Assessment of Nitrate-N Load in Subsurface Drainage Water from the Agricultural Fields in the Fergana Valley, Uzbekistan

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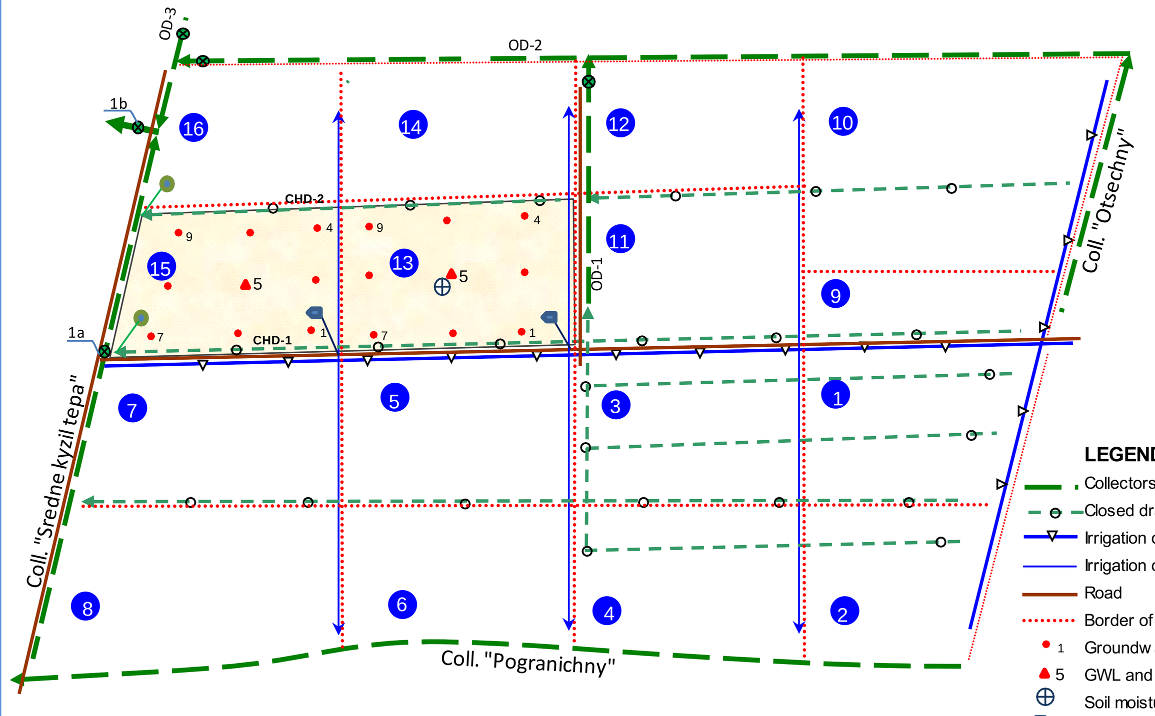
I. Abstract

Leaching of nitrate (NO_3^-) from irrigated agricultural land and water contamination have become a worldwide concern. Amount and time of water and nitrogen fertilizer application are thus should be investigated to understand its movement to groundwater and surface water. This study was conducted to investigate the amount of NO_3^- leached to groundwater and surface water from irrigated cotton, winter wheat and maize fields in the Fergana Valley, Uzbekistan.

II. Study Area



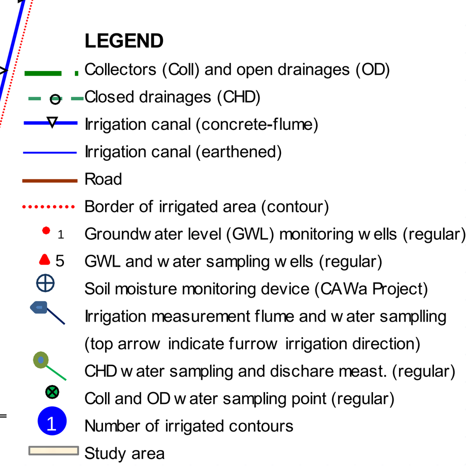


Figure 1: Scheme of plots location and measurement points in Azizbek site (40°28'N; 71°32'E), Fergana province, Uzbekistan. 2 fields: contour 13 (10.2 ha) and contour 15 (8.9 ha) were investigated and contours #14 (10 ha), #16 (7.4 ha) were monitored for agronomic practices.

Table 1: Design parameters of subsurface horizontal drainages

Name of closed horizontal drains	Service area (ha)	Drainage spacing (m)	Length (m)	Drainage depth (m)	Diameter of pipe (mm)	Slope	Designed drainage module, ($l\ s^{-1}$ ha)	Construction year	Pipe type
CHD-1	40	250	1668	3.3	147	0.0025	0.17	1959	asbestos-cement
CHD-2	20	250	750	3.2	147	0.0025	0.17	1962	asbestos-cement

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III. Methodology

❖ **Agronomical monitoring and phenological observation**

Irrigation, fertilization etc. - field visits, visual observation, farmers questionnaire

❖ **Water and soil sampling and analysis**

Irrigation water (Q) &	
CHD water (q)	- trapezoidal weir (WCH-50, Q ~ 0.005-0.082 $m^3\ s^{-1}$)
GWL & sampl.	- sounding device with measuring tapes and manual peristaltic pump (Eijkelkamp, the NLD)
pH, T °C and EC	- snap-shoot (pH/Cond 340i, WTW, Weilheim, GER)
NO_3^-	- photometric method (SANIIRI, KFK and UzNIGMI, SP Specord 50, Analytik, Jena, GER)
Soil moisture	- hourly msrt. (Decagon ECH_2O EC-5, Pullman, WA, USA)
Soil texture, chem. & hydraul.	- pit excavation and auger (Eijkelkamp, the NLD)

❖ **Water balance**

Aeration zone (Dukhovny V. et al, 2005)

$$\Delta W_a = P + Ir + (1\text{-}a)Fc - Si - ET \pm q \quad [1]$$

where: ΔWa: change in water stock in aeration zone within the boundaries of balance site over the estimated period; P: precipitation; Ir: irrigation; a: coefficient expressing a share of seepage that recharges groundwater; Fc: seepage losses from canals, Si: surface runoff (from irrigation); ET: evapotranspiration; ±q: vertical water exchange, "+" capillary rise (Cg), "-" deep percolation (DP) (fig.2).

❖ **Nitrogen balance** (Portela S. et al, 2009)

$$\Delta Soil + Fert. + Ir + GW - Dr - CropN = Difference \quad [2]$$

where: ΔSoil: difference in soil N (up to 1 m) between sowing and harvest; Fert: fertilizer N; Ir: Irrigation water N; GW: groundwater N, by capillary rise (Cg); Dr: Drainage N run-off; CropN: crop N uptake.

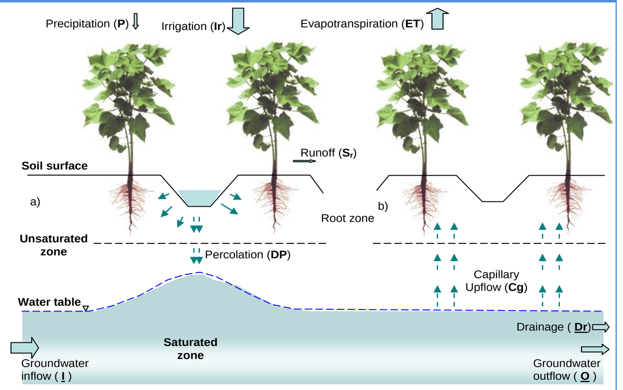

Figure 2: Schematization of water balance components of the study site (interaction of water fluxes in aeration zone: during irrigation period and heavy rainfall – deep percolation starts, rises of GWL, higher drainage discharge (a); and between irrigation events – crop water demand is mainly from capillary upflow, gradual decline of GWL and lower drainage discharge (b)

IV. Results and Discussion

❖ During 2009-2011 monitoring years, cotton yield was highest (6.4 t ha^{-1}) in 2010 (C-15) when application rate of synthetic fertilizer was optimal according to recommendation level (tab.2).

Table 2: Cropping calendar, fertilization rates (nutrient form) and harvested yield of agricultural crops in the study area

Year	Contour 13&14 (20.2 ha) Crop type	Area (ha)	Planting-harvest date*	Fertilization (kg ha^{-1}) N	P_2O_5	Yield** (t ha^{-1})	Contour 15&16 (16.3 ha) Crop type	Area (ha)	Planting-harvest date*	Fertilization (kg ha^{-1}) N	P_2O_5	Yield** (t ha^{-1})
2009/2010	Wheat	20.2	14.10.2009 - 21.06.2010	170	38	3.1	Fallow	16.3	15.10.2009 - 17.04.2010			
2010	Maize	8	26.07.2010 - 17.10.2010	51	-	6.4	Cotton	16.3	19.04.2010 - 30.09.2010	238	38	3.4
2010/2011	Fallow	20.2	18.10.2010 - 14.04.2011				Wheat	16.3	15.10.2010 - 21.06.2011	163	19	4.9
2011	Cotton	20.2	15.04.2011 - 28.09.2011	204	19	2.8	Maize	13.9	29.06.2011 - 15.10.2011	51	-	8.0

* harvest date for cotton was taken as first harvest in the second half of September (about 74 % of total harvested yield), however the last harvest was done during first decade of October; **yield for maize is given as a dry biomass (sown for silage after harvest of winter wheat).

❖ Cotton sown in 2011 was not irrigated enough to meet crop water demand thus water balance for aeration zone was negative (tab. 3). Groundwater contributes about 19 % of cotton water demand.

Table 3: Components of aeration zone water balance (C-13)

Year	Crop	GWL[1] (m)	Water balance ($m^3\ ha^{-1}$) P[2]	Ir[1]	(1-a)Fc[3]	Cg[4]	Si[1]	ETc[5]	DP[6]	ΔWa	Cg/ETc (%)
09/10	Wheat	1.1-2.7	2152	4833	725	na	231	4349	1162	1968	na
2010	Maize	1.8-2.3	292	1871	281	na	68	2590	486	-700	na
2011	Cotton	1.3-2.4	330	4080	612	1358	302	7268	868	-2058	19

na: not available; [1]measured in situ; [2]meteostation "Fergana" (No 4047180), UzHydromet; [3]Canal seepage loss was taken as 15 % of gross water intake according to accepted value by BAIS and WUAs in Fergana province (SIC ICWC, 2011); [4]Calculated by Upflow (Raes D., 2009a); [5]Calculated by ETo (by ETo calculator, Raes D., 2009b) multiplied by Kc values (FAO method, Allen G. et al., 1998); [6]according to efficiency of furrow irrigation method (Abirov A. et.al, 2011).

❖ Nitrogen balance (kg ha^{-1}) for cotton sown in 2011 showing surplus (tab. 4). The gaseous N_2 losses can significantly reduce this value (N_2 loss range within 10-70 % of applied N, Scheer et al, 2008).

Table 4: Nitrogen balance (kg ha^{-1}) for cotton during 2011 growing period (C-13)

Year	Crop	Inputs Δsoil NO_3-N[1]	Ir[1]	Fertilizer	Ground water[2]	Outputs Dr[1]	Uptake[3]	Surplus
2011	Cotton	-18	9	204	5	9	131	61

[1]measured in situ (net irrigation N);
[2]calculated by Upflow;
[3]according to SoyuzNIKHI: 1 t row cotton under yield of 2.5-3.0 t ha^{-1} contains about 46 kg N (Mamarasulov U., 1989).

❖ Soil moisture and GWL between two irrigations of cotton (C-13) has a same trend and negatively correlated (R^2=0.86, fig.3). The range of NO_3 concentration in surface waters is lower than soil waters (fig.4) and relatively stable in subsurface drainage water (<14 mg l^{-1}) during no or less irrigation and fertilization but increased sharply (>30 mg l^{-1}) afterwards (fig.5).

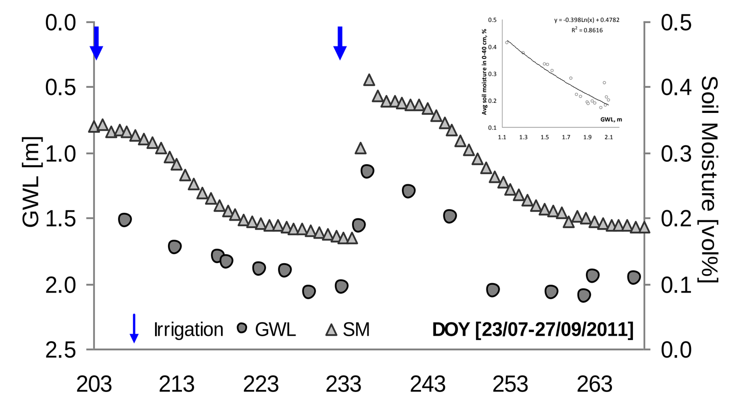

Figure 3: Dynamics of soil moisture (vol%) and groundwater level (m) in C-13 between two irrigation events

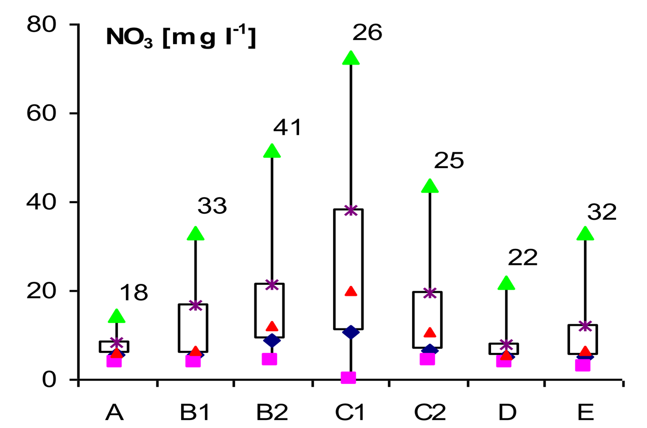

Figure 4: The boxplot, showing the range of NO_3 concentrations (A: irrigation, B1: CHD-1, B2: CHD-2, C1: groundwater in field-15, C2: groundwater in field C-13, D: open drainage OD-2, E: collector Col-1a; numbers above the boxes indicate the number of samples)

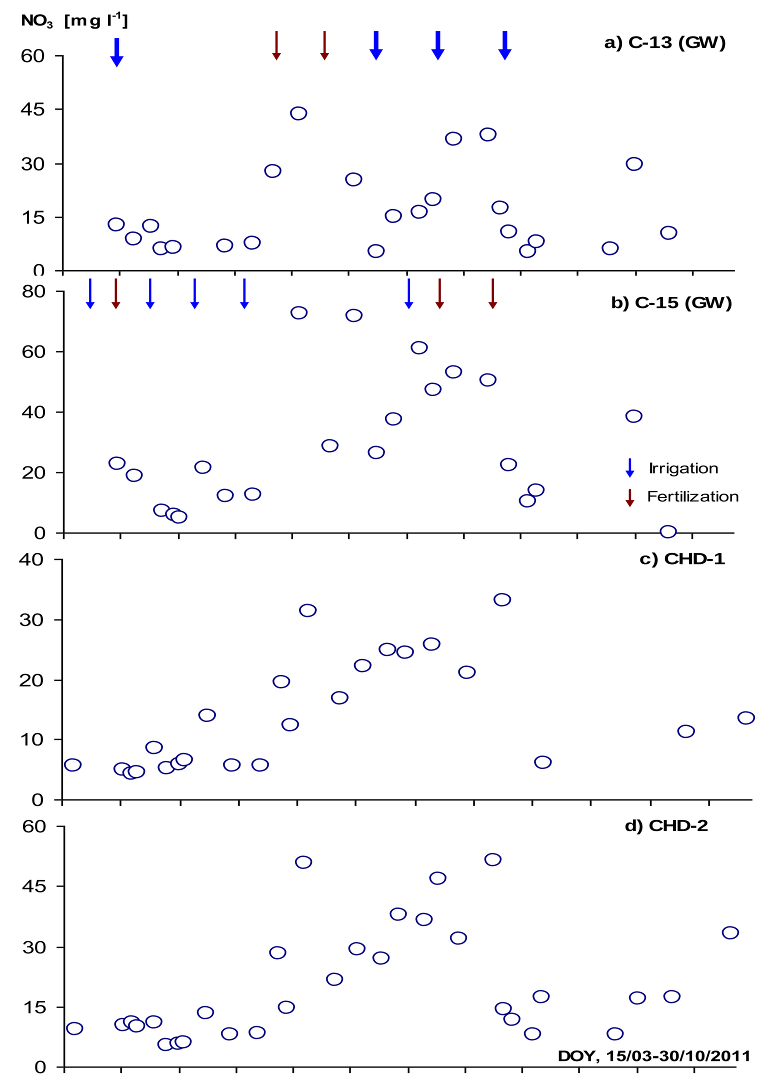

Figure 5: Nitrate concentration (mg l^{-1}) at phreatic groundwater in fields C-13 and C-15 (a&b) and closed hor. drainage (c&d)

V. Conclusions

- There is high competition on water resource use both, among farmers and within local harvesters (especially during 1st irrigation of cotton and secondary crops after wheat harvest);
- The field measurements confirm that Model Upflow can predict upward water movement to the root zone in the correct order of magnitude;
- Continuous upward water movement and further evapotranspiration may result secondary soil salinization (groundwater mineralization - TDS: 2.5-3.3 g l^{-1});
- Caution should be taken to account capillary rise in water balance and recommending to reduce surface irrigation;
- The subsurface drainage enables to control waterlogging and soil salinity. While excess water application washes nutrients as well (especially nitrate form of nitrogen);
- Results of water and N balance for cotton in 2011 reveals that irrigation amount (includeing charging irrigation) is not enough to meet crop water demand and drainage N loss is not significant;
- Proper irrigation water management with combination of fertilizer application reduces unproductive losses under irrigation and drainage interactions;
- Awareness and understanding of local people, farmers and decision makers on this processes could help to improve agricultural productivity and effective use of scarce water resources.

VI. References and Acknowledgements

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The authors would like to acknowledge the Center for International Development and Environmental Research (ZEU) for bilateral cooperation and management
This research was funded by the Volkswagen Stiftung under framework of the Project "Land Use, Ecosystem Services and Human Welfare in Central Asia"