities were made in limited quantities (on average, annual funding for these activities in comparable prices has decreased by 5-6 times, compared with the last years of the USSR existence).

However, in recent years there is a tendency, indicating on stabilization of the technical state of irrigation infrastructure after a long period of its degradation. These trends are stipulated, first of all, by a significant increase of investments from international lending and donor agencies for rehabilitation and development of the national agricultural and irrigation sectors. Along with this factor, the efforts of the Kyrgyz Government on modernization of legal and institutional framework, technical upgrading of irrigation fixed assets and workforce preparation have also played a positive role. According to the report of the Ministry of Finance of the Kyrgyz Republic "On implementation of projects of the State Investment Program (SIP) from 1992 to 2013", for the given period in the aggregate $ 821.5 million were formed for maintenance and development of the agricultural and irrigation sectors, including $ 482.7 million in the form of loans and $ 338.9 million in the form of grants. The total budget of 22 investment and development projects in these sectors for 2014 amounted to $ 17.1 million, including loans - $ 9.5 million and grants - $ 7.6 million. Among the projects, implemented in the Republic in 2014, the most significant long-term projects in this area are the following:

- "Second On-Farm Irrigation Project" (World Bank) - grant of $ 16 million;
- "Improvement of Water Resources Management" (World Bank) - grant of $ 23.4 million;
- "Livestock and Market Development -1" (International Fund for Agriculture Development) – in total $ 20 million, including loan - $ 10 million, grant - $ 10 million;
- "Additional funding for the second On-Farm Irrigation Project" (World Bank), total - $ 4.2 million, including loan - $ 2.3 million, and grant - $ 1.9 million;
- "Agricultural Services and Investments" (World Bank) - grant of $ 9 million.
- "Rural Water Supply and Sanitation – 2" (World Bank) - total $ 10 million, including loan - $ 5.5 million, and grant - $ 4.5 million.

In addition to the above projects, over the last decade a significant contribution to the strengthening of technical and institutional capacity of the irrigation sector have been also made by international development agencies and funds of the European Union, the USA, Switzerland, Japan, UK, Germany, Turkey, FAO UN, UNECE and others. According to the summary data on the activities of international projects in Kyrgyzstan, as a whole for 2000-2014 more than a half of the actual costs of O&M and rehabilitation of inter-farm irrigation and drainage network of Kyrgyzstan were covered through foreign credit and donor assistance.

The main objectives of these projects are increasing productivity of irrigated agriculture and effectiveness of water resources management, assistance in poverty reduction in rural areas and improvement of conditions for more productive and profitable livestock and crop production. Of particular note are some of the international projects aimed at raising awareness of the rural population on reclamation and crop irrigation issues:

- "Improving water productivity at the field level" Project (SDC) - 3 million Swiss Franc;
- "Irrigation infrastructure development support in the rural areas of Osh, Batken and Dzhalal-Abad Oblasts of the Kyrgyz Republic" Project (European Union) - 1.9 million Euro;
- "Institutional building and strengthening the capacity of WUAs in Kyrgyzstan" Project (European Union) - 50 thousand Euro;
- "Complex of activities for development and implementation of a pilot demonstration project to improve agricultural irrigation" Project (European Union / UNDP) - $ 30 million;
- "Development and implementation of capacity building campaign on climate-sustainable development planning and water resources management in local communities of Batken Oblast" Project (UNDP) - $ 13 thousand;
- "Efficient use of water" Project (Swiss Association for International Cooperation "Helvetas") - $ 100 thousand / year for 2009-2017;
- "Micro irrigation technology" Project ("Helvetas") - $30 thousand /year for 2009-2017;

- "Modernization of the small-scale irrigated agriculture to improve and develop the economic situation of the rural population" Project (FAO) - $ 411 thousand;
- "Capacity building of farmers by using irrigation technologies" Project (FAO) - $ 459.5 thousand.

However, even attraction of such significant foreign investments contributed only to overcome the prolonged degradation tendencies in both sectors of the economy, but does not provide for possibility of their further sustainable development. For example, according to experts data, set out in the reports of the EU/ UNDP project "Development and implementation of IWRM strategy in Kyrgyzstan" (2010) and the World Bank Project IWRM (2011), for providing the effective management of water resources and O&M of inter-farm irrigation and drainage infrastructure by DWMM, the annual financial demand in specific indicators is from 20 to 36 $ US / hectare. Therefore, under the ratio of KGS/ $ US exchange rates by the end of 2014, the annual demand for financing in absolute terms is estimated from 1.2 to 2.0 billion KGS. The same experts estimate the demand volumes of annual investments for the rehabilitation of technical condition and development of inter-farm irrigation infrastructure, at least for $ 15 million / year (about 900 million KGS / year).

For comparison, the annual total budget of DWMM for these purposes (excluding minor additional allocations for capital construction of irrigation facilities) for the previous years did not exceed 1 billion KGS (see Table 6 and Figure 7).

Table 6. Annual investments for the Department of Water Management and Melioration

Name of the source of investment	**2009**	**2010**	**2011**	**2012**	**2013**	**9 months of 2014**
State budget funds	544,3	613,3	690,6	717,7	726,8	611,5
Special funds from European Commission on Food Safety	84,1	68,4	61,6	67,7	83,5	90,4
Funds from Payments for Irrigation Services (PIS) by water users	20,103	50,594	91,585	117,963	105,919	90,398
Total:	**648.503**	**732,294**	**843,785**	**903,363**	**916,219**	**792,298**

Source: Statistical reporting data of DWMM for 2009-2014.

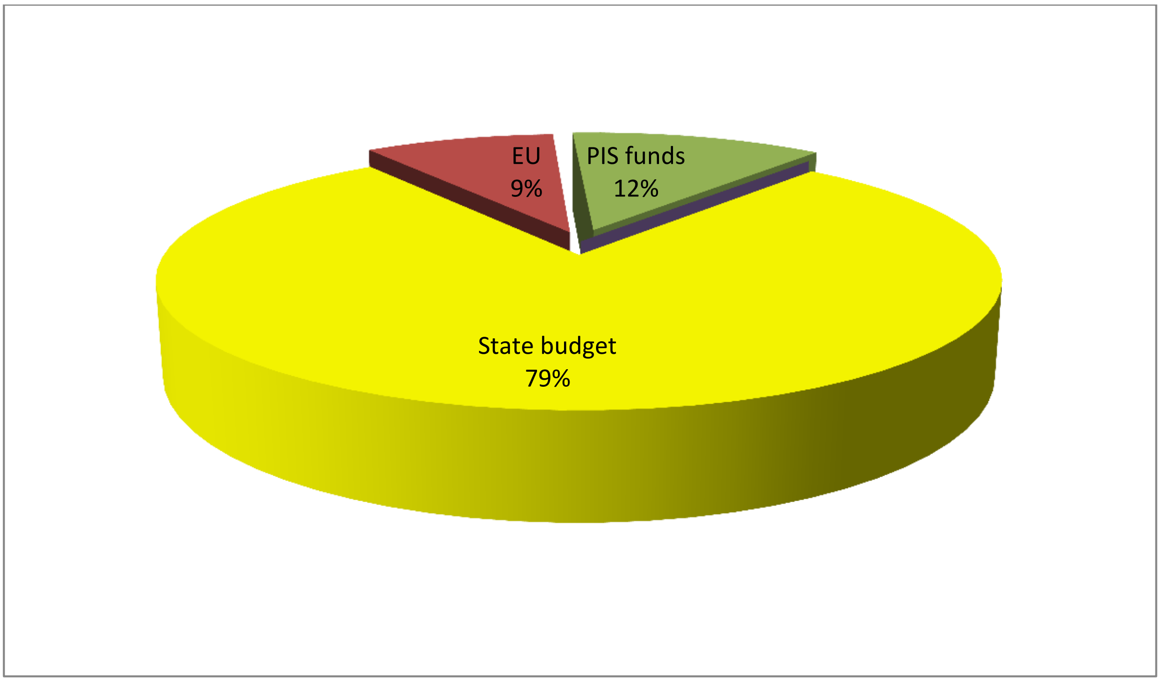

Figure 7. Structure of internal source of investments in the budget of DWMM for 2013 (In %)

It should be emphasized that in recent years the annual increase of amount of funding for the irrigation sector actually only offset the rise in prices for materials, equipment, water management works and services due to inflationary processes and fluctuations of the national currency rates. In this regard, it is appropriate to conclude that during this period the internal investment policy in regard to the irrigation sector provides only for the possibility of its maintenance at a relatively stable, but insufficient level, but did not provide a real opportunity for large-scale rehabilitation and development of waterworks infrastructure.

According to the conclusions set out in the report of the ADB Project “Study of pricing system and cost recovery mechanisms for irrigation” (2006), the structure of irrigation costs of water users of the agricultural sector (farmers and peasant farms, agricultural enterprises, etc.), as a rule, includes the following components:

- Costs of fees for irrigation water supply services (PIS) to the State water authorities and / or to WUAs;
- Costs of maintenance and development of irrigation network within their own land allotment;
- Costs of irrigation of their own arable lands and homestead plots.

At the present level of tariffs PIS (not more than 0.03 KGS / m³ for water supply by the DWMM’ enterprises and an average tariff rate for WUA members at the level of 0.064 KGS / m³ in 2014), the share of costs for payment for water supply services is of little importance in the cost structure of water users of agrarian sector - not more than 4-5% of the total expenditure budget items of the farms. This factor does not help to intensify measures for rational use of water resources by water suppliers and consumers. As for the costs for maintaining their own irrigation network, for the vast number of water users of the agricultural sector of the Kyrgyz Republic they are mainly related to the annual cutting of temporary sprinklers and irrigation furrows for the surface irrigation methods. The use of sprinkler equipment, equipment for drip irrigation and other advanced irrigation equipment is currently affordable only for a limited number of large agribusinesses.

As the key water user entities in the agrarian sector of Kyrgyzstan are WUAs, it is appropriate to reflect some aspects of their economic activity. Revenues of WUAs' budgets are formed by the first shares of members of these associations. Size of shares is set according to their Charters, based on the decision of the general meetings of members of the WUA. Estimated size of shares at present constitute, on average, about 700-1,000 KGS / hectare per year, but traditionally not more than 60% of the planned amount is collected. Low collection rate of shares is the most difficult problem for the most of WUAs and negatively impacts on the state of on-farm irrigation network. Part of the collected funds is used to pay for water supply services of local DWMM on the basis of contracts and approved tariffs.

The remainder of the fees is used to finance WUA' own production activities, including O&M of irrigation infrastructure, as well as current repairs of canals and facilities. In 2014 for current repairs were allocated 33% of the total costs of WUA for the O&M purposes. In the period from the beginning stage of formation of WUAs and to date, the vast majority of work on the rehabilitation and development of on-farm infrastructure facilities was financed at the expense of internal credit and donor support, mainly in the framework of the World Bank and the Asian Development Bank Projects.

3. Assessment of capacity of rational use of water resources in the irrigation sector of Kyrgyzstan

The above given information is an objective evidence that, despite the measures have taken by the Government of the Kyrgyz Republic and substantial external support, so far the current status of irrigation systems does not provide the necessary conditions for rational water use in the country. In the context of the subject matter of this project, it is expressed by the following indicators. Based on the statistic data given above, characterizing the average annual water intake in the Kyrgyz Republic in the last 5 years at the range of 8 to 10km^3 / year, the share of irrigation sector from total water use volume of 90-93%, and also an average values of specific water loss (by the most optimistic estimates) at the level of 40%, it is appropriate to estimate the total volume of water losses in irrigation systems of the country in absolute terms as a value of about 2.9-3.7 km^3 / year.

It is not difficult to understand that only the volume of water losses in the irrigation sector in its scale goes beyond of total volume of annual water consumption by all other sectors of the economy and population of the country. In general, the water losses can be caused both by natural causes (evaporation, transpiration by plants, irregularity of water supply due to the daily flow fluctuations in natural sources) and technical reasons (filtering from the canals), as well as technological reasons associated with poor management, breaches of water use conditions by water suppliers and consumers, and often with a voluntary water intake to the detriment of other water users.

To determine the approximate ratio of water losses volume along the links of irrigation systems, we can base on the data of the final report of the GEF / IFAS "Management of water resources and the environment" (2003), implemented in the framework of preparation of "Aral Sea Basin Programme". In particular, these data give the evidence that in Central Asia as a whole, the specific losses of water in the main and inter-farm canals are on average about 25% of the water intake volume, and water losses in on-farm irrigation networks are about 24% of the volume of water supply to the farms. However, according to reporting data of DWMM for 2014, in Kyrgyzstan on the average the Coefficients of Efficiency (CoE) of on-farm irrigation network are about 0.68, that is, the specific losses of water slightly higher than the averaged figures for the Central Asian region as a whole and make up about 32% of the volume of water supply to the farms. Thus, tracing the structure of water losses at all levels of the irrigation systems, it is easy to verify that the total annual water supply to the entities of irrigated agriculture actually constitute from 5.4 to 7.0 km³ / year, but only 3.7-4.8 km³/year of water reaches directly the irrigated tracts of land. The results of presented approximate calculations confirm the data of expert estimates on the size of specific irrigation water losses on the level of 40%.

However, these data do not take into account the actual losses of water in the irrigated areas, volumes that are directly related to the applied crop irrigation technologies. In this regard, it should be emphasized that the current system of statistical reporting of the Kyrgyz Republic does not have any data on this subject. In this regard, statistical reporting data of regional DWMM bodies for 2013, reflected in Table 7 and, in turn, based on questionable reporting data of WUAs, in a careful analysis are seem not sufficiently complete and reliable.

Table 7. Performance indicators of on-farm irrigation network by Oblasts

Oblasts	Name of indicators				
	CoE of on-farm n-work	CoE of irrigation techniques	Average No of irrigation	Irrigation standards, m^3/hectare per year	Irrigation standards, m^3/hectare
Batken	0.64	No data	4.5	4,691	1,021
Osh	0.69	No data	3.6	5,874	1,632
Dzhalal-Abad	0.67	0.74	2.8	5,778	1,509
Issyk-Kul	0.68	0.74	1.87	2,827	1,509
Naryn	0.67	0.70	2.5	4,037	1,688
Talas	0.64	No data	2.97	5,800	1,950
Chui	0.71	No data	No data	No data	No data

Source: Statistical reporting data of regional DWMM bodies for 2013.

Therefore, for a more realistic assessment, you can use the findings of the Food and Agricultural Organization of the United Nations (FAO, "The geography of the world economy") indicating that in traditional irrigation areas of Central Asia up to 50% of water supplied to irrigated lands is lost through filtration, evaporation and discharge, not reaching to irrigate plants. The value of water losses essentially depends on the applied irrigation methods and can, on the average, constitute:

- At uncontrolled watering, free flow and strip irrigation 50-60%;
- At furrow irrigation 32 - 40%;
- At sprinkler irrigation 20-25%;
- At drip irrigation 5-10%.

Since the vast majority of irrigated lands in Kyrgyzstan (over 90%) at present are irrigated by furrows or by free flow, even at a moderate assessment of specific losses at the level of 40%, the absolute annual losses of water directly on the irrigated lands of the Kyrgyz Republic may be about 1.5-1.9 km³ / year.

To clarify the potential possibility of water resources savings in the irrigation sector, we can use as a benchmark the working standards of the Kyrgyz Republic "Construction codes and performance requirements" (CNiP 2.06.03.85), which provide for the need to achieve the following indicators of effectiveness of the irrigation systems, expressed in Coefficient of Efficiency:

- CoE of the main canals and their offtakes (i.e., inter-farm network) - 0.90;
- CoE of irrigation canals (i.e., on-farm network) - 0.93;
- CoE of crop irrigation techniques - not less than 0.85.

Therefore, to ensure regulatory technical condition of various parts of the irrigation infrastructure in KR, it is required to implement a set of activities related at least to improve the CoE on inter-farm level by 15%, on-farm level by 25%, and the CoE of irrigation techniques by 15%. For inertial scenario of maintaining the annual volumes of water intake in the Kyrgyz Republic at the level of 8.10 km³ / year, including for irrigation - about 7.2-9.3 km³ / year, saving of water resources in absolute terms may constitute:

- On inter-farm systems - within 1.1-1.4 km³ / year, while the volume of water supply to entities of irrigated agriculture can be increased up to 6.5-8.4 km³ / year;
- On on-farm systems - within 2.1-2.4 km³ / year, while the volume of water supply directly to the irrigated tracts of land can be increased to 6.0-7.8 km³ / year;
- Directly on the irrigated areas, through the use of more efficient irrigation technologies - within 1.5-1.9 km³ / year.

Thus, the totality of the above statistics and approximate calculations allows for conclusion that at present Kyrgyzstan has sufficient reserves of land and labor resources for sustainable development of the agrarian sector, including crop production on the basis of irrigated agriculture. At the same time, continuing cycle of dry years in the Central Asian region has led to the widespread increase in water scarcity. With the prospects of further reductions of water resources due to the negative manifestations of global climate change, as well as the growth of volume of domestic water consumption in Kyrgyzstan because of population growth and development of water-using sectors of the economy, the trends of aggravation of this deficit can only grow. Under these conditions, an effective solution of the problem may be connected not to the increase in water intake volumes from natural sources, the potential of which over time will only be reduced, but with the rational use of resources already involved. In this regard, the results of calculations presented above demonstrate the fundamental opportunity (even without an increase of the annual volume of water intake for irrigation needs, only by reducing water losses) for additional water supply to the irrigated agriculture sector of about 4.6-5.7 km³ / year.

On the basis of pragmatic considerations, first of all taking into account the limited opportunities for attracting additional investments, realization of this ambitious goal in Kyrgyzstan in full even in the medium term perspective is hardly possible. However, the urgent need to intensify activities in this direction is not in doubt. When planning a set of measures in this area an adequate attention should be given to issues of upgrading of crop irrigation technologies, since the proportion of water losses within the irrigated areas is about 1/3 of the total volume of annual water losses within the irrigation infrastructure.

IV. Experience and lessons learnt in use of different irrigation methods in Kyrgyzstan

1. Introductory historical reference

References to publications and archival materials of a century ago show that in territory of Central Asia within the present borders of Kyrgyzstan by 1914, there were developed about 434 thousand hectares of irrigated land. Of these, the cotton was cultivated on 22 thousand hectares, vegetables and potatoes on 14 thousand hectares, rice was planted on less than 5 thousand hectares, and the vast majority of the irrigated arable land area has been set for cereal crops and perennial grasses. Comparing these figures with the data on Figure 7, we should admit the obvious fact - although the size of the irrigated areas of Kyrgyzstan for a century has increased more than twice, but the cropping pattern has not changed much (!). Also the data deserve consideration that in 1914 crops and perennial grasses watered by so-called “wild flow” or by the strips, cotton and vegetables – by furrows; and limited plantations of rice – by check flooding. A comparison of this information with the data related to the end of 1990s, that is, the period of maximum development of irrigation in Kyrgyzstan, as well as with modern data caused certain difficulties, primarily because currently in the Kyrgyz Republic the official statistical reporting on the applicable crop irrigation technologies is not underway. Nevertheless, based on extant archival data and the results of interviews with specialists of the central office and regional bodies of DWMM, as well as representatives of the WUAs, farmers and peasant farms, we managed to get the information on this subject, as summarized in Table 8.

Table 8. Information on trends of application of different irrigation methods in 1990 and 2014 years.

Irrigation methods	**Main irrigated crops**	**Application of given irrigation method on total area, Thousand hectares // %**	
		1990	**2014**
Furrow irrigation	Industrial crops, vegetables, fruit (gardens, vineyards), cereal crops	450//40.4%	420//46%
Strip irrigation	Perennial grasses, cereal crops	650//58.6%	330.3//36%
Check irrigation	Rice	8//0.7%	1.2//1.2%
Drip irrigation	Fruit (gardens), leguminous plants (bean), vegetables (including in greenhouses)	0.15//0.1%	0.789//0.8%
Sprinkling	Fodder crops, perennial grasses, sugar beet, cereal crops	0.2//0.2%	147.7//16%

Sources: 1. Archival data of DWMM (former Ministry of Water Economy of the KyrSSR) for 1990.

2. Indicative research data of the Specialists of KRII for 2014.

At first glance, when comparing data for 1914 and 2014 years, it can form an impression about the absence of any progress for a hundred years period in the area of development of advanced irrigation technologies in Kyrgyzstan. In this regard, it is appropriate to make some additional clarification. Indeed, before the beginning of 1960s in Kyrgyzstan insufficient attention was given to improving irrigation technologies, but a radical revision of attitude towards this problem is appropriate to date as of May 1966, in connection with the issue of the Resolution of Central Committee of CPSU and USSR Council of Ministers “On the broad development of land reclamation ...” In the Governmental long-term programs for development of irrigated agriculture, have been developed on the basis of the given Resolution, the priority specialization of the Republic for steady increasing output of agricultural products was in production of sugar beet, cotton, alfalfa seed, and to a lesser extent - in expanding production of vegetables, fruit, and tobacco. As a consequence, a priority objective was the optimization of irrigation regimes for these key crops according to the specific conditions of different regions of the Republic. To address this and related objectives the leading research and educational institutions of the country were engaged: KyrgRIWE (later – ARIIARW, now KRII), Kyrgyz RIAF, KIA (now - Kyrgyz Agrarian Academy) as well as design institutes “Kyrgyzgiprozem” and “Kyrgyzgiprovodhoz”. It should also be noted a significant contribution of the Kyrgyz Experimental Breeding Station in breeding and adaptation to local conditions of high-yielding varieties of crops. Due to the joint efforts of these organizations was developed the basic normative document “Natural-reclamation land zoning and optimal crop irrigation regimes for administrative areas of the Kyrgyz SSR", which served as the basis for further work in the field of development of irrigation technologies.

In the 1960s, furrow irrigation was seen as the most progressive, that is why in this period in the Republic the majority of studies were carried out with the aim of its further improvement. In particular, the experiments were carried out on experimental plots with different slopes to determine the optimal length of the furrow, the possibility of irrigation over the furrow and with variable flow, as well as cutting curvilinear furrows in accordance with the field terrain features (contour irrigation). At the end of 1960s numerous experiments were set on introduction of mineral fertilizers and pesticides, as well as organic fertilizers (livestock waste) onto the field, which were dissolved in the irrigation water. This technology in the world practice is called “fertigation”, and in Central Asia – “Sherbet suu”; at first it was tested on crops of cotton and vegetables, and soon became widespread throughout the Republic.

Further, since the 1970s, ARIIARW and KIA have regularly conducted research and experimental developments of new types of equipment for furrow irrigation, irrigation water metering devices and devices for automated stabilization of water volume directly on the irrigated lands. Typically, such works finished by introduction of several prototypes of new technics, and seldom – by introduction of an experimental batch, designed for service, at the best, of about tens or hundreds hectares of irrigated land. However, such modest results do not show the drawbacks of designed technics. On the contrary, the facts are known, when the most successful examples of new irrigation equipment, such as tube-siphons for water supply from trays directly into the furrow, plastic pipe regulator with valves or a portable bridge from reclamation fabric, were very popular among the local population, and were immediately spread from collective warehouses to the homestead or garden plots. At the same time, most of the new facilities for water metering and automation of water supply in the field has not been further used because of the high cost and also due to complexity of installation and maintenance.

Also, since the 1970s, in Kyrgyzstan was conducted intensive introduction of different types of sprinkler installations, mainly for irrigation of perennial grasses and vegetables. A special role in promotion of sprinkler equipment in those years belonged to Kant machinery-test station (MTS), which has carried out testing of all new models of sprinklers, imported into the Republic. As a result, by the end of the 1980s, more than a hundred thousand hectares of irrigated land, mainly in the northern regions of the country, were watered using sprinkler equipment.

Unlike sprinkler irrigation, in the Soviet period subsurface irrigation technologies did not receive significant application in Kyrgyzstan, even at an experimental level. Although in Uzbekistan (since 1958), and a little later in Tajikistan (since 1965) an extensive research was carried out on irrigation of experimental plots with an area of about hundreds hectares with the help of closed pipes and flexible hoses. Although the results of experimental introduction of subsurface irrigation technologies in the neighboring Republics have demonstrated the high efficiency of this method in terms of water saving, in Kyrgyzstan such research has been suspended on the stage of planning for a trivial reason - due to the high cost and deficit of asbestos and polyethylene pipes and flexible capron hoses. Later, pilot implementation of this method has revealed some design drawbacks of the set of equipment for subsurface irrigation (so-called “Sharov- Sheinkin system”), and this work in Kyrgyzstan were finally brought to a close. If proceeding from the modern achievements in the field of development of subsurface irrigation technology, then it is appropriate to consider this decision as a reckless.

Modern mass media and even scientific publications often refer the first steps of pilot implementation of drip irrigation systems in Kyrgyzstan to the beginning of the 2000s. However, historical data show that the first experiments on testing of drip irrigation technology were carried out as early as in 1979. Since 1981-82 a number of projects on introduction of drip irrigation technology were implemented on experimental plots with an area larger than 10 hectares in the Batken Oblast (vineyards), Issyk-Kul Oblast (apple and apricot orchards), Chui Oblast (vegetables), and other regions. As a rule, these projects used scientific and engineering developments of Scientific and Production Association "Rainbow' (Kolomna, Russia), but also were tested the prototypes of droppers received from Ukraine, Georgia, and other Republics of USSR. Even the first experiments in this direction have shown promising results, in particular, the possibility to save irrigation water for more than 2-3 times, compared with furrow irrigation technology or strip irrigation. As a result, by the early 1990s about 800 hectares of perennial fruit plantations were watered by the drip irrigation method. Soon, however, further promotion of drip irrigation systems in the Kyrgyz Republic stopped. First of all, this was due to a sharp deterioration of the socio-economic situation in the USSR as a whole and, as a consequence, the impossibility of implementing such projects that require significant investments. Along with this objective factor, previous experience of pilot operation has shown the low reliability of equipment, primarily droppers, if there is insufficient water purification. It is noteworthy that in the early stages of pilot implementation of drip equipment, main focus was on the cleaning of irrigation water from suspended solids, without taking into account the possibility of sedimentation of hydrocoles inside droppers and internal surfaces of pipelines, as well as calcium and magnesium compounds at increasing the water hardness (pH over 7.0). Meanwhile, in the past it was known that during the growing season, especially during the passage of floods in July and August, water hardness indicators in the mountain rivers of Kyrgyzstan sharply increase. For these reasons, in the first months of operation there were regular failures in the work of experimental drip irrigation systems, causing distrust of local communities to this type of irrigation equipment.

Period from 1965 to 1988 is now recognized as an epoch of most intensive irrigation development in the USSR, including Kyrgyzstan. Moreover, from modern position it may be a puzzle the fact that in the Republic the most advanced at that time irrigation technologies have found limited use (at least 17% of the total irrigated area), and later even sharply degraded. Especially when you consider that Kyrgyzstan has in those years a powerful scientific capacity, developed industry, well-balanced water management infrastructure, and local water and agriculture professionals were as valued as to be often invited to participate in international projects providing assistance to poor countries of Asia, Africa and Latin America. Obviously, such development of events can only be explained by fundamental factors emanating from the ideology of too centralized "planned economy". It is relevant to recall that the main criterion of the success of any enterprise in those years was the gross output of produce, despite its quality and even costs. Under such conditions, agricultural workers lacked sufficient motivation for introduction of any innovation technologies, the use of which require additional knowledge and efforts, but did not promise tangible wealth. It should be borne in mind that for the most people in rural areas of the Kyrgyz Republic proceeds from the sale of agricultural products grown on private homestead plots, were much higher than wage rate in collective or soviet farms. It is useful to note another important fact: with the high level of technical condition of canals and waterworks and tight cross-checking control of standards compliance of water allocation in the 1980s, irrigation water losses were minimized, and that is why insignificant deficit of irrigation water was felt only in rare extremely low-water years. As a consequence, the need to implement costly water-saving technologies was not manifested as acute as at present time.

After the collapse of the Soviet Union, during the 1990s in Kyrgyzstan due to a well-known reason have been temporarily minimized research, practical work and training activities on implementation of crop irrigation innovative technologies. Their renewal and development, since 1998 and to date, is carried out mainly in the framework of international projects listed in the section of this report “Characteristics of previous investments in the irrigation sector”, or with the support of national organizations - the Republican Union of WUAs, Training center for consultation and innovation (TCCI), Agribusiness Competitiveness Center (ACC), Regional Rural Consulting Services (RCS), and others. It should be noted that in recent years there was an increasing interest to implementation of efficient irrigation methods, including drip irrigation and low pressure sprinkling, thanks to the personal initiative of a few economically successful farmers and agricultural enterprises.

On the basis of summary results of the work completed within the framework of international projects, we can conclude that their main focus in the last 15 years was given not to pilot introduction of high-technological irrigation methods, but to training of rural population on skills of the more efficient use of traditional irrigation methods, in the first place – furrow irrigation. At the first glance, this approach may seem controversial, especially since the most of programs and training methods supposed and suppose now the use of technologies and equipment, have been tested in Kyrgyzstan and other Republics of Central Asia several decades ago.

However, the usefulness of such a pragmatic approach becomes obvious if we take into account that since sovereignty of Kyrgyzstan significant part of qualified specialists of agricultural sector has migrated outside the Republic or has changed their occupation or resigned due to the age. These elite of agricultural production were replaced by poorly trained young people or rural residents who previously had other specialty, but after receiving allotments during the agrarian reform in the early 1990s were forced to learn the basics of irrigated agriculture “starting from scratch”. Indeed, it is for this greater part of the rural population as the target audience the training programs were oriented, so that to increase their access to relevant information and master practical skills on irrigated agriculture. The effectiveness of implementation of this approach is characterized by the statistics data showing that for today in one degree or another at least 30% of the able-bodied rural population of Kyrgyzstan was covered by training.

Noting a substantial increase of the qualification level of the entities of agrarian sector of the Kyrgyz Republic in recent years, it is appropriate to emphasize that in the process of practical training directly on experimental irrigated plots, the large amounts of data were obtained on irrigation regimes, productivity and profitability of various crops, and so on, which can be used in the formulation of recommendations on further improvement of irrigation technologies. It should be borne in mind that these data require careful analysis and additional verification. The fact is that, according to experts of KRII, on a number of experimental plots indicators of yield growth or water savings were achieved not only due to the introduction of new technologies, but only because of better compliance with the well-known agricultural practices. By the way, these facts demonstrate the possibility of achieving significant water savings directly on the field even without involvement of additional innovative resources, only by careful dosage of irrigation water by using simple tools. On the other hand, in other test plots very little effects were obtained in terms of rising crop yield using different irrigation methods. As a rule, such results have been reported on the fields, where the experiments were conducted only with different methods of irrigation, often on insufficiently planned and fertilized plots, where crop rotation and quality seeds have not been applied for many years. These data clearly confirm the trivial truth that in agricultural production it is not possible to achieve significant progress only through the implementation of narrow-specialized advanced technologies, including irrigation, without simultaneous increase of soil fertility, the use of high-yielding varieties of crops, plant protection products, reclamation activities, and others. Implementation of such integrated work can begin on a limited scale in the near future, for example, on the basis of the most successful farms, WUAs and large agricultural enterprises, with adequate support from the state budget and external donors. When planning such pilot projects it will be expedient to use the long-term experience of application of different irrigation methods in Kyrgyzstan and neighboring countries, which is briefly summarized in the next section.

2. Summary of application of different irrigation methods in Kyrgyzstan

Irrigation method by flooding and by strips

Irrigation by "wild flooding" has practiced in Kyrgyzstan over the centuries, but since the second half of the 20th century is mainly used its variety – strip irrigation. In this method of irrigation water is supplied from the temporary distributor (outlet furrow, "ok-aryk") to the head part of the strip of irrigated field and further is distributed by gravity, forming a water layer with thickness of 5-10 cm. On poorly planned fields with difficult terrain or cross slope, it is more often used method of lateral water supply. Forming strips in width from 1.5-2 to 20-30 m and a length for several hundred meters is done by making earth barriers with height of 20-30 cm in the direction of maximum slope. As a rule, the width of the strip shall be equal or multiple to the grasp width of the seeding-machine used in the farm. Depending on the area of the strip, water supply into it is carried out at a rate of 10 to 200 l / s. At the maximum water flow sometimes it is possible to simultaneously irrigate several (up to 5-7) strips, while the productivity of one irrigator can be up to 10 ha / turn. At present in the Kyrgyz Republic this method is the most common and is used for crops of narrow-row and solid sowing: cereals, grains, leguminous plants and herbs, as well as at water charging and pre-sowing irrigation.

This method has proved itself the best on the well-planned plots with longitudinal slope of not more than 0.015 and transverse slope not more than 0,002. The main advantage of the irrigation method by flooding and by strips is relatively low initial investment and operating costs, lack of energy costs, as well as the relatively high work efficiency of irrigators. In addition, this type of watering does not require high-skilled staff. At the same time the key disadvantages include large water losses and uneven soil moisture and distribution of fertilizers introduced with water, especially in irrigated areas with difficult terrain and insufficient planning. Judging from the experience of neighboring countries, increasing of efficiency of water use when using this method is possible by more careful monitoring and dosage of water supply through the use of siphons, irrigation units, mobile pipes, automated water outlets, etc.

However, the use of such mechanized devices leads to a significant increase of investments and operating costs, while not radically reducing the water losses on the field. In this regard, the devices for mechanized irrigation by flooding and by strips in the Kyrgyz Republic are used very rarely. It should also be borne in mind that in the Kyrgyz Republic, this method is often used in the irrigated areas with slopes which significantly exceeded admissible value, causing irreversible processes of soil erosion.

Flood irrigation method

Flood irrigation on checks also long been used in the southern regions of Kyrgyzstan, mainly in areas located in the floodplains of the lower reach of rivers. In addition, at present flood irrigation is used in other regions of the Republic in the non-vegetation period - when flushing saline soils and for water charging irrigation. For rice cultivation the part of floodplain is usually shielded with earthen dam from the main river bed and broken by temporary earthen ridges into the horizontal irrigation plots (checks) which are usually arranged in a cascade. Since the checks were usually built on the pebble basis, the formation of fertile soil layer was made by flooding the checks during river floods when the flow contained a considerable amount of suspended particles of small fraction fines. Sometimes, to create in checks a layer of soil with thickness of 10-15 cm it was required several years. A necessary condition to ensure uniform wetting of irrigated area is horizontal surface, with a tolerance of not more than ± 3-5 cm. In complex terrain of submontane zone to create such conditions over large areas is difficult, so the size of the checks in Kyrgyzstan rarely exceed 1 hectare, while the CNiP 2.06.03.85 recommends the optimal size of checks from 1 to 4 hectare, and the size of the card-checks, even from 12 to 16 hectare.

Noteworthy is the fact that local varieties of rice grown in the territory of Uzgen rayon of Osh Oblast has long been in high demand not only among the local population but also in nearby regions of Uzbekistan and Tajikistan. However, in 1960-1980s the area of rice crops have been dramatically reduced, and in especially dry years, even banned, because the cotton was considered as the priority crop in the south of the Republic. Conventional farming techniques of rice cultivation include the need to create and maintain a variable layer of water with depths ranging from 5cm to 25-40cm by the end of the growing season. This condition is associated with use of high irrigation rates, which constitute for different climatic zones of Central Asia from 10 to 35 thousand m^3 /year. The actual water consumption for rice cultivation is far superior to the biological needs of plants, since a significant portion of water is inevitably lost by filtration, evaporation and groundwater recharge. In particular, according to a number of studies, water consumption for initial saturation of the soil layer is 1-2 thousand m^3 / hectare, the volume of evapotranspiration is from 5 to 14 thousand m^3 / hectare, and the loss on the lateral and vertical filtration sometimes exceeds 10 thousand m^3 / hectare. Thus, for rice cultivation the flood irrigation is considered a major method, but its key disadvantages associated with significant water consumption, and real opportunities to reduce it are limited.

It should also be considered that formation of rice checks requires substantial initial costs, moreover, this method of irrigation contributes to destruction of the soil structure and formation of consolidated dry crust, and to eliminate the effects of these processes require additional manual labor. Against this background, the results of modern experiments in the Kyrgyz Republic on replacement of irrigation of rice by flooding for the furrow irrigation, although deserve some attention, but are not persuasive enough so far.

These circumstances allow suggesting that in the face of growing scarcity of water resources significant expansion of rice crops using the method of flood irrigation in Kyrgyzstan is hardly possible.

Furrow irrigation method

As noted above, the most studied in Kyrgyzstan are the various modifications of furrow irrigation method. For example, it was found that this method can be successfully applied for irrigation of any cultivated crops, including industrial crops, vegetables, leguminous plants, etc., as well as perennial plants in the irrigated areas with slopes up to 0.05. In areas with steep slopes watering by this way is possible in the case of using contour furrows. Depending on the slope of irrigated plot, composition of cultivated crops and soil permeability parameters, width of inter-rows can range from 45 to 90cm, for perennial plants - up to several meters. Based on the gradient of the slope and inter-row width on the plot, furrows are made of varying depth: on steep slopes and narrow inter-rows - small (8-12cm), on flat slopes with a width of rows exceeding 45 cm - average (12-15cm) or deep (18-20cm). There are open-end furrows and blunt end furrows, short (60 - 80 m) or long (up to 500 m). Under furrow irrigation it is necessary moisten the soil evenly across all the width of the rows, and at a minimum depth of 40 cm. To this effect, at the manual tilling furrows are cut by hoe or shovel in the middle between the rows, but with a width of inter-row more than 70 cm they often are cut at a distance of 20-25 cm along both sides of the row.

Depending on the slope on the plot, the soil structure and the type of irrigable crops water flow into the furrow head can vary from 0.1 to 4 L / s. The smaller water flow is selected the more is slope of the furrow. In the different regions of the Republic the different ways of water supply are used, for instance, by constant or variable stream. For example, when watering without discharge by the deep blunt-end furrows with depth of 25 to 30 cm and on slopes up to 002, furrows are filled with water, and then supply is stopped until the water is absorbed into the soil. Connecting furrow is arranged at the end of irrigation card to capture the residual water. When watering by the deep furrows without discharge, with filling them on about two-thirds, with an average slope of 0.002-0.004, supply of water stopped before the stream reaches the end of the furrow, and remaining part of its lengthwise is moistened by flowing water. When watering by open-end furrows with depth 8-25cm with discharge, with slopes more than 0.004, part of the water which is not absorbed into the soil enters the irrigation and drainage canals and then used repeatedly for irrigation of downstream fields. Irrigation by slot-furrows with a depth of 35-40cm more often used in recharge and pre-sowing irrigation on areas with not enough flat surface and on soils with low permeability. At such irrigation with water flow increased for 2-3 times as compared with conventional watering, soil is moistened more quickly and evenly. Watering of corn is often carried out through the furrow. Such methods of irrigation were previously well known to irrigators, especially in the south of the Republic, but now a new generation of people in rural areas often had to learn it all over again.

Advantages of furrow irrigation, as well as other methods of surface irrigation, are the relatively low cost for initial investment and maintenance of equipment, the possibility of watering crops, which are sensitive to leaf diseases, and watering in a strong wind. Furrow irrigation also is advantageous if the irrigation water contains a lot of mud and sand. Based on previous experience, it allows the possibility of using various means of mechanization of agrotechnical works and irrigation equipment, which significantly increase labor productivity, but with simultaneous increase of capital expenditures.

The key drawback of this method is the inability to use in areas with difficult terrain, significant losses of water by filtration and evaporation and uneven moistening of the soil. These drawbacks are common, as an automorphic soil moisture regime requires frequent watering by small rates, not exceeding the root zone moisture capacity (500-700 m^3 / hectare). Furrow irrigation technique in principle not able to meet these standards at a sufficiently uniform distribution of moisture over the entire area of the field and it causes inefficient use of water (if present) or drying of crops due to increased irrigation interval (with a deficit of water). Discharge of the “extra” water from the fields causes soil erosion, decreases its fertility and leads to subsequent contamination of water resources and the environment. At the same time it is quite possible to achieve tangible water savings at a more accurate dosage of water delivery by “variable stream” method with use of known types of irrigation aggregates, mobile irrigation pipes and even the simplest irrigation equipment, such as siphons.

Subsurface irrigation method

The study of archival materials has shown that in 1960-1970 years in Kyrgyzstan it was repeatedly planned the implementation of pilot projects on experimental introduction of subsurface irrigation systems, but evidence of their implementation was not found. However, in other Republics of the USSR in these and later years it was gained sufficient experience in the construction and operation of such systems, which allows to objectively evaluating their strengths and weaknesses. At various times their use was tested in cultivation of vegetable crops, grapes and cotton, mainly on flat areas, as well as on the slopes with loose soil cover, but later they were used mainly for irrigation of perennial fruit trees. Under subsurface irrigation method water (usually with a nutrient fertilizer) is fed directly to the roots of plants. The most effectively this method has proven itself on soils prone to salinization, with well-marked capillary properties, with relatively deep groundwater occurrence, more than 2.0m.

Subsurface irrigation is carried out by pipes-moisteners with diameter of 20-40mm and a length of 200m, located in the soil at a depth of 0.15-0.6m, on the distance one from another corresponding to the row spacing, typically - from 0.45 to 1.5m. Pipe-moisteners are connected to the top of the distribution pipe, and at the bottom – to the discharge (flushing) pipeline or to the open trench. Perforated tubes or flexible hoses, most commonly polyethylene, have round (diameter 2-3 mm) or slot holes (length of 5-10 mm and a width of 1-2 mm), located in every 20-40cm. By method of water supply subsoil irrigation systems are divided into vacuum (adsorption), non-pressure and pressure types. Most often, water is supplied to distribution and moistening pipelines under slight pressure, with a water head of 0.3-0.5m and flow rate at the head of a moistener in the range of 0.2-0.6 l / s.

Compared to the methods of surface irrigation, subsurface irrigation has several advantages, including:

- Enables the use of various means of mechanization and automation of the watering process;
- Provides the more economic use of irrigation water;
- Provides saturation of soil with oxygen, thereby creating favorable conditions for the root growth and plant nutrition, and hence raising the level of crop yield; the surface soil is not compacted and remains loose; infestation of fields is reduced and thus labor costs for weeding and cultivation of the soil is also significantly reduced;
- Subsurface irrigation do not interfere with other lawn-and-garden works on the plot;
- Less development of fungal diseases in the plants.

However, the relatively weak spread of this method is primarily due to the high level of costs for the purchase and installation of equipment set and its operation. Other disadvantages are:

- Restriction of use on the light (sandy), subsidence and saline soils;
- Weak moistening of topsoil that worsens conditions for germination and seedling survival of vegetable and other crops;
- Massive loss of water through filtration into the horizons below the active soil layer;
- Need for the additional work to prevent possible clogging of intrasoil moisteners and perforation holes with debris, silt or soil particles, for example, by the use of mesh, gravel or sand filters and / or providing periodic flushing of pipelines with clarified water;

- Significantly higher demands on the quality of irrigation water (the size of solid particles not more than 1 mm, the turbidity of water not more than 0.05g / liter), as compared with surface irrigation methods, in order to avoid siltation of distribution and moistening pipelines.

It should be noted that in recent years more sophisticated sets of equipment for subsurface irrigation were developed, which can significantly reduce the cost and time for construction using mechanized technology of trenchless layer of plastic pipes. Additional upgraded equipment also allows introducing to the fields together with water the dissolved mineral fertilizers and treated livestock and domestic sewage. However, the high cost of modern subsurface irrigation systems is a crucial factor hampering their applicability in Kyrgyzstan in the coming years.

Sprinkler irrigation method

As noted above, in Kyrgyzstan since the mid-1960s, it was accumulated considerable experience in the use of various types of sprinkler technique. This was due to the fact that this method of irrigation could be used on the plots where other methods are complicated, for example, on non-planned plots with complex micro relief. Sprinkling technique is most popular in the northern regions of the Republic - Chui, Issyk-Kul and Naryn Oblasts for irrigation of cereal, grain, vegetable crops and perennial grasses. A wide range of nozzles for sprinklers machine were used – short-range with grasp width of 5-8m, medium-range (15-35m), and long-range (40-100m). However, in the early years of introduction the most widely were used simple and relatively cheap long-range units DTN-70 and DDN-100, and especially the short-range dual console installations DDA-100M used on the basis of tractors DT-75. Later in the USSR was mastered the serial production of durable thin-walled pipes made of steel and aluminum alloys, which made it possible to create a more perfect samples of sprinkler technics. As a consequence, in the Republic, along with the mounted equipment, application of sprinkler machines of frontal movement has increased, for example, “Volzhanka” and “Dnepr” types, and the machines of circular movement - the “Fregat” type. It should be noted that in contrast to these, the wide-grasp frontal installation “Kuban”, portable long-range sprinklers of type DD-15, DD-30 and their modifications, as well as imported irrigation machines, such as “Sigma” manufactured in Czechoslovakia, were used in the country as a single prototypes.

Also the fine-dispersed sprinkler irrigation systems were used in limited cases, mainly in the greenhouses. Typically, the source of water for irrigation by sprinkling is open canals or boreholes of underground deposits. The required water pressure is provided by diesel portable pump installations of stand-alone type or mounted on tractors, as well as through the electrified pumps installed in boreholes.

Summarization of extensive practical experience in the application of different types of sprinkler technics in the KR allows drawing objective conclusions about their advantages and disadvantages. In particular, the main advantages of the sprinkling irrigation method are:

- Possibility of use in the fields with complex topography and large slopes, as well as on sandy and under-developed soils without conducting or at a minimum grading;
- Suitability for irrigation of most cultivated crops;
- Economic use of water (about 10-25%) and provision of uniform wetting of irrigated area, compared with the surface irrigation methods;
- A high level of mobility of equipment and capabilities to ensure high irrigation labor productivity;

- Ability to regulate in real time the volumes of water supply and irrigation intensity, depending on the period of plants development, soil characteristics and reclamation condition of the land;
- Ability to more precisely control the flow rate of water on the plot;
- An increase in the coefficient of land use by compaction of crop sowing, in compliance with the optimal dietary habits and lighting;
- Possibility of irrigation with simultaneous application of fertilizers and pesticides during extra nutrition for the control of pests and diseases, as well as the defoliation of leaves of plants before the harvest;
- Possibility of irrigation at any time and by small irrigation rates ranging from 30 m^3 / hectare.

In addition to these advantages, the method of sprinkling irrigation has a number of drawbacks, the main ones are:

- High initial investments for the purchase of expensive irrigation equipment and construction of the inlet pipelines;
- Additional costs for electricity or diesel fuel for pumping systems to create the needed water head for a sprinkler installations;
- High probability of topsoil compaction and crusting of the soil surface;
- A negative impact on the foliage cover of plants (leaf burn);
- Uneven distribution of water in the field in the wind;
- Significant loss of water in the periphery of irrigated areas, particularly in the plots of rectangular from, at using irrigation technics of circular movement, for example, type “Fregat”.

It will be useful to note that the effective operation of the sprinkler equipment requires a high level of qualification of personnel and careful observance of all agronomic techniques and irrigation regimes. For example, it is necessary take into account that irrigation standards at sprinkling irrigation is generally lower compared to the standards calculated for surface irrigation methods (in favorable conditions - up to 400-800 m^3 / hectares). Under these standards the necessary depth of soil soaking is not always provided, that is why it is necessary to increase the number of watering. This increases the cost of irrigation and leads to an increase in water loss. The basic principle of sprinkler irrigation is the observance of condition under which the intensity of sprinkling must match the speed of water absorption by the soil, and any deviation from the optimum irrigation regime is associated with negative consequences: either drying of plants, or to formation of puddles on the plot and runoff, occlusion of the soil, displacement of air out of soil, and even to the development of diseases in plants, and ultimately - to lower yields. However, implementation of this principle can only be achieved as a result of years of practice.

In general, from the above listed disadvantages the following factors most noticeably contributed to trends of degradation of sprinkler irrigation systems: the high cost of irrigation technics, a manifold increase in the cost of diesel fuel and tariffs on electricity, the lack of qualified personnel, as well as the consequences of land reform, which resulted in the small size of land plots for farmers and peasant farms and often make it impossible to use many types of irrigation devices. However, this fact does not exclude the possibility of using compact sprinkler installations of stationary, drum-hose and other types on the small irrigated plots.

Drip irrigation method

Chronology of application of the drip irrigation technology in the Kyrgyz Republic has several characteristic stages – period of the first experiments since 1979, period of the pilot implementation in small areas in the mid-1980s, the short period of sustainable use in the late 1980s, when the total area of gardens, irrigated by this method reached almost 800 hectares and subsequent, more than a decade period of stagnation and degradation. After 2010, due to the increasing scarcity of water resources, application of the drip irrigation systems in Kyrgyzstan was once again activated. As a consequence, in 2014 the use of this method was registered for watering beans in Talas Oblast in the area of 2 hectares, for watering orchard in Osh Oblast on slope area of 2 hectares, for irrigation of vegetables in greenhouses in Chui Oblast on a total area of 0.6 hectares. However, in the nearest future it is planned the more intensive use of this method. For example, in Kara-Buura Rayon of Talas Oblast the construction of system for watering potatoes on the area of 20 hectares is carried out, and in Ton rayon of Issyk-Kul Oblast - even more ambitious project is planned for watering the garden on an area of 85 hectares. The experience has been already gained in the Kyrgyz Republic, along with the summarization of the practice of use of drip irrigation systems abroad, allows us to formulate some preliminary conclusions.

Essentially, drip irrigation is the improved modification of the above mentioned method of subsurface irrigation. Therefore, it is fully characterized by the key advantages and disadvantages mentioned above, but there are some differences. In particular, under drip irrigation water is supplied directly to the root system of the plants through special micro-water-outlets - droppers with a very low flow rate, typically between 1 and 4 liters / hour. This provides the possibility of watering by small irrigation rates and with short irrigation intervals. Together with water if necessary, dissolved fertilizer can be delivered by injection into the main pipeline via an injector.

The variety of developed to date drip irrigation technologies allows their use in the areas of different configurations of complex terrain, including steep slopes, that do not require careful planning. However, the scope of its use is limited by unsalinized soils and groundwater table more than 2 m from the surface, and with highly saline ground waters - over 4 m. In contrast to the sprinkler irrigation, drip irrigation can be carried out in all climate conditions, even in strong winds, and allows performing various kinds of agricultural work directly during irrigation.

Another indicator of the effectiveness of this method is the use for irrigation of different types of crops. However, the high cost of equipment and maintenance of drip irrigation systems suggests the expedience of their preferential use in cultivation of highly profitable perennial crops (orchards, vineyards, berry fields) and annual vegetable and melon crops of wide-row planting (with inter-rows width of 0.7 - 6 m), in conditions of limited water resources .

The latter condition characterizes a major advantage of this method - the significant savings of the irrigation water by reducing filtration losses outside the root zone, vaporization, and runoff and also due to the elimination of uneven irrigation. The practice shows that drip irrigation allows reduce water losses up to 50% of water, and on the maximum estimates - to reduce for 2-3 times irrigation rates, compared with surface irrigation methods and sprinkling.

However, it should be taken into account the serious obstacles to the widespread introduction of drip irrigation systems associated with high requirements on quality of irrigation water, even in comparison with other methods of subsurface irrigation, not to mention the technology of surface irrigation. Therefore, a set of equipment for drip irrigation must, as a rule, include devices for water purification. But although Kyrgyzstan has sufficient experience of cleaning of irrigation water from bed silt and suspended particles in sedimentation tanks, at the same time effective methods of reducing the water hardness (salinity of water by calcium and magnesium compounds) has not yet worked out, which significantly reduces the reliability of drip equipment. In this regard, there is an increased risk of frequent clogging of droppers water-outlets with deposits of salts and plankton, which are formed in pipelines-moisteners during the inter-irrigation intervals, and in consequence it cause the uneven wetting of irrigated plot. This calls for regular flushing of the entire system by preparates, which are not always beneficial to cultivated crops. In addition, the use of drip irrigation is associated with a number of other specific issues, for example, with the possibility of damage the plastic drip tapes during cultivation of the soil, or even by rodents.

Yet, along with other factors, currently the main reasons for limited use of the drip irrigation systems are the highest, compared with other methods of irrigation, costs of the purchasing, installation and maintenance of equipment. This is due to the necessity of mounting a dense network of pipelines, moisteners, a large number of drip water-outlets, and application of additional equipment for water purification. It is clear that at present the significant initial investments and subsequent operating costs are affordable only for the most successful farmers in Kyrgyzstan. But the larger farms will be able to achieve rapid cost recovery of capital investments only in the case of a radical modernization of the entire spectrum of agronomic technologies and cropping patterns. This conclusion is confirmed by the results of comparative tests have been carried out in recent years in Kyrgyzstan as part of the training programs of a number of international projects for the staff of the WUAs. In particular, these results demonstrate the possibility of achieving tangible water savings by using water-saving irrigation technologies, but this will sharply increase the unit costs, compared with traditional methods of irrigation. It is important to note that the conducted experiments have shown, that a marked increase in crop yields, irrigated by using of water-saving technologies, and thus increase of the profit, can be only achieved under additional extra nutrition of plants with mineral and organic (“sherbet suu” method) fertilizers and a more thorough treatment of the soil.

V. Summary of international experience in the development of advanced crop irrigation technologies

1. Introduction

The availability of sufficient water resources in Central Asian countries is a key factor of development of all sectors of the economy. The arid type of climate makes possible efficient agricultural production exclusively through the advanced and efficient methods of irrigation. On the other hand, the reduction of water availability, intensification of salinization and other forms of land degradation at the global and regional climate change also affect the level of yield of all crops. In the Central Asian countries it is the most important to assess timely the impact of climate change on the agricultural sector as a major consumer of water resources. It is known that warming leads to an increase of evaporation, as the basic flow of water balance, and as a result, causes an increase of the number and rates of all types of watering: vegetation, recharge and flushing watering. To further reduce the negative impacts and mitigate the climate change effects on the environment, it is necessary to efficiently use the water resources and introduce the advanced water-saving technologies in irrigated agriculture, such as sprinkling and drip irrigation. With the current situation in irrigated agriculture, climate change will result in an increase of water deficit and additional risks for agriculture.

Therefore, information on innovative methods of irrigation is important to assess long-term needs for water resources to the agricultural sector of the Kyrgyz Republic, as well as from the point of view of a possible increase in crop yields.

At the same time, with the growth of economic potential of the Central Asian countries, some of them will have serious problems related to water supply and wastewater treatment. These processes are, of course, associated with the ongoing organizational and structural reforms and, in particular, in agriculture sector, including the introduction of water charges to cover the real costs of water supply.

But irrigation water is not only the life; in some sense it is a threat for the field. Overirrigation frequently leads to the fact that the salts, hidden before deep in the soil, will drawn up by groundwater to the surface, making the soil completely unsuitable for use. On the other hand, the use of highly mineralized irrigation water leads to degradation of irrigated land, especially when using technologically inefficient irrigation methods. The overall situation is exacerbated by the fact that the large areas of irrigated land in the country are in a poor reclamation state.

Analyzing and summarizing the international experience and trends of development of irrigation technologies, it should be noted that at the international level it is customary to compare countries by their natural **water availability**. According to the UN definition the mark of water deficit is 1,700 cubic meters of water per capita per year, and the red line is about of 500-700 cubic meters, so the specific solutions for development largely depend on this article. According to official data of FAO (AQUASTAT, 2002), the specific water availability per capita in **Kyrgyzstan** is **4,182 m³ / year** at the expense of natural (renewable) water resources [Water resources: total renewable per capita] while in Kazakhstan - 6.778; Tajikistan - 2,625; Turkmenistan - 5,218; Uzbekistan - 2,026; Egypt - 859; India - 1,880; Turkey - 3,439; China - 2756; Israel - 276.

For comparison, it is also important to note the data on **water consumption** per capita (including components of agricultural, industrial and domestic water consumption), but very different from the previous data:

- Kyrgyzstan – 1,717 m³ / person per year
- Kazakhstan - 1,436
- Uzbekistan - 1.536
- Turkmenistan-3,596
- Tajikistan - 1,016
- Egypt - 485
- Israel - 191

Since the comparison of agrarian countries by efficiency of water use is accepted to count by the **average irrigation rate in m³ / ha per year**, in the case of Kyrgyzstan, the scenario differs from the above methodology:

- According to the FAO data in 2006 water supply for agricultural sector of KR amounted to **7.447 million m³** of water (i.e., 93% of the total water consumption equal in that year to **8.007 million m³**). In this case, the **average irrigation rate** based on these data was about **7,300 m³/ha per year**, and such a result can be considered quite acceptable in comparison with neighboring countries in the region and reflecting the needs for the dominant agricultural crops in the basket of goods.
- Taking into account that this result also includes a loss of irrigation water in the main, inter-farm and on-farm systems, estimated at 45-50%, then **water supply for irrigation** can be assessed in an amount of about **4.1 cubic kilometers per year**, and adjusted results of the average irrigation rate (net on the field) at the amount of **4,000 m³/ha per year**. Such analysis unexpectedly brings us closer to the almost actual results of **irrigation water supply** according to DWMM data for 2014 equal to **4,438 km³ per**

year on an area of 914 thousand hectares of irrigated land with averaged in this case irrigation rate on the field at the amount of **4,850 cubic meters per hectare per year**.

On the other hand based on the irrigation rates recommended in Kyrgyzstan (based on average figures net /field) in the amount of:

- Cotton 4,800-6,700 m^3 / ha per year
- Corn for grain 3,800-5,600
- Winter wheat 2,500-3,800
- Alfalfa 5,800-7,900
- Gardens 6,300

And substituting these data into a known basket of agricultural crops (according to MAM KR data) we get approximately **water supply for irrigation** at a rate of **5.5 km^3 per year, while water supply for agrarian sector** (taking into account recognized losses) in the amount of **10.0 km^3 per year.**

In conclusion, it can be noted that based on this scenario, we get the average irrigation rate of **9-10 thousand m^3/ha per year**, reflecting a more realistic result for the Central Asian countries.

These data reiterate the need to clarify information on the water balance of the Kyrgyz Republic, taking into account the need to ensure food independence. It is recommended to start planning such a balance already now for 2020, 2030, 2040 and even for 2050 years, taking into account the needs of all sectors of the country. This information will also allow more realistic considering the recommendations on introduction of advanced irrigation technologies on the basis of development of necessary infrastructure for agricultural sector.

2. Review of modern advanced and efficient irrigation technologies

The most important activity aimed at improving the productivity of land in arid areas is irrigation. The optimality of the irrigation method used and technical perfection of irrigation and drainage systems are evaluated by the minimum flow of irrigation water and maximum yield. This problem can be solved in a complex, creating technically perfect water-saving on-farm systems with the use of efficient equipment and advanced technologies.

Choice of rational irrigation technologies and equipment for these specific conditions should be carried out in stages. At first it is necessary to determine technical acceptability of a particular irrigation technology, and then choose the most economically sound method for this area (basin) taking into account dominant crops.

Technical applicability depends on a number of environmental-economic factors or climate conditions (1), soil (2), relief (3), hydro geological (4), economic conditions (such as estimated depth of the root system and irrigation rate) and the number of qualified irrigators.

- (1) deficit of evaporation, wind speed;
- (2) Absorption rate for the first hour, depth of soil thickness;
- (3) Maximum slope, volume of planning works;
- (4) Depth of occurence of fresh and saline groundwaters.

Economic evaluation of the appropriateness of particular equipment and modern irrigation technologies is set by comparing the number of technical and economic parameters, the most important of which are: the amount of capital investments and payback period. Examples for these items are shown below.

Drip irrigation

Features of drip irrigation systems

Many international companies have invested a lot of efforts and funds in research and development of drip irrigation. Obtained positive results have contributed to the rapid spread of drip irrigation in many other countries. As a result of technological improvements over the years the drip humidifiers (droppers) and other highly reliable equipment of drip system have been developed, suitable for water of any composition (quality) and for various field conditions.

Under the drip irrigation the soil is moistened by water supplied by the small points of water sources of low flow, whereby only a small portion of the total volume of soil is wetted, but even in this volume the content of soil moisture is uneven. Therefore, the root system of plants developed according to this nonuniform moisture content.

Branched and relatively shallow root system develops in the volume of soil (often presented with cone in a shape of "bulb") with high moisture content close to the point source of water (dropper). As moving farther from the source of water, the content of moisture in the soil is reduced and accordingly the root system development is also reduced.

In the transition from other types of irrigation to drip type, the process of adaptation of root system is fast and goes without problems.

Drip irrigation is the most efficient system for plant nutrition. Rapid and intense absorption of nutrients occurs due to the greater development of the root system in the area around the roots. Due to the fact that water is circulating in the soil by capillarity principle, it almost does not displace air. Soil macro pores largely remain dry, with good aeration and moisture level only slightly above the field moisture capacity, except for a small water-saturated area near the dropper. This provides a more intensive breathing of roots throughout the growth cycle, which is not interrupted during or immediately after the irrigation.

Another feature of drip irrigation is the ability and, most often, the need for watering and fertilizing at short intervals, which makes it possible to achieve high productivity with more efficient use of water, compared to any other method of irrigation.

Drip irrigation also allows using the saline water for irrigation, but in this case it is necessary to give special attention to salt distribution in the soil solution.

Due to the features of motion and distribution of moisture from a point source, the salt concentration at the limit of wetted area ("cone") can be higher than salt concentration in irrigation water or the concentration in the area directly under the drip.

The use of saline water creates areas of high salt concentration also on the surface of the soil around the drip and deep in the soil under the soaked front. Therefore, in the case of salt accumulation it is necessary to carry out their artificial flushing below the main root layer by adding water to the irrigation rate at the end of the season (also taking into account the natural rain washing).

It should also be noted the high sensitivity of drip systems to clogging, so in these systems focus to be on filtration of the devices and chemical treatment of the irrigation water.

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Water flow from a point source

The main forces acting on the water flow in the soil are the gravitational and capillary forces, which provide movement in all directions. The relationships between these two forces affect to distribution of water in the soil.

For soils with low hydraulic conductivity (infiltration rate) and high field moisture capacity (such as clay or dust clay) it is common to represent the configuration of water-wet volume under the dropper as a “bulb”. For soils with high infiltration rate (with low available soil moisture) soaked profile is presented in the form of an oblong “carrot”.

The distribution pattern both of soil moisture content and concentration of salts in the soil solution of wetted circuit depends on:

1) Soil properties;
2) Dropper flow;
3) Distance between droppers;
4) Salt concentration in the irrigation water;
5) Irrigation rates;
6) Conditions of initial moisture.

In the area directly under the dropper the conditions of saturation are created, and infiltration rate decreases. It is generally believed that the diameter of this saturated area reaches a certain fixed size.

In light soils with a high content of coarse particles (sand), characterized by high infiltration rate (even under conditions of saturation), directly under the dropper is formed a small transition region of saturation.

In the heavy soils (clay) with a high content of fine particles and low rates of water absorption into the soil (infiltration rate), this transition region of saturation under the dropper can achieve relatively large dimensions.

It is important to remember that maximum diameter of the area for a particular type of soil depends on the dropper’ flow rate and does not depend on the duration of watering period.

Aeration in this area is inadequate, and its great size may adversely affect the growth of plants.

Wetting front (wetted “cone”) of different soils after irrigation process by the same irrigation rate is different and extends to a greater depth in the light soils, compared to heavy. These provisions are very important for selection of the drip rate and the distance between droppers.

Therefore, the heavier the soil, it is possible to increase the distance between adjacent droppers (by capillary movement of water). On light soils it is recommended to reduce these distances, as in this case, gravitational force has a dominant effect on the movement of water in the wetted area.

Using mathematical models it is possible to find the best ratio between the drip flow and the distance between droppers, depending on the type of soil and plants.

It should be noted that during washing of salts accumulated in the wetted “cone”, in case of the light soils (sand), there is a gradual accumulation of the salts on the edge of wetted front; in case of loamy soil the salts are distributed in a fairly broad strip in parallel to the wet front.

Specifications of droppers

As noted above, the drip irrigation systems refer to the irrigation under the pressure. The role of dropper is the supply of water from irrigation tube (diameter from 12 to 25 mm and a wall thickness from 0.25 mm to 1.2 mm) into the atmosphere in the form of drops without energy.

The design of the labyrinth flow with its small size is the core of the dropper and this labyrinth corresponds to controlled reduction of pressure. Labyrinth is characterized by three parameters: the shape, length and transverse dimensions. These parameters define the drip flow depending on the pressure, allowing constructing the corresponding characteristics Q / P, and affecting on the ability to resist clogging. Dimensions of the cross section of one of the most common droppers with consumption of 2.3 L / s: depth - 1.2 mm, width - 1.2 mm, length - 15

Nominal drip flow of the dropper usually reflects flow at a pressure of 1 atm (10 meters). In agriculture, the most common are droppers with drip rate from 1.2 L / hour to 4 L / hour.

Quality of dropper is expressed by its ability to provide a nominal flow rate at a given pressure, by uniformity of drip flow of droppers and less sensitivity to clogging.

Over the years, the designers of droppers had to overcome two contradictory requirements: on the one hand, the design of the labyrinth with long stream and narrow dimensions of cross section to get a low drip flow, and on the other hand - the desire to increase the size of cross section and shorten the length of stream in the labyrinth in order to reduce the clogging sensitivity.

In recent years, a whole series of droppers with the above qualities - short labyrinths with a relatively large cross sections and turbulent flow, providing low consumption and little sensitivity to clogging.

Particular attention at the design of droppers is paid to creation inside it of a built-in filter component.

Work characteristic of droppers

- Droppers of conventional operation (without compensation of flow) - drip flow varies with pressure change.
- Droppers of compensating operation – drip flow remains constant over a relatively wide range of pressures (6-40 meters).

The following formula can represent the relationship between drip flow and pressure at dropper’ inlet:

$q = kP^e$,

Where:

q - Drip flow (l / h);

k – Dropper’ constant;

P - Pressure at the inlet of the dropper (in meters);
e - Coefficient depending on the flow regime in labyrinth.

As an example a calculation is presented of one specific integral dropper at the pressure P = 10 m and P = 20 m:

$Q = 0.911 \times P^{0.48}$ л/ч,

Where

P. = 10 m $Q = 0.911 \times 10^{0.48} = 2.75$ l/h

P. = 20 m $Q = 0.911 \times 20^{0.48} = 3.84$ l/h

In droppers with turbulent water flow the rate varies according to the square root of the pressure and coefficient e = 0.5. In this case, the design of drip systems allows a deviation of the pressure between the extremely located droppers of 20%, providing 10% deviation in flow rate respectively.

In droppers with laminar flow coefficient e = 0.7-0.8, and it allows respectively the maximum deviations only by the size $\delta P = 15\%$, $\delta q = 7\%$.

It is considered that the less is the coefficient e (closing to 0.4), the more turbulent flow is expressed, and the drip flow of the dropper becomes less sensitive to pressure changes.

The practical significance of this situation lies in the possibility of designing drip irrigation systems with wide variations in pressure, while maintaining the deviation of the drip flow at required regime, but not more than 10%.

For droppers of compensatory operation is taken coefficient e = 0.05, and the compensation range e = 0 (for the same dropper).

The operating principle of droppers with pressure compensation

Water in drip pipelines is at a certain pressure, and passing through the dropper labyrinth it enters the pressure compensation chamber. Under normal operating conditions, when the water pressure in a drip pipeline is above the pressure at which the process of compensation begins, in the chamber itself the pressure will be below the operating pressure of the pipeline. The flexible membrane mounted in the dropper and located between the two pressure levels, will begin to bend towards the compensation chamber outlet, whereby the size of the outlet also will change, which in turn is in inverse relation to the pressure in the irrigation (drip) pipeline.

With increasing pressure in the irrigation pipeline outlet size is reduced; thus, there remains a constant drip flow, regardless of pressure change in a wide range of pressures.

Types of drip (irrigation) pipelines

There are three main ways of joining droppers to the irrigation pipeline, which determine its types:

- Integrated drip irrigation pipes. In this case, the dropper is “welded” to the inner wall of the plastic irrigation pipe during its manufacture.

- Fitted in-line (linear) dropper. Independent droppers, connected with plastic irrigation pipe using serrated nipple on both sides of the dropper.

- Fixed side line droppers. (So-called push-button droppers with pressure compensation and conventional).

Subsurface drip irrigation

One of the main advantages of laying of subsurface drip (irrigated) pipelines is to protect drip equipment from damages associated with the annual installation and removal at the end of the season, as well as damage by mechanized equipment and animals. In addition, the subsurface laying significantly reduces the moisture of the soil surface, thereby significantly reduce water loss through evaporation and weed growth.

Combinations of these benefits with others which are inherent to drip irrigation, in some cases justify the rationale of subsurface drip irrigation, in spite of its high initial investments.

Designing systems of subsurface drip irrigation has to be at the highest professional level, as after laying and putting into operation there is almost no possibility of any changes and amendments.

One of the problems associated with subsurface laying of drip pipelines, is the inability of preplant irrigation. In this case it is necessary to apply additional sprinkling irrigation systems.

The main feature of subsurface dropper, compared with one laid on the soil surface, is a characteristic of distribution of moisture around the dropper.

In the case of subsurface laying water, leaving the dropper, moves in all directions, and the wetted area takes the form of ellipse, resembling an egg, with extended side up.

In soils with a high content of fine particles (clay) the wetted area (volume) takes the form resembling the ball. In light soils with a high content of coarse particles (sand) the vertical movement of water in depth from the dropper is more significant as compared with the horizontal.

In the case of identical irrigation rates, soil moisture content in the wetted circuit around the dropper at its surface laying will be larger than around subsurface dropper. This is explained by the fact that in this case the volume of the soil with accumulated moisture is less than the wetted volume around subsurface dropper. As a result, the radius of the wetted circuit of subsurface dropper is less than the radius of the wetted area under the dropper laid on the soil surface.

An additional distinctive phenomenon of subsurface-laid drip pipeline is to reduce drip flow, compared with the nominal, due to the opposite pressure arising in the process of irrigation and directed toward the water outlet (holes) of the droppers. The cause of the opposite pressure is the difference between the drip flow and the water infiltration rate into the soil from a point source. Water emerging from the dropper must be pushed into the water which is already exists around the dropper.

At the beginning of the irrigation period the infiltration rate is relatively high, and the water coming from the dropper encounters little resistance. With moisture of the wet circuit during irrigation process the rate of absorption usually decreases. Under these conditions, the water coming from the dropper encounters considerable resistance, i.e. high opposite pressure, resulting in reduced drip flow.

The level of this opposite pressure depends on the drip flow of the dropper and the soil properties. The greater is the drip flow, the greater is the resistance. In soils with low infiltration rate opposite pressure is higher than in sandy soils. Drip flow with pressure compensation is less sensitive to counter-resistance compared to conventional dropper.

Opposite pressure may have a significant influence on the uniformity of moisture distribution in the field, due to the fact that this factor depends on the rate of water absorption into the soil and may vary over a wide range.

There are models, allowing selecting the depth of laying of drip pipelines according to the drip flows and the distance between droppers. There is a definite relationship between the depth of laying, drip flow and soil properties.

Sprinkling

Fundamentals

The water flow enters the nozzle of sprinkler under a defined pressure and is emitted from it in a form of jet into the atmosphere, thus giving initial velocity to drops by transformation of specific pressure energy into the specific kinetic energy (corresponding to velocity head). The degree of expansion of jet into the drops, given the trajectory, depends on diameter of the nozzle, water pressure, rate of sprinkler rotation and an angle (trajectory) of the "flight".

It is considered that:

- At the same pressure drops "split" stronger with decreasing of diameter of the nozzle;
- If the nozzle diameter is constant, then drops split stronger with increasing pressure;
- In shock reciprocating rotary sprinklers the radius of trajectory increases with decreasing of speed of rotation and with increasing the angle of the flight;
- The design of sprinklers tends to seek achieving the maximum increase of the radius of the trajectory and thus the maximum distance (pace) between adjacent sprinklers with the best coefficient of uniformity of irrigation.

Each sprinkler (with one or two nozzles) has the region of optimal pressure in which the sprinkler (under certain distances between adjacent sprinklers) can irrigate in the acceptable range of coefficients of irrigation uniformity. Region of optimal pressure is wider at the shock reciprocating rotary sprinklers; however, this area is reduced for the nozzles with a smaller diameter and, accordingly, increases to the nozzles with a larger diameter. It should be noted that the small-diameter nozzle at high pressure significantly split drops of the jet (silon) and work of sprinklers with a larger diameter of nozzle at low pressure leads to formation of excessively large drops.

"Shock" sprinklers usually have one or two nozzles with diameter of 2-6 mm (up to 8.5 mm), and in long-range-jet devices with location, for example, at 36 x 48 meters, respectively, 18.0 x 9.5 x 4.0 mm. Sprinklers with two nozzles are typically designed to larger sizes than sprinklers with one nozzle. The nozzle of smaller diameter is used for spray, while nozzle with larger diameter - to create trajectories.

For oversprinkling irrigation of crops and gardens most often are used sprinklers with an angle (trajectory) of the jet in the range of 20-30º (sometimes also within 9-14º for irrigation of vegetables). For under-crown sprinkling irrigation of gardens and plantations it is recommend choosing the angle within 4-7º.

It should be noted that optimally designed sprinkler does not always ensure a uniform distribution of water in the field, this conditioned by correct selection of the optimum pressure mode, the distance (pace) between adjacent sprinklers and consideration of wind speed and direction.

Recommended range of operating pressures:

- Mikrosprinklers with flow of 20-100 l / h - 2.0-4.0 bar.
- Mikrosprinklers with compensated pressure or flow control - 1.2-4.0 bar (atm).
- Sprinklers for overirrigation (vegetables) with flow 150-400 l / h - 2.0-4.0 bar.
- Sprinklers for field crops with flow of 1.3-3.5 m³ / h and distances up to 18 m - working pressure 3.0-5.0 bar.
- Sprinklers for field crops with flow of 2.5-5.5 m³ / h and distances up to 24 m - working pressure 4.0-6.0 bar.

The uniform distribution of water under irrigation

Uniformity of irrigation is one of the most important factors determining the high crop yields and successful growth of the garden vegetation. Best results are achieved with a uniform wetting of land profile to the level of occurrence of the main root layer. In practice, absolute uniformity cannot be achieved. The main factors affecting the uniformity of irrigation are the wind strength and direction, as well as pressure. Due to the fact that the sprinkler' flow depends on the pressure, it is recommended to adhere to the requirements of uniformity of sprinklers (by type and size of the nozzle) on the entire plot, as well as to maintain the operating pressure in the optimal mode (range).

Placement of sprinklers

Most sprinklers supply the greatest amount of water directly at the riser / sprinkler, and this amount is gradually reduced to zero at the edge of the wetted perimeter, therefore:

1. It is recommended to ensure maximum overlap of wetted profiles of adjacent sprinklers both at irrigation pipeline and between parallel lines (pipelines).
2. Reducing the negative effects of wind on uniformity of water distribution at sprinkling is achieved, if necessary, by reducing the distance between adjacent sprinklers along the irrigation pipeline and between parallel positions in accordance with the recommendations presented in Table 8.

Table 9. Recommended distance between adjacent sprinklers, depending on the wind speed and the field configuration

Location	Wind speed, m/s	Distance
Square or rectangular	Calm 2 m/s 3.5 m/s More than 3.5 m/s	60% of wetting radius 50% of wetting radius 40% of wetting radius 30% of wetting radius

Triangular	Calm 2 m/s 3.5 m/s More than 3.5 m/s	65% of wetting radius 55% of wetting radius 45% of wetting radius 30% of wetting radius

3. It is recommended to design the location of watering pipelines perpendicular to the wind direction prevailing during the sprinkling.
4. It is recommended to install the sprinklers at the height of 30 cm above the watered crops.
5. Irrigation pipelines should be placed in parallel, and the distance between sprinklers must be equal.
6. It should be noted that the best profile (shape) of the water distribution curve around the sprinkler in vertical section appears as “triangle” or “trapezium” (distribution pattern), which allows to achieve the best overlap of profiles and uniform water distribution.

Methods of evaluation the uniformity of water distribution under the sprinkling irrigation

One of the methods of evaluation was proposed in the fifties by J. I. Khristiansen.

In this case the irrigation uniformity coefficient is determined by statistical formula and is used in particular to determine the correct placement of sprinklers.

$$Cu\% = 100\left(1 - \frac{\sum\left|Xi - \overline{X}\right|}{\overline{X} \times n}\right)$$

Where:

Xi - Measured amount of water in the experimental reservoir (vessel) in cm^3
$\overline{X}$ - Average value of water in the vessels cm^3
n - Number of vessels (readings)
$\sum$ - Total absolute value of deviations from the average value

The minimum acceptable value of the coefficient Cu = 85%.

The second method of evaluation of uniformity in irrigation refers to the coefficient Du, which expresses the ratio of the average value of 25% of the smallest measurement to the average value of all indicators.

$$Du = 100 \times \frac{\text{average value of the quarter of smallest measurements}}{\text{Average value of all measurements}}$$

This method allows you to identify a specific area of the watered plot, receiving a minimum rate of irrigation. This ratio allows calculating the rate of irrigation and the required additional water on the basis of the plot, receiving the minimum amount of irrigation rate.

Micro-irrigation (under-crown sprinkling)

The methods of micro-irrigation are the most effective for gardens, plantations, fields for growing vegetables and other crops, especially on lands with difficult terrain and severe deficit of water resources, where the use of other methods of irrigation is difficult or impossible.

A distinctive feature of micro-irrigation compared to conventional uniform distribution of water in the process of sprinkling is the inability in most cases to ensure full coverage and even distribution of water throughout the irrigated plot. In this case, another goal is set - to achieve uniform supply of water to each tree and seek for optimal allocation of water in accordance with location of the main root systems.

The use of micro-irrigation systems provides:

- Increase of productivity;
- Saving of irrigation water;
- Possibility of the development of low-capacity, low-productive soils and slopes;
- Reduction of labor costs for maintenance of the systems by automating the processes of irrigation management and control of system operation;
- Introduction of fertilizers with irrigation water;
- Lack of moisture of the lower foliage of trees and thus protection from burn influence of irrigation water with high mineral content;
- Reducing the penetration of nitrates (from fertilizer) into groundwater;
- Irrigation by small (fine) droplets provides easy germination and sprouting, and does not create a compacting crust on the soil surface.

When selecting micro-sprinkler it should be considered the relationship between the sprinkler flow rate, wetted diameter and the rate of irrigation. Therefore, if the wetted diameter is small, and the designed irrigation rate is high, it is possible infiltration of moisture below the depth of the main root layer. Irrigation of area with a large diameter of spray can lead to a slight moistening of the soil (on depth) and contribute to its salinity.

It should be noted that the intensity of irrigation (sprinkling), calculated on the basis of the distance between adjacent micro-sprinklers (without overlap of wetted fronts) gives less results than in reality.

3. Comparison of effectiveness of advanced irrigation technologies

To sum up above said, we cannot disagree with the fact that in the countries of Central Asia inefficient water use in the agricultural sector is dominated as a legacy of obsolete water supply systems, as well as because of backward techniques and irrigation technologies and technological losses when supplying by open canals of gravity, and as a result of these the plants receive only about 40-45% of the total water intake.

The growing scarcity of water resources determines the need to develop new approaches to sustainable development of water supply for the countries in the region with a focus on the effective use of all available water resources on the territory. It is obvious that in this situation, the recovery of deficit may be primarily by improving the technological level of irrigation systems and the transfer of agriculture to water-saving irrigation methods and technologies. Therefore, there is a keen question of justification and recommendation of such methods and irrigation technologies that will provide the most economical and rational use of irrigation water with the minimal non-productive losses and the significant increase in crop yields.

At present, international experts are most concerned with the introduction of modern, efficient irrigation methods such as sprinkling and drip irrigation; introduction of batching valves (allowing the supply of irrigation water by volume); reconstruction of pumping stations, supply and distribution pipelines and canals; pressure control in accordance with the technical requirements of a particular irrigation equipment; recommendations for filtration plants; introduction of automation and reuse of drainage water (partially containing fertilizers introduced during fertigation). Development and introduction of automation in the agricultural sector is an important additional factor in the efficient use of irrigation water, allowing saving up to 15-20% of irrigation rates.

In addition, in recent decades, additional irrigation technologies of micro- and macro-sprinkling have been introduced. These include sprinklers for under-crown irrigation of plantations and orchards, which replaced less efficient overirrigation. Micro-sprinklers also are widespread in growing vegetables in small farming areas, reaching a high coefficient of uniformity of irrigation.

Today, it is not disputed that the water use under drip irrigation is more efficient compared to other irrigation technologies. It is considered that the efficiency of drip irrigation exceeds 90%. Introduction of drip irrigation can save the following amount of water in relation to the accepted irrigation rates:

- 20 - 23% for irrigation of vineyards
- Up to 50% for irrigation of tomatoes
- Up to 27% for irrigation of cotton

Simultaneously it is achieved the yield increase by 48%, 39%, 53% for the respective crops.

As it is known, the efficiency of irrigation (Irrigation Efficiency - IE) can be represented as the ratio between the surplus of moisture in the root zone to the irrigation rate, where irrigation rate includes the increase of moisture in the root zone, evaporation, runoff, infiltration into the depth of the soil and water loss in the furrows (pipelines) on the irrigated area.

As noted above, irrigation is one of the key elements for the success of cultivation of crops and their efficiency. In view of this, it requires special attention, learning and generalization of international experience including modern irrigation technology trends. So let’s once again represent concentrated tables for comparison of the most common current irrigation technologies:

Table 10. Comparison of irrigation systems (agrotechnical)

A. <u>Surface irrigation</u>

№	**Advantages**	**№**	**Disadvantages**
1.	Low investments	1.	Large water loss
2.	Low cost for energy (water head)	2.	Low efficiency of irrigation
3.	Low operating costs	3.	Possibility to spread plant diseases
4.	Possibility of irrigation in wind	4.	This method is not acceptable on adverse slopes
5.	Suitable for irrigation of plants susceptible to leaf diseases	5.	Is not acceptable as refreshing and anti-frosts irrigation

Б. <u>Sprinkling</u>

№	**Advantages**	**№**	**Disadvantages**
1.	Possible on the fields with complex topography, where it is impossible to use surface irrigation	1.	Sound initial investments

2.	Suitable for irrigation of the most crops	2.	Additional costs for energy consumed to create the required pressure in the irrigation systems
3.	Possible economical use of water, high irrigation efficiency, yields increase	3.	Uneven distribution of water on the field in the wind
4.	Provides extensive mechanization of all farm operations and their implementation in a short time	4.	Irrigation with saline water adversely affects the foliage cover (leaf burn), reducing the harvest
5.	A wide range of choice of sprinkler nozzle size facilitates the design and adjustment of irrigation intensity	5.	Problems of topsoil compaction associated with formation of a crust on the soil surface and increased runoff
6.	Makes it possible to accurately measure the water flow on the plot	6.	Water loss of on the border of the area
7.	Increases the coefficient of land use	7.	Complicates the agricultural works on the irrigated area (plowing, spraying, harvesting).
8.	High mobility of irrigation systems		
9.	Fits to all subsidiary irrigation		
10.	Suitable for washing of fields in profile		
11.	The possibility of achieving the same intensity of watering on the irrigated area (uniform distribution of water on the field)		
12.	Ease of application of fertilizers with irrigation water		

B. <u>Drip irrigation</u>

№	**Advantages**	**№**	**Disadvantages**
1.	The higher possible yield, followed by saving of irrigation rates, water consumption per unit of production is lower	1.	Not suitable as anti-frosts irrigation
2.	Wet loss due to evaporation is less than at sprinkling or surface irrigation (less area of wetted plot)	2.	Not suitable for additional technical irrigation
3.	Wind does not affect the distribution of moisture	3.	Problematic for irrigation of young trees (plantations) in arid areas with sandy soils and strong winds
4.	Does not require careful planning of irrigated plot, prevents runoff even in difficult topographical conditions	4.	The cardinal question when choosing an irrigation system - whether investment for the purchase of drip irrigation systems is justified by increase yields and water savings
5.	Allows carrying out agricultural works during irrigation (orchards, vineyards, etc.).	5.	
6.	Provides for supplying of fertilizer directly into the root layer		
7.	No peripheral loss of water		
8.	With sufficient rainfall, salinity is not a problem. If there is insufficient rainfall then		

	it needs additional irrigation rate, often supplied by sprinkling		
9.	Possibility of watering by small irrigation rates and short inter-irrigation intervals		
10.	Weeds are less than with other methods of irrigation		

Economic models of comparison of advanced irrigation technologies

Summing up the information on international experience, we can note a significant advantage of modern advanced irrigation technologies, such as sprinkling and drip irrigation, as compared to surface irrigation. For example, the net income for potatoes incomes rise almost twice; for melons to 4 times; for onion to 1.5-3 times, and for tomatoes to 2 times.

Unfortunately, it is very difficult to get for comparison such additional information even from the leading international irrigation companies and therefore it should be treated only as informative, due to the fact that many local components affect the final results, that can significantly change the picture, **but the direction is clear**.

Summarizing the current trends of development and introduction of advanced irrigation technologies we should mention the most corrected and relevant statistical work carried out in California, USA (Survey of Irrigation Methods in California in 2010):

This work has summarized the survey of 10 thousand farmers in California from 1991 to 2010 and gives a reliable picture of trends in the development of irrigation technologies for different crops including surface irrigation, sprinkling, microsprinkling, and drip irrigation.

During this period, on the one hand there was a steady increase of the proportion of drip irrigation and microsprinkling, and on the other hand, a decrease in the area under surface irrigation for almost all crops. The most distinguished crops were vegetables, fruit orchards and vineyards, with a corresponding increase of 32%; 28% and 33%.

Despite the above-said in California in 2010 the surface irrigation methods remain dominant for some agricultural crops, such as corn for 78%; cotton for 73%; leguminous plants (haricot, beans) for 66%; sugar beet for 85%; permanent pastures for 69%; alfalfa for 77%; pumpkin for 50%; and cereals for 79%. At the same time, surface irrigation on potatoes was only for 2% of all irrigated fields, 33-44% for tomatoes and 19% for onion.

For clarity, there are also very interesting results of the experiment in the neighboring republic, once again confirming the benefits of drip irrigation compared with furrow irrigation methods of vegetables (Table 11).

Table 11. Consumption of irrigation water and its unit costs for produced tomatoes, peppers and cucumbers (2007-2010)

Irrigation method	Number of watering	Irrigation rate, m³/ha	Average irrigation rate, m³/ha	Average yield, center/ha	Productivity of water use by the yield	
					Water consumed for 1 ton of yield, m³	Yield received for 1m³ of water, centner

Tomatoes						
Furrow	9	5,120	569	433	118	0.68
Drip	23	3,912	170	563	69.5	1.15
Cucumbers						
Furrow	10	5,125	512	368	139	0.63
Drip	13	3,752	289	497	75.5	1.17
Pepper						
Furrow	10	5,130	513	96	53	0.88
Drip	22	3,886	177	125	31.08	1.93

Source: Drip irrigation of vegetable crops in central Tajikistan. D. Siltonmamadov GU "TajikNIIGiM, the Republic of Tajikistan

SUMMARY

The totality of the data collected and systematized in this project once again clearly shows that the socio-economic development of Kyrgyzstan to a large extent depends on the state of water resources. It is well known that for Kyrgyzstan, as well as for other countries in the arid zone, the availability of sufficient water resources of acceptable quality is a crucial factor for sustainable development - for comfortable living conditions, to meet the comprehensive needs of the people in water, food security and environmental conservation. But in the last decade in the Republic there are becoming more distinct the signs of increasing deficit of water associated with global warming, especially after 2012, due to the negative manifestations of the cycle of dry years. These warning signs are further exacerbated by high population growth rates, and hence water consumption, as well as excessive loss of water at all levels of the national water management infrastructure.

Since emerging trends of reduction of water resources (in particular, manifested in Kyrgyzstan by a marked decrease in the volume of glaciers and snowfields, as well as the annual river runoff) will have long-term character, it become evident the need for planning and implementation of appropriate preventive measures at the national level. If take into account that about 90% of domestic water consumption in KR is used for irrigated agriculture, it may not cause doubt the obvious conclusion - the majority of potential reserves of water savings can be productively used by reducing water losses in the supplying sections of irrigation systems and directly on the irrigated areas, through the application of advanced crop irrigation technologies.

However, even at the first stage of justification of such measures it is appropriate to define the root causes of the current unsatisfactory state of the agricultural sector in general and the closely related irrigation sector in particular. It should be emphasized that often the main problem is seen as a chronic shortage of investments for the development of agricultural production, as well as for the modernization and maintenance of irrigation infrastructure. However, presented in this report materials allow us to conclude that inadequately low levels of annual investments are not the primary cause, but rather a consequence of the impact of more fundamental factors. Therefore, it seems more appropriate to designate as a fundamental factor the ill-considered land reform of the early 1990s. As noted above, as a result of this reform, there was a division of large arable areas into small plots of land shares assigned to individual farms. It was not taken into account that on the isolated area of irrigated arable land with an average area of less than 2 hectares it is extremely difficult, and often impossible, to implement cost-effective crop production in the face of fierce competition with agribusiness has been long-established in other countries. The situation was further complicated by the fact that more than half of working-age people in rural areas who have received allotments were forced to be involved into the sphere of agricultural production, but they previously have very limited knowledge and practical experience in agriculture only within their homestead plots. Thus, by the mid-1990s, the number of agricultural workers in KR were more than 30% of the total population of the Republic, while, in most industrialized countries of the world, this share is less than 5%. Under these conditions, soon after the agrarian reform, the processes of impoverishment of significant part of peasant farmers become irreversible, and this entailed the following consequences:

- The mass migration of the most active part of the rural population to the cities or abroad (for permanent residence or for temporary employment);
- In turn, the outflow of manpower resources from the rural areas led to the spontaneous (i.e., not controlled by the state) redistribution of land relations, both in a civilized manner, for example, by sale or lease of cultivable land for rent, and by unauthorized seizure of land allotments;
- The most of peasant farmers who are trying to develop their agricultural business, but do not having initial savings to do this and access to cheap credit, were objectively forced to use mostly low-cost farming techniques for the cultivation of grain and fodder crops, incidentally - potatoes, vegetables and fruit, etc., to meet their own needs. In the absence of opportunities for the purchase of mineral fertilizers, plant protection products, quality seed materials, not to mention costly mechanisms and irrigation techniques, these entities of the agricultural sector are able to supply on the domestic and foreign markets only slight excess of their crop production, since they often operate in a mode of notorious "subsistence farming". Moreover, in conditions of low profitability of agricultural production, this kind of activity is increasingly become of secondary importance among farmers and peasants, as they are forced to combine it with the trade, crafts and other more profitable ways of survival;
- Finally, after many years of "natural selection" in Kyrgyzstan to date, class of producers of profitable commercial agricultural production only began to emerge. Basically, it consists of a small number of agricultural enterprises, created on the basis of collective and state farms which escaped liquidation, the so-called "auxiliary farms", departmental and municipal greenhouse enterprises, newly created agricultural cooperatives and other associations, as well as the largest farms and gardening farms. According to various tentative estimates, the area of irrigated land available for such relatively successful farms so far is less than 5-10% of the total irrigated area. In this regard, the current potential for introduction of innovative water saving technologies of irrigated agriculture is seemed very limited.

There is no doubt that these trends have systemic nature in KR, and overcoming them is possible only with a comprehensive reorganization of the conditions of industrial activity in the sector of crop production. The main directions of these reforms in the country are well known (at least, already have been thoroughly worked out at the expert level) and suggest the following:

- Accelerated development of transparent secondary market of agricultural land;
- Accelerated development of agricultural cooperatives on the basis of peasant farms;
- Creation of market infrastructure, ensuring a close relationship and sustainability of all parts of the technological chain of agricultural production, including crediting, logistical support, cultivation and harvesting, production distribution, wholesale purchase and profound industrial processing and further - down to the sales to final consumer.
- Establishment of effective mechanisms of state support to rural producers.

Implement all the proposed measures will only be possible over a long period of time. Therefore, as a priority it is appropriate to aim at strengthening efforts to build agricultural cooperatives and organize mass training of rural residents on more perfect, but at the same time affordable technologies of irrigated agriculture. In this case, sufficient attention should be paid to conservation of soil fertility, promotion of the replacement of traditional crops by the high-yield and profitable crops, environmental aspects of land use, etc. If start from the positive results of such training activities carried out in recent years in the Kyrgyz Republic within a number of international projects, the development of this trend could have a serious impact with limited costs.

The above brief summary of the situation allows only a judge on the root causes hampering the development of the national agricultural sector as a whole. Returning to the main topic of this report, we can conclude that split of the previously created large areas of irrigated land during reform, directly or indirectly led to a number of negative consequences for all parts of the irrigation infrastructure. This statement can be justified by the following arguments.

Currently, the vast majority of water use entities in rural areas - are poor peasant farms, which due to their fragile economic situation cannot adequately pay for the irrigation water supply services (PIS) by public water management. Therefore, the current specific contribution of main consumers of irrigation water into the maintenance and operation of inter-farm section of irrigation systems is only about 12% of the actual costs of the structural units of DWMM for the O&M purposes and less than 5% of the estimated demand costs. Comparing these figures with the statistics published by FAO, it is easily seen that in Kyrgyzstan, the share of costs of entities of irrigated agriculture for these purposes is several times less compared to the average figures in other countries located in the arid zone. Consequently, the main burden of the cost of management and operation of inter-farm irrigation infrastructure has to take on the state budget, and capital repairs and new construction of irrigation facilities are invested mainly at the expense of foreign credit and grant support. However, even the substantial financial assistance from the international organizations allows only stabilize the technical condition of the irrigation systems, but does not provide their further development. In the meantime, as a result of damage and physical deterioration of irrigation facilities and communications the trends of increasing water losses can be traced in the main and inter-farm canals in all regions of the Republic. As a rule, these losses cannot be substantially reduced by the current repairs of individual sections of the canals, and the large-scale capital repairs will be difficult in the coming years due to the lack of funds. Therefore, for pragmatic reasons, it is hardly possible to plan a sharp reduction of losses (for example, more than 5%) in the inter-farm irrigation network. However, achieving water savings is possible with the implementation of relatively low-cost measures, such as stabilization of water supply by using previously built pools for daily and decade run-off regulation, strengthening the control of water use, prevention of unauthorized water use and others.

The estimates presented in the report indicate that most of water is lost within the on-farm irrigation systems. It is appropriate to clarify that the growth of these losses is due to two main reasons. The first is a direct consequence of repeatedly noted earlier process of splitting of irrigated areas into small plots of land. This significantly increased the length of the distribution network, ranging from water outlets of inter-farm level and up to separate outlets to each farm, respectively increasing loss of water through filtration, evaporation and transpiration by weeds. As a result, the average rates of efficiency of on-farm irrigation network in Kyrgyzstan were the worst in comparison with the neighboring countries of Central Asia. The other reason is the lack of tangible incentives in water users of the agricultural sector to conserve irrigation water. With persisting in the Kyrgyz Republic for a long period amount of tariffs payment for water supply services at the level of 1-3 KGS / 100m³, water charging mode is more of a symbolic nature, as in the total annual term costs for payment for water rarely exceeds 2-3% of the expenditure budget of an average household. In that case, arguments about the excessively grievous burden on farmers due to the introduction of water charges are unlikely have a good reason. Moreover, the profitability of irrigated agriculture is usually multiply increased, compared to the rainfed agriculture. On the contrary, inappropriately low price of water supply, together with the lack of effective accountability mechanisms for its rational use, only contribute to the growth of water loss. Often amounts of technological losses related to violations of the rules of water use (egg, unauthorized deregulation of water supply up to the capture of water resources, the unauthorized discharge of water from canals, and etc.) exceeds the natural water loss through filtration from on-farm canals. These facts lead to the conclusion that achieving significant water resources savings in on-farm irrigation network only through its reconstruction is problematic, without the simultaneous use of economic, regulatory and administrative mechanisms of incentives. For example, calculations have been previously made by consultants of the World Bank IWRMP have demonstrated the rationale of increasing tariff rates of PISs to the level at least of 20KGS / 100m³. In this case, at the average irrigation rate gross of about 7-10 thousand m³ / ha per year, the annual unit cost of a typical farm for payment for irrigation water supply will not exceed 2 thousand KGS / ha. For comparison, it should be noted that the current size of the rent per hectare of irrigated land in Kyrgyzstan is usually many times higher than this amount. This simple example shows that for the most active agricultural producers seeking to grow their business, increase in tariffs for the water supply at least up to the specified level will not appear too burdensome, but at the same time will encourage the use of water-saving technologies. However, the increase in tariffs will most likely cause discontent among the weak peasant farms, but further will continue to contribute to the development of a new stage of redistribution of land ownership and the development of cooperative structures in irrigated agriculture. Such effects and associated political and economic risks, of course, have to be taken into account in decision-making. For example, based on the international experience of such reforms, in order to avoid worsening of the political situation in the country, the implementation of such decisions should be preceded by extensive information campaigns; preventive measures of social support of the poorest group of the rural population, training and / or reorientation of their professional activities.

The above presented brief summaries and conclusions were accentuated on the establishment of the key factors that cause water loss in two key links of the input lines of irrigation systems. However, given the topic of the project, the reason causing the loss of irrigation water directly in the fields, as well as possible ways of a more efficient use of water resources, require a more detailed analysis. First of all, it should be clarified that a clear separation of water losses in the irrigated areas to natural and technological types is not always correct, as both of these types are closely related and dependent on local soil and climatic conditions, applicable methods of farming and irrigation, as well as compliance with best irrigation regimes.

To substantiate this conclusion it is appropriate to narrow the scope of further analysis, assuming that for the Kyrgyzstan's conditions the most promising may be three methods of irrigation: **a) improved furrow irrigation, b) sprinkling irrigation and c) drip irrigation method**. This restriction can be explained by the following arguments:

- Widespread in the Kyrgyz Republic methods of surface irrigation by free flow or flooding belong to the least efficient in terms of saving of water resources and their further use should be extremely reduced;
- In the face of growing water scarcity marked increase in water-loving crops, such as rice in the southern regions of the Republic, is hardly possible. Therefore, the method of

surface check irrigation of rice will continue to be used, at maximum, on 1-2% of the total irrigated area, and it cannot be considered as a promising;

- Method of fine-dispersed (sprinkler) irrigation, as a kind of sprinkling irrigation method, taking into account the climatic conditions of the KR, can be used mainly in greenhouses;
- Method of subsurface irrigation by means of underground pipelines can be considered as a simplified kind of the drip irrigation, with its inherent advantages and disadvantages.

To date, sufficient experimental data have been accumulated in foreign countries, Central Asia and, in particular, in Kyrgyzstan, allowing objectively assess the types and structure of irrigation water losses in the field, depending on the application of each of the three selected irrigation methods. Key findings on the basis of these data can be summarized as follows:

Water losses by evaporation are relatively large in cases of furrow and sprinkling irrigation methods and it increase at high air temperatures and strong winds, especially when using long-range sprinkling devices. For the drip irrigation systems this type of loss can be almost completely eliminated. However, even with furrow irrigation it is possible to achieve a significant reduction in evaporative losses by carefully loosening the top layer of soil after irrigation or mulching the soil surface by film. However, these measures require additional costs for materials and manual labor. At sprinkling evaporation loss can be slightly reduced by selection of the most efficient equipment from a wide range of sprinkler equipment, as well as by optimizing the time of watering during the day.

Water losses through transpiration by weeds are particularly noticeable in cases of furrow and sprinkling irrigation, but also occur under drip irrigation. Obviously, in relative terms, these losses are not as large and can be eliminated by introduction of herbicides and regular weeding. Currently, however, the high cost of herbicides limits their widespread use, and the small size of the most irrigated plots does not allow extensive use of mechanized methods of soil cultivation. In this connection manual weeding usually requires an enormous effort of physical labor and does not allow completely eliminate this type of losses.

Water losses associated with uneven moisture of irrigated plots are most typical for surface irrigation methods, including furrow irrigation. Their amount is mainly dependent on the quality of planning of irrigated plots and water supply methods. In particular, on the high and end sections of the fields there is usually observed lack of soil moisture, and on the head sections and local declivity of the terrain - excessive soil moisture, up to waterlogging. In these cases, as a rule, it is required more careful planning of the irrigated plots, along with the use of irrigation technologies by variable stream or less extended furrows. Under using a sprinkler technics small irrigation rates often cause insufficient moisture of root layer of the soil. But increase in the intensity of rain causes uneven soil moisture, especially in windy weather, and leads to destruction of soil structure and compaction, as well as the formation of puddles and the surface runoff on the field. In turn, this causes an increase of evaporation losses and discharges, and provokes the development of diseases in vegetable and fruit crops. Therefore, the use of sprinkler technics requires high level of proficiency and practical skills of the staff. Furthermore, the use of the sprinklers of circular operation on the fields of rectangular shape causes additional problems associated with wetting of the angular areas not covered by the watering. In the case of use of drip irrigation method, it is possible to almost completely eliminate this type of loss.

Filtration water losses on the field depend on several factors: the water permeability characteristics of fertile soil layer and subsoil, groundwater levels, types of cultivated crops in terms of the thickness of the root zone of the soil, physiological water demand, as well as of the applied irrigation methods. Ultimately, other things being equal, relatively large filtration losses are inherent to furrow irrigation, to a lesser extent to sprinkler watering, while in the drip irrigation systems they can be minimized. The latter circumstance is explained by the fact that the drip irrigation technology provides supply of dosed water volumes directly to the root system of plants. However, this circumstance can cause negative effects, such as drip irrigation contributes to the accelerated development of surface rootage, especially in orchard crops and simultaneously weaken a pivotal component of the roots, the need for which gradually is being lost. This often leads to mass death of fruit trees in strong winds, as well as in cold winters with little snow.

Losses due to discharge of water from the fields, as a rule, are associated with natural or technological reasons: due to the unevenness of the daily water supply because of fluctuations of water flow in the surface sources, unauthorized catchment or discharge of water by other water users, temporary stopping of watering at night, and so on. In this case, difficult terrain typical to Kyrgyzstan does not always allow reuse of waste waters for irrigation of downstream land areas. In this respect, modern technics of sprinkling and drip irrigation allow for rapid adjustment of the volume of water supply to the field and thus minimize effluent run-off from the fields. However, even for such reliable systems we cannot exclude the possible risks of technological failure, for example, caused by the abrupt power cut. Meanwhile, in rural areas of Kyrgyzstan in recent years, long-term power cuts have become commonplace.

Of course, the limited format of this report does not allow to thoroughly explaining most of the features of each of the three irrigation methods. Nevertheless, the above data suggest that in terms of water savings and labor productivity drip irrigation technology has undeniable advantages, even compared with sprinkler irrigation, especially if compared with furrow irrigation. However, to justify the massive use of a particular method of watering these two indicators are not sufficient, since it is necessary to take into account factors such as the price-quality ratio, compliance of innovative technologies with a variety of local conditions of application, and etc. In this respect, a rash reference to the world experience not always can be a weighty argument. This conclusion can be illustrated by several examples drawn from the available FAO publications, ICID and the Russian Research Institute of Land Reclamation.

- For example, in the USA, where irrigated agriculture is most developed, almost half (44%) of the area is irrigated by the surface irrigation methods, but the level of mechanization and automation of irrigation reaches 90%. The specific contribution of drip irrigation is about 5.5%, and the sprinkling - about 50%. It should be noted that because of the diversity of sprinkler technology used in the USA, about 50% are wide-sprinklers, while for dual console mobile units - only 0.2%, and hose-drum units - more than 15%. At the same time, in the California State in the USA – the proportion of drip irrigation is about 42%;
- Unlike the USA, in the African continent irrigation applies only on 4% of cultivated land. In this case, more than 70% of irrigated land is watered by the surface irrigation methods: by check, contours or furrows. However, in one of the most developed countries of the continent - South Africa – the drip irrigation systems have been already used for 71% of irrigated areas;
- In 11 countries in Asia, where irrigation has centuries-old traditions, 96% of irrigated lands are covered by surface irrigation, and only 2% - by drip irrigation systems and sprinkling. It should be taken into account that the countries of South-East Asia are mainly focused on cultivation of rice, irrigated by checks. While, for example, in India and China in recent years there has been intensive development of the drip irrigation method, and the total area irrigated by this method are, respectively, 2.5 and 3.0 million hectares, while in Saudi Arabia 78.1% of the area is watered by sprinkling and micro-irrigation methods. As for the Israel, this country is a recognized leader in the

development and implementation of drip irrigation systems. Therefore, the drip irrigation there is a basic method and is applied, according to various estimates, on 74-90% of the cultivated lands;

- In European countries, on the average, 82% of the irrigated area is irrigated via sprinklers and drip systems and only 14% - using surface irrigation methods. At the same time, the sprinkling irrigation is most common in countries with temperate climates, and in the southern countries of the continent where there are shortages of water, drip irrigation is most common, for example, in Spain it is used by more than 21%, in Italy - by 14%, in France - 7%, and in Greece - 9% of irrigated areas;
- In the Russian Federation, the share of irrigated lands covered by surface irrigation methods roughly corresponds to European average figures and is approximately 15%, the proportion of drip irrigation is estimated in the range of 2-4%, and the precedence has a sprinkling irrigation - about 80%.

The above data allow us to conclude that none of the most effective methods of irrigation can claim for absolute universality in extreme diversity of the specific conditions prevailing in different regions and countries of the world. At the same time, it is useful to note the global trend: over the last 20 years, the greatest development (more than 6.5 times) have got exactly the drip irrigation systems, which now cover more than 10 million hectares or 3% of the total irrigated area. However, this fact does not prove yet the need for mandatory development of irrigation in Kyrgyzstan being directly dependent on global trends. Of course, we should take into account other indicators, and in the first place - the relative costs for the purchase and operation of various types of irrigation equipment.

It should be noted that such a comparative evaluation cause challenges because market prices even for similar irrigation equipment with approximately identical specifications may vary in a few times, even for the manufacturers of one country. However, when comparing data from different sources of information, it can be established that averaged unit costs for the introduction of drip irrigation systems is about 1.2-4 times higher than the cost of use of the sprinkler techniques and 6-12 times the cost of the furrow irrigation with limited use of mechanized equipment. Of course, with such a wide range of price indices only a general idea of the costs ratio can be obtained. As a typical example, it can be specified, that for conditions of the Russian Federation or Ukraine the indicative unit costs for the use of sprinkler technics constitute a wide range of $ 0.6-2.5 thousand / ha, while in the United States and European countries, they are estimated at $ 2 -10 thousand / ha. The limited experience of introduction of relatively inexpensive sets of equipment for drip irrigation in Kyrgyzstan also has shown that in prices for 2013 the unit cost of such systems for watering gardens amounted to about $ 0.8-1.0 thousand/ha, and for irrigation of vegetables - about $ 2.0 thousand/ha. Typically, the annual costs for operation of the sprinkler and drip systems account for about 10-15% of the initial investment for the purchase and installation of the sets of equipment. From the previous comparative analysis, we can conclude that the total costs of purchasing and operating the equipment for sprinkler and drip irrigation approximately higher than similar costs for furrow irrigation. Such impressive difference in costs with cost-effective irrigated agriculture can be compensated only by adequate growth of high-yield crops.

Systematized results of studies carried out by the project team of experts allow us to formulate the following **conclusions and recommendations**:

1. Strengthening measures to introduce more sophisticated irrigation methods in Kyrgyzstan is an urgent task that promotes economic use of water resources, increases productivity of the irrigated agriculture sector, increases fertility of the irrigated lands,

promotes the labor productivity growth, as well as the manifestation of associated positive effects related to prevention of soil erosion and environmental pollution.

2. To date, application of the innovative irrigation technologies was restrained due to the impact of negative factors, discussed in detail in this report. Since most of these factors have a systemic nature, it is necessary beforehand to provide a package of preventive measures to ensure favorable conditions for a large-scale implementation of these technologies. Priority actions in this regard include:

   - Further reform of land relations, stimulating consolidation of irrigated tracts of land;
   - Creation based on small farms and peasant farms of cooperative associations of water users and / or independent agrarian enterprises;
   - Formation of effective motivation for the entities of the agrarian sector, contributing to a more rational use of water resources and introduction of water-saving irrigation technologies. At the same time the well-known economic, legal and administrative levers of stimulation can be applied, first of all - associated with a marked increase in tariffs for PISs;
   - Cardinal changes of the current structure of crop production by pre-emptive use of more productive and profitable crop varieties - fruit, berries, vegetables, etc. instead of the most common cereal crops. It is necessary to achieve more ambitious goals so that specific types of agricultural production in Kyrgyzstan, for example, beans, fruits berries, etc., got steady sales on foreign food markets as brands;
   - Development of market infrastructure of the agricultural sector for the sustainable logistical support, production, procurement, processing, transportation and marketing (sales) of crop production.
   - Development of enterprisers' capacities, processing of agricultural raw materials in order to significantly increase the surplus value of crop production.

3. Based on a pragmatic assessment of the current socio-economic situation in Kyrgyzstan and the state of the national agricultural sector, **it would be imprudent to offer as the sole priority the widespread introduction in short-term perspective such high-cost irrigation methods such as sprinkling and drip irrigation. In condition of the deficit of investment resources it is more appropriate to implement gradual promotion of these innovative technologies, while expanding the use of various modifications of furrow irrigation, with considerable potential, which previously was used, in terms of water savings and labor productivity growth**. Increase of the specific share of furrow irrigation method is quite possible in the case of a planned reduction of the area devoted to cereal crops, usually watered by free flow / by strips, and replacing them with more profitable vegetables, leguminous plants, melons and others crops.

4. Extensive experience of using the furrow irrigation methods in Kyrgyzstan, in other Central Asian countries and other foreign countries convincingly demonstrates that substantial savings of water can be achieved by relatively simple and cheap well-known methods, for example, by selection of the optimal length of furrows, watering by variable stream, mulching, more thorough dosing of water supply using portable equipment, etc. However, the furrow irrigation provides ample opportunities for growth in labor productivity of irrigators and quality of irrigation through a variety of technical means, ranging from simple equipment - siphons, portable water outlets and connectors, and up to automated control systems of machine water supply. Although, in general, the

specific costs of the furrow irrigation are higher for about 30-40% compared with the methods of irrigation by free flow / strips, it is quite possible to compensate these additional costs due to increased yields and purchase prices by growing the more profitable crops.

5. Inadequate distribution of the drip and sprinkler irrigation methods in the Kyrgyz Republic, as well as mechanized technologies of the furrow irrigation to a large extent is explained by weak awareness of a significant part of the entities of irrigated agriculture about their advantages and application features, as compared to the primitive methods of watering. Therefore, their wider application can be helped by widespread awareness campaigns and training activities, taking into account the positive experience gained in implementation of a number of international projects in Kyrgyzstan.

6. Assumptions that the furrow irrigation will be most common in the short term do not exclude the possibility of a simultaneous expansion of the areas covered by the sprinkler and drip irrigation. As previously mentioned, at present stage the use of sprinklers and drip systems are likely to be preferred by the large and economically sustainable farms and their cooperative associations, and with mandatory implementation of all agricultural activities related to quality tillage, plant protection, fertilization, weed control, and in cultivation of row crops - with introduction of the planned crop rotation. For example, the practice of implementation of drip irrigation systems in Central Asia shows that only in strict compliance with mandatory agronomic techniques the growth of fruit crops and grapes yield can be achieved up to 50-60%, and of vegetable crops - at least 50-80%. However, this fact once again emphasizes the need for preventive development of measures of information provision and mass training of producers of agricultural products on a wide range of agronomic, reclamation, engineering, economic and marketing and others issues.

7. Since livestock traditionally is one of the key and most profitable sectors of Kyrgyzstan, fodder crops for the foreseeable future will occupy a significant portion of the sown area. Extensive experience of 1970-1980-s substantiated a number of advantages of watering fodder crop by sprinkling, especially in the northern regions of the Republic. Later, however, the use of sprinkler equipment decreased markedly due to its physical deterioration, as well as the sharp rise in price of diesel fuel and electricity. Nevertheless, currently sprinkler systems have been successfully used for irrigation of about hundreds of thousands of hectares of irrigated lands. This shows that an economically sound return to the use of sprinkler irrigation methods of fodder and vegetable crops in the Kyrgyz Republic is quite possible, especially given the emergence on the world markets cheaper and more economical nomenclature of sprinkler technics. It can be assumed that a more thorough market research can justify this hypothesis.

8. As for the drip irrigation technologies, the above data in the report demonstrate their incomparable advantage compared to alternative methods by a number of objective indicators. However, significant costs for the purchase and maintenance of drip equipment, as well as increased requirements for the qualification of the staff will be in the coming years the major constraints for its large-scale implementation in Kyrgyzstan. Nevertheless, given the previously specified vector of global trends in the development of irrigation, experimental and industrial introduction of various modifications of the drip irrigation systems is not only desirable, but also rational from the point of view of

working-up necessary experience. But in any case, on the first phase of implementation it will require substantial support from the State budget.