FROM IMPROVED WATER ACCOUNTING TO INCREASED WATER PRODUCTIVITY IN THE FERGANA VALLEY

L'AUGMENTATION DE LA PRODUCTIVITÉ DES RESSOURCES D'EAU DANS LA VALLÉE DE FERGANA PAR VOIE D'AMÉLIORATION DE LEUR RECENSEMENT

A. Karimov[1], D. Molden, A. Platonov and T. Khamzina

ABSTRACT

Facing competition for limited water resources with domestic, industrial, hydropower and environmental uses, agriculture has to adapt to produce more food with less water. This paper proposes to apply water accounting procedure to identify the scope for water productivity improvement. The Fergana Valley, a highly productive area within the upstream of the Syrdarya River Basin, was selected to examine the proposed procedure. Significant non-productive depletions of water as evaporation at 31-34% of the available water were identified in the Fergana Valley. There is also flow to sinks and pollution in the downstream at 1-5% of the gross inflow due to the changes of the river flow regime, its quantity and quality, caused by the return flow from the irrigated land and the winter hydropower releases from the upstream. Total non-productive depletions of water at 4,200-5,200 million m^3 (Mm^3) were identified in the form of evaporation, flows to sinks, and pollution. Proper water saving technologies to reduce non-productive depletions will improve water productivity in the Fergana Valley and increase water availability for the downstream water uses.

Key words: *Water accounting, Syrdarya River basin, non-productive water, Fergana valley*

RESUME

Le bassin du fleuve Syr-Darya en Asie Centrale manifeste des symptômes de l'insuffisance des ressources en eau dans la situation de concurrence entre la disponibilité d'énergie hydraulique dans le cours supérieur et les besoins écologiques, les villes et l'agriculture dans le cours moyen et inférieur du fleuve. Les conséquences de cette concurrence sont les inondations hivernales et la pénurie d'eau estivale, et l'aggravation de la formation des

1 Regional Researcher, IWMI Central Asia Office, Uzbekistan, E-mail : a.karimov@cgiar.org

marais et la salinisation des terres irriguées à l'aval. L'augmentation de la productivité de l'eau peut réduire le stress de la concurrence, et augmenter la stabilité de l'agriculture. Cet article propose d'utiliser une meilleure procédure de recensement des ressources en eau pour définir les limites de la conservation des eaux et de l'augmentation de la productivité des ressources en eau. Cette procédure a été utilisée dans la vallée de Fergana située dans le cours supérieur du fleuve.

Le processus de la conservation de l'eau se manifeste dans la redistribution des ressources en eau permettant la transformation de l'utilisation inutile ou apportant un profit insignifiant en utilisation rentable. La procédure échelonnée de recensement des ressources en eau est ainsi conçue : 1) recensement complet de l'utilisation actuelle des ressources en eau; 2) définition des dépenses inutiles ou peu rentables des ressources en eau; 3) élaboration et analyse des stratégies de la conservation des eaux pour réduction de ces dépenses et leur transformation en utilisation rentable. Cette approche se distingue des approches traditionnelles de conservation de l'eau qui signifie la réduction du débit d'eau. L'augmentation de l'efficience de l'utilisation des ressources en eau au niveau des petites exploitations agricoles en réduisant la distribution de l'eau à la limite du champ sans changer le niveau de l'évapotranspiration des cultures, ne peut aider dans la conservation des eaux du bassin. Pour estimer la valeur de la conservation des eaux, il est nécessaire de connaître l'utilisation de la partie des ressources en eau non livrée à la parcelle.

L'application de cette procédure pour recensement des ressources en eau dans la vallée de Fergana, a décelé que les dépenses improductives des ressources en eau eau font presque 4,000 Mm^3/an ou 33% des ressources en eau accessibles, dont l'évaporation des terres irriguées représente 2,863 Mm^3/an. Aux pertes improductives des ressources en eau dans la vallée de Fergana s'ajoute l'évaporation des territoires en plantation d'arbres, des terres non-irriguées et de la surface d'eau. De plus, il y a des dépenses improductives des ressources en eau à l'aval liées à la concurrence entre l'énergie hydraulique et l'agriculture irriguée. Les dépenses productives des ressources en eau représentent en moyenne 4,687 Mm^3/an, ou 38% des ressources en eau accessibles.

Le résultat des études montre un potentiel considérable de la conservation des eaux dans la vallée de Fergana. Les études ultérieures mettent en évidence les stratégies de conservation des eaux pour réduction des dépenses improductives, et pour augmentation de la productivité des ressources en eau. Nous appliquerons cette approche aux autres régions du globe terrestre où les besoins en irrigation et la pénurie d'eau sont très marqués. Cette approche est fondée sur la nécessité de la prise en considération des profits d'un bassin et du recensement des ressources en eau afin d'optimiser l'utilisation des ressources en eau.

Mots clés: *Recensement d'eau, bassin fluvial de Syrdarya, eau improductive, vallée de Fergana*

1. INTRODUCTION

Growing population and demand for food and energy and competition between different water users increase pressure on water resources. In addition, water resources in many regions have become vulnerable due to global climate change and regional environmental problems. The Syrdarya River Basin is an example, where all of these threats continue to grow. Creating new independent states complicated the water allocation in the river basin and increased competition between hydropower in the upstream and agriculture in the midstream and downstream. Moreover, there are severe environmental concerns within the Aral Sea basin (Ataniazova, 2003). Increase in hydropower generation by increasing winter releases from the upstream Toktogul reservoir caused summer water shortage in the lower reaches, including the territory of Uzbekistan and Kazakhstan.

Earlier studies focused on improved water resources allocation rather than on efficient use (D. C. McKinney and X. Cai, 2007). This paper presents an innovative structured method based on water accounting to identify strategies across scales that will lead to real water savings and increased water productivity. This paper proposes to apply water accounting procedure to identify the scope of water productivity improvement. The Fergana Valley, a highly productive area within the upstream of the Syrdarya River, was selected to examine the proposed procedure. The results are important in the overall management of the Syrdarya River Basin. To achieve this, first we applied a water accounting methodology developed at IWMI to calculate use and productivity of water, and non-process water depletions (Molden, 1997) where water use does not generate benefits. The research findings show significant potential for water saving and increasing water productivity.

2. METHODOLOGY

Water accounting procedure

A water accounting procedure developed at IWMI (Molden, 1997; Molden and Sakthivadivel, 1998) was applied to identify non-beneficial water depletions. The water accounting classifies water balance components into water use categories that reflect the consequences of human interventions in the hydrologic cycle. Using the water accounting framework provides guidance in increasing water productivity. As opposed to conventional approach of reducing water withdrawals, the approach proposed is to "back into the problem", by first identifying water flows or depletion that yields limited benefits or are non-beneficial. The next step is to determine ways to reduce these non-beneficial depletions of water. Following such an approach will yield a variety of possibilities of water savings and help to identify areas where application efficiency gains will increase water productivity. The stepwise procedure is given in Figure 1.

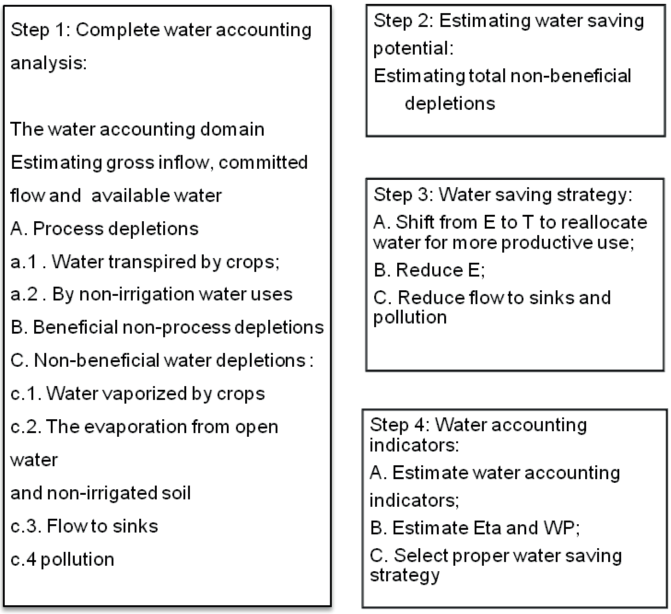


Figure 1. Steps of the assessment of water saving potential

This procedure is applied to evaluate a potential of increasing water productivity in the Fergana Valley.

3. APPLICATION OF WATER ACCOUNTING PROCEDURE FOR THE FERGANA VALLEY

Study Area

The Fergana valley is one of the water-rich upstream sub-regions of the Syrdarya River Basin. Two rivers, the Naryn and the Karadarya confluence in the Fergana valley and form the Syrdarya River. There are also many small rivers originating in the mountains surrounding the valley, and making for ample water resources in the area. The small rivers and deep percolation from irrigation recharge the widespread groundwater aquifers of the Fergana valley. The aquifers accumulate a part of the surface flow in summer and feed the Syrdarya River in winter. In spite of favorable hydrogeological conditions groundwater irrigation is practiced in a few areas as an approach to prevent waterlogging and supplementing canal irrigation.

Research Method

Steps followed in assessing water saving potential in the Fergana valley are given in Figure 1. The study considers the time period from 1992 to 2004. Three stages of water management were specified during this period:

Stage 1 includes period before 1993 when the upstream Toktogul reservoir was operating in irrigation mode. Cotton was dominating among the irrigated crops in the Fergana Valley.

The area under alfalfa was at 22% of the total irrigated area, while winter wheat was grown on 8% only.

Stage 2 includes period from 1994-1996 when the operation of the upstream Toktogul reservoir is shifted from irrigation to hydropower generation mode.

Stage 3 includes period from 1997 to 2004. During this period the upstream reservoir operates in a hydropower generation mode. Cotton/alfalfa rotation was replaced by cotton/wheat sequence. The area under irrigated winter wheat increased to 29%.

Water accounting data for various use categories were calculated using data from the Hydrometeorology Service of Uzbekistan, the Institute of Hydrogeology and Engineering Geology and the Basin Water Organization (BWO) Syrdarya (Ivanov, personnel communication, 2009; Mavlonov et al., 2006; CAWATERinfo, 2009). Depletions were calculated using the FAO method of evapotranspiration estimation (Allen et al., 1998).

To assess depletions land use data were collected. The cropping pattern was determined using secondary data from the water management organizations in the area (Umarov, personnel communication, 2009). Unavailable land use classes such as water surfaces, non-irrigated lands and tree plantation areas were obtained from the images for 2000-2002. The Landsat-7 ETM+ satellite images on the dates of maximum vegetation condition of the two main crops (winter wheat in May and cotton in August) were used for land use classification. Land uses were classified by using two seasonal Normalized Difference Vegetation Index (NDVI) raster layers and NDVI threshold values.

Data on non-irrigation water uses including industrial and municipal water supply was obtained from the Department of Water Inspection of the Ministry of Water Management (Umarov, personnel communication, 2009). The evaporation from fish ponds (pan evaporation) was calculated from the reference evapotranspiration (Allen et al., 1998). Evaporation from non-irrigated soil within the irrigation zone was estimated at 50% of ET for cotton that dominates in the region (Rubinova, 1979).

Flow to sinks was determined as discharge of winter flow into the Arnasai depression using data of the Basin Water Organization (BWO) Syrdarya (CAWATERinfo, 2008). The winter releases from the Toktogul reservoir passing further downstream Chardara reservoir are often blocked by the frozen Syrdarya River and forced into the Arnasai depression which became evaporative basin. Flow pollution was calculated as extra leaching applied due to increasing river water salinity by return flow from irrigated lands to the riverbed. According to FAO, irrigation with water having total dissolved solids (TDS) less than 2,000 mg/l does not causes salinity issue; leaching rate is to be increased by 20% if TDS of the irrigation water is from 2,000 to 4,000 mg/l and by 40% if TDS exceeds 4,000 mg/l (Ayers, et.al., 1985).

4. RESULTS AND DISCUSSION

Step 1: Complete water accounting analysis

A. The water accounting domain

The study classified considerable area under perennial plants in irrigated zone at 199,000 ha, of which 77,000 ha are orchards and vines and 122,000 ha are trees such as poplars and mulberries and agro-forestry farms. The forest area in the non-irrigated zone was estimated at 7,500 ha. The area of abandoned land was estimated at 20,000 ha and the area under rain-fed wheat was estimated at 500 ha. The riverbeds with an area of 3,500 ha were dominating among water surfaces followed by tail-end reservoirs and fish ponds covering 2,700 ha area each. The area of freshwater reservoirs was found to be at 600 ha.

Gross inflow to Fergana Valley

The water accounting studies use value of gross inflow, which is the total amount of inflow crossing the boundary of the domain including flow of the Naryn River, the Karadarya River, small rivers, effective precipitation and underground inflow. The average total amount of gross inflow to the Fergana Valley estimated at 27,530 Mm^3. There are seasonal surface storages within the boundary of the domain only. The groundwater fluctuates from year to year. On average, the change is negligible.

Committed flow to the downstream uses

The committed flow to the downstream uses is calculated based on permits ('limits') established by The Interstate Coordination Water Commission for each riparian state of the Syrdarya River Basin and for environmental uses (CAWATERinfo, 2009). Committed water is part of the flow of the Syrdarya River for uses in the downstream in Tajikistan, Uzbekistan and Kazakhstan and for environmental uses in the lower reaches. The total committed flow for the downstream of Fergana valley is 19.5 km3 which is equal to 71% of the gross inflow to the Fergana Valley (Table 1).

Available water

Available water for Fergana Valley is calculated as a part of gross inflow withdrawn from the water sources within the Valley. The data presented in Table 1 shows that volume of the available water varies widely, from 10,707-14,370 m^3/ha depending on rainfall and river flows.

Table 1. Water resources of the Fergana Valley (Mm^3/year)

Inflow to the Fergana valley	Stage 1	Stage 2	Stage 3
Small rivers	5157	4972	4910
Naryn	11270	15076	14166
Karadarya	3460	3098	3262
Precipitation	3873	3251	4828
Underground inflow	1721	1721	1721
Gross inflow	25480	28118	28885
Available water	12638	10949	12206
Committed flow	19540	19540	19540

The data presented in Table 1 suggests that Fergana Valley sources the downstream of the Syrdarya River Basin. Water available for use in the Fergana Valley is 42% of the gross inflow.

a.1. Process Depletion: Water transpired by crops

Results of estimation of water transpired by crops derived from evapotranspiration (ET_c) are given crop-wise in Figure 2. Total transpiration by crops in the Fergana Valley from 1992 to 2004 was reduced from 3983 Mm^3/year to 3648 Mm^3/year, or by 9%. However, the main changes have occurred crop-wise. From 1992 to 2004, the transpiration was significantly reduced from cotton and alfalfa fields while it increased from winter wheat, vegetables and orchards. Since water requirements for wheat are less than for alfalfa, a shift from alfalfa to wheat production reduced process depletions by crops and contributed to the water table rise. The transpiration by rainfed wheat was found to be insignificant due to small size of the area. The total amount of water transpired by crops is totaled to 16% of gross inflow or 32% of the available water to the Fergana Valley in stage 1 and reduced to 12% of the gross inflow or 30% of the available water in stage 3.

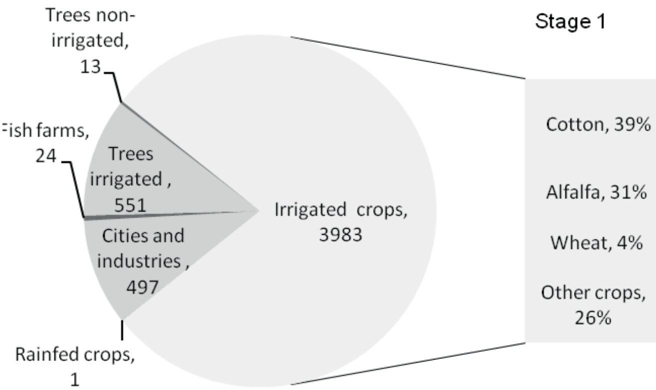
a.2. Process depletion by non-irrigation water uses.

Water depleted by non-irrigation water uses estimated at 497 Mm^3 in 1992 had been reduced to 426 Mm^3 by 2004 due to some decrease in water intake for domestic and industrial needs (Figure 2). Process depletions from fish farms were found to be much less as compared to the municipal and industrial consumptive use. Total process water depletions in the Fergana valley are given in Figure 2. The share of process depletions for non-irrigation water uses amounted to 1.5% of the gross inflow or 4% of the available water only.

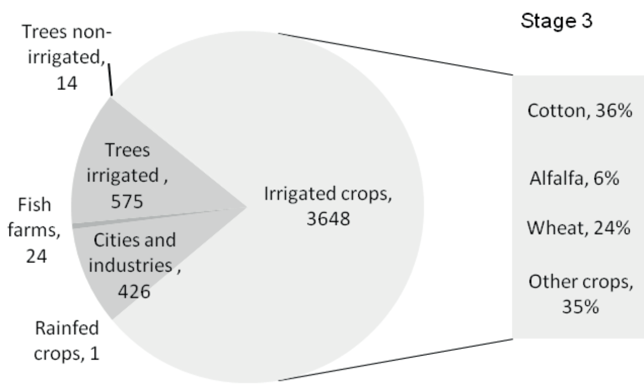
B. Beneficial non-process depletions

The beneficial non-process depletions are the water transpired by tree plantations including agro-forestry plantations. Calculated values of the beneficial depletions from the irrigated tree plantation and non-irrigated forest areas are given in Figure 2. Transpiration by tree plantations was estimated at 551 Mm^3 or 4% of total available water which shows that the perennial plants contribution to maintaining the water table in some areas is significant.

a)



b)



c)

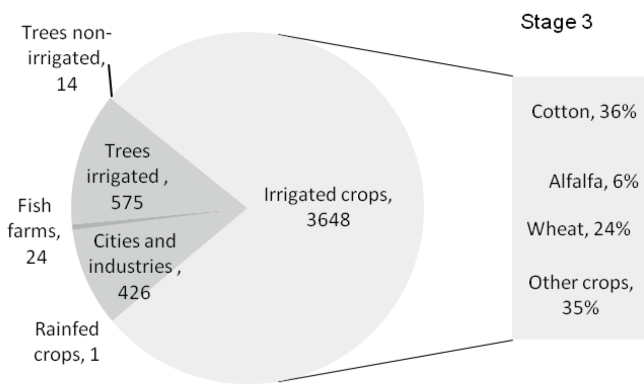


Figure 2. Process depletions in the Fergana at different stages (Mm^3/year)

C. Non-beneficial water depletions for evaporation

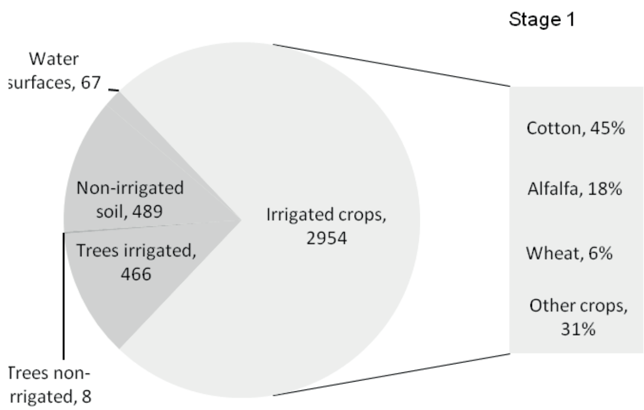
c.1. Water evaporated from irrigated soil, ETc (E), calculated on a monthly basis were corrected for shallow water table conditions using results of the lysimeter studies in Fergana Valley (Ganiev, 1979). Non-beneficial water depletions for evaporation calculated for crop vegetation and non-vegetation seasons are given in Figure 3.

Figure 3 indicates that the main non-process depletions in the crop vegetation season have occurred from cotton and vegetable fields. Non-beneficial depletions in the non-vegetation season amounted to 39% of the total non-beneficial depletions in 1992 and increased to 47% in 2004. Non-beneficial depletions in the non-vegetation season increased from 1992 to 2004 by 17%, while in the vegetation season they were reduced by 14%. Crop-wise, in 1992, 42% of evaporation in the non-vegetation season occurred from fallow land after cotton harvesting, 26% from vegetables, 11% from alfalfa, 13% after wheat harvesting and 9% from orchards and vines. In 2004, 28% of the total physical evaporation occurred after cotton harvesting, 37% after wheat harvesting, 26% after vegetable harvesting and 9% from fruits and grapes. Non-beneficial depletions for crop production on the irrigated fields make 25% of the available water.

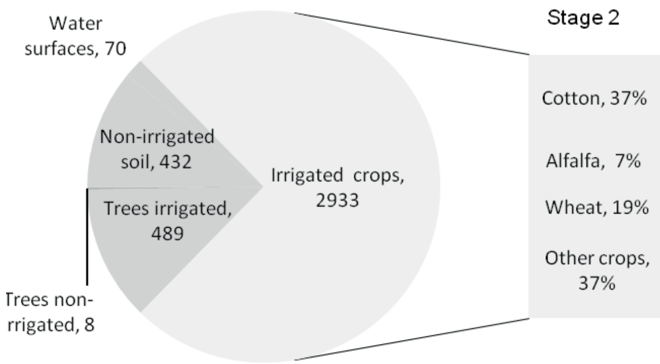
c.2 Non-beneficial evaporation from open water bodies and non-irrigated soils.

Non-beneficial depletions for evaporation from open water surfaces given in Figure 3 consist of 47-49% of water surfaces of riverbeds and 37-40% of water from reservoirs. The amount of water that evaporated from the area with tree plantations in the irrigated zone was 466-489 Mm^3, and that from non-irrigated areas within the irrigation zone was 432-559 Mm3. Non-beneficial evaporation from open water and non-irrigated soil within the irrigated zone makes 4% of the available water.

a)



b)



c)

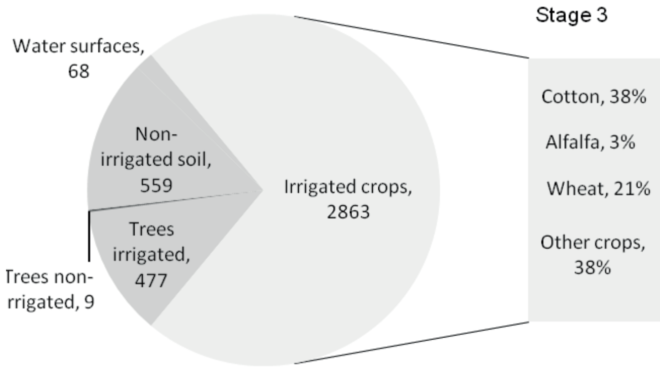


Figure 3. Non-process water depletions (Mm3/year) in the Fergana Valley at the different periods (stages)

c.3 Flow to sinks and pollution

The average annual flow to sinks for 1992-2004 was 1,430 Mm^3 which was discharged into Arnasai depression for physical evaporation (Table 2). This flow partly filled the saline aquifer. Flow to sink made 5% of the gross inflow in Stage 2 and from 1-5% in Stage 3. Flow pollution caused by saline return flow from the irrigated soils and estimated by the amount of extra water applications associated with increased salinity of the river flow applied for irrigation in the downstream was estimated at 172-239 Mm^3 per annum (Table 2) which amounts to about 1% of the gross inflow.

Table 2. Water saving potential of the Fergana Valley

Accounting category	Stage 1	Stage 2	Stage 3
Gross inflow	25,480	28,118	28,885
Available water	12,638	10,949	12,206
Process depletion	4,505	4,237	4,099
Non-process depletion beneficial	564	599	588
Non-process depletion non-beneficial	3,985	3,932	3,976
Outflow from the Fergana valley	16,427	19,349	20,222
Flow to sinks	0	1,336	1,026
Pollution	239	196	195
Outflow for use in the downstream	16,188	17,817	19,002
Committed flow	19,540	19,540	19,540
Utilizable flow			0
Water deficit	3,352	1,723	538

The data given in Table 2 shows that those non-beneficial water depletions in the Fergana valley increased from 4,224 Mm^3 in 1992 to 5,197 Mm^3 in 1997-2004, 77%of which relates to evaporation and 23% to flow to the sinks and pollution. By the end of the study period the non-beneficial depletions amounted to 18% of the gross inflow or 43% of available water.

Step 2: Estimating water saving potential

The data obtained in the previous step allows calculating total outflow from the study area to meeting the commitments for the downstream uses. Main results of estimating water saving potential are given in Table 2. The data presented does not consider evaporation losses from the Kairakum and Chardara reservoirs located downstream of the study area. Therefore shortage of water in the downstream is higher as compared to the presented in Table 2. The summary of water accounting for Fergana Valley is given for 2004 in Figure 4.

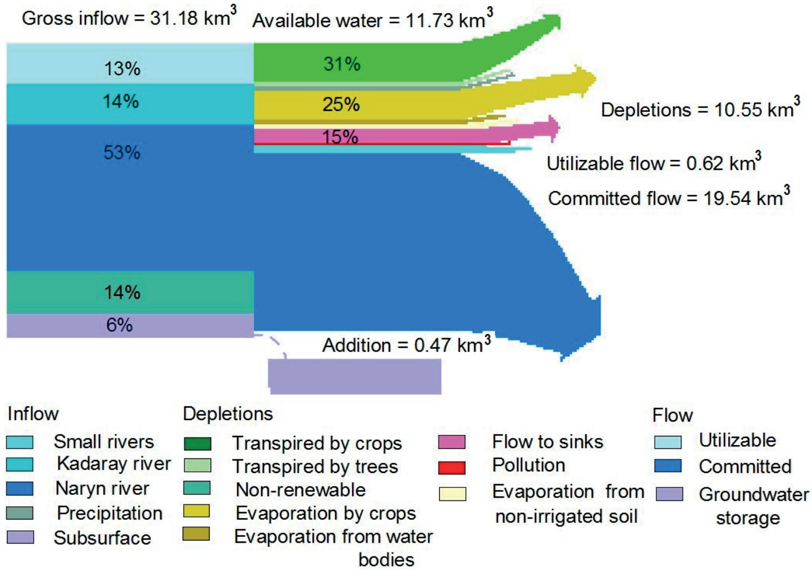


Figure 4. Water accounting categories for Fergana Valley for 2004.

Figure 4 shows that 25% of the available water in Fergana Valley depletes for non-beneficial crop evaporation, 18% makes flow to sinks, 4% for evaporation from water bodies and non-irrigated soils and 2% for pollution. The studies found that potential of water saving in Fergana Valley amounts to 4.2-5.2 km^3. Adopting proper water saving technologies will increase water productivity in the Fergana Valley and increase river flow available for the downstream uses and environment.

5. CONCLUSIONS

Using water accounting procedure for Fergana Valley indicated high potential for water saving and increasing water productivity which is associated with reducing non-process water depletions and reallocating the saved water for beneficial use. Proper water saving strategies are to be identified to reduce non-process water depletions. Further water use accounting studies are required to estimate and optimize water productivity at the basin level considering hydropower in the upstream, and irrigation and environmental needs in the downstream.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to the OPEC for financing this work.

REFERENCES

Allen, R.G., Pereira, L.S., Raes, D., Smith, Martin. 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper. 56. 300p. FAO, Rome.

Ayers, R.S., Westcot, D.W. 1985. Water quality for agriculture. FAO Irrigation and Drainage paper, 29 Rev.1. FAO, Rome.

CAWATERinfo. 2009. Water resources of the Syrdarya River Basin. Basin Water Organization (BWO), Syrdarya. http://www.cawater-info.net/syrdarya/water_e.htm

Ganiev, K.G. 1979. Evaporation and infiltration recharge of groundwater. Fan, Tashkent, Uzbekistan, 210p. In Russian

Mavlonov, A. A., Borisov, V.A., Djumanov, J. Kh. 2006. Assessment of underground water resources of Fergana valley. Paper presented in the Regional Conf. on: Conjunctive use of ground and surface water resources of Fergana valley for irrigation. 2 November 2006. Tashkent (In Russian).

McKinney Daene C., Cai, X. 1997. Multiobjective water resource allocation model for Toktogul reservoir. Working paper. Center for Research in Water Resources. UTA.

Molden, D. 1997. Accounting for water use and productivity. SWIM Paper 1. International Water Management Institute, Sri Lanka.

Molden, D. J., Sakthivadivel, R. 1998. Water accounting to assess use and productivity of water. International Journal of Water Resources Development, 15, (1/2), 55–71.

Rubinova, F.E. 1979. The change of flow of Syrdarya River as affected by basin water development. Moscow, Gidrometeoizdat, 135p.