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EFFECT OF WATER TABLE MANAGEMENT ON WATER QUALITY

Jusuf TAIRI & Dorina GRAZHDANI

Agricultural University of Tirana, Tirana. Albania

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SYNOPSIS

Water table management is increasingly recognized as one component of a total water management system, which must be designed and operated in conjunction with the other components. Use of subirrigation and controlled drainage is increasing and new methods for managing these systems are being rapidly accepted and applied in some parts of Albania. A proper design and operation of water table management systems could satisfy both off-site environmental concerns and on-site agricultural requirements. The objectives of this research were to analyze the effects of a controlled drainage-subirrigation system on shallow ground water and outflow nutrient concentrations as compared to those found in adjacent forested and grassland areas. A study for obtaining the information about the effect of water table management on soil and nutrient erosion and water quality was conducted from 2002 to 2005 in Korça province, southeastern Albania [40^0 35' N, 20^0 46' E, elev. 899 m]. The results taken by this study show that controlled drainage-subirrigation system has an evident effect on subsurface and outflow water quality. This system effectively reduced the potential influx of high nitrate-N, ammonium-N and dissolved ortho-P concentrations into surface waters. Thus, controlled-subirrigation systems can be managed to reduce their potential for contamination of groundwater and surface water resources.

INTRODUCTION

Controlled drainage is a form of water table management (WTM) system in which the drainage outlet is controlled to hold excess water for crop use. WTM, in the form of controlled drainage, has been termed as “best management practice” for reducing outflow water quality (EVANS ET AL., *1989*). With the use of CD-SI, the potential exists to further reduce chemical concentrations in the outflow waters

(THOMAS ET AL., *1991*). Many studies by environmentalists have identified and evaluated the nature and extent of non-point sources of pollution (AHUJA, *1986*). A large number of experiments have been carried out in which the overall loss of nutrients was determined from different land uses, cropping systems, management practices and climatic conditions. Our opinion is that WTM ranks very high as a “best management practice” for soil erosion and pollution control. The influence of WTM combined with normal fertilizer and chemical applications for crop production will affect the shallow groundwater quality and may influence the quality of our surface water resources. A comprehensive evaluation of the quality of water entering, residing in and exiting WTM can provide essential information for the best management of these systems and our water resources.

The level at which nitrate-N constitutes a problem is a function of water use, but the environmental constraints indicate that a concentration of 10 mgL^{-1} NO_3-N is a primary limit for drinking water standards. Eutrophication of water bodies can occur with considerably lower concentration. Unionized ammonia (in solution) is a poison that may be hazardous to animal (fish) life. Rainbow trout, for instance, have a documented sensitivity to ammonium-N when concentration exceeds 2 mg L^{-1}. Ortho-P is one of the most detrimental nutrients in our lakes and smaller impoundments due to its promotion of eutrophication (CHAPRA*, 1996*). CD-SI has the potential to reduce phosphorous concentrations in outflow waters due to the low slope characteristics and the potential to reduce run off and erosion. However, phosphate ions attach more readily to clay particles, so the sandy soils may have a higher capacity for leaching phosphates.

Research to date has shown that there are several different management schemes and that each must be adapted to the local condition if it is to be effective. A practice, which has proven to be successful or have potential for future use to improve soil and nutrient erosion and water quality, is discussed in this paper.

MATERIALS AND METHODS

a. Experimental site

The effects of CD-SI system on subsurface and outflow water quality are evaluated in the experiment located in Plasa County (Arenosol-FAO). The CD-SI system covers about 20 ha and is composed of corrugated plastic tubing on a 17.6 m spacing and average depth of 1 m. The soils are of sandy type, typically poorly drained and are subject to moderate and severe high water table, poor trafficability. However, the soils require supplemental water for desired crop growth during dry periods in the growing season due to the low water-retention characteristics. The CD-SI area was in a field crop rotation (corn-soybeans-corn). Nitrogen fertilizer application for each year of the study included 100 kg ha^{-1} for the corn and 40 kg ha^{-1} for soybeans. Phosphorous fertilizer application included 60 kg ha^{-1} and 60 kg ha^{-1}, respectively (all amount relate to active ingredient). The experimental field included a scrub forest (12 ha) in northeast corner of the farm and a non-irrigated grassland area (23 ha) in northwest part of the farm. Both are adjacent to CD-SI area.

b. Data collection

The water quality sampling sites in Plasa County experiment (Figure 1) are described in Table 1. All samples on outflow, open ditch, inflow and instream (site 1, 5, 5.1, 5.2, 5.3, 5.4, 6 and 7) were collected using grab techniques at approximately two-week intervals. Obviously, this sample interval cannot provide estimates of the total nutrient movement, but it does illustrate the relative variation in concentrations between sites. The grab samples were obtained with a 1, 000 ml glass bottle. After sampling, the water was transferred to a 500 ml nalgene sample bottle and placed on ice. The apparatus used to collect the shallow-well samples in the field (site 2, 3, and 4) consisted of a peristaltic pump, a filtering flask, and dedicated Teflon sampling tubes inserted in PVC monitoring pipe (50 mm diameter and 1.6 m length) at each site. All monitoring pipes were installed to 1.50 m below the surface. When sampling from the wells, the Teflon tube was inserted into a 1,000 ml filtering flask and held in place with a rubber stopper. The suction pump was connected to the side port on the flask and samples were drawn into the flask and then transferred to 500 ml nalgene sample bottles. The flasks and bottles were cleaned using standard laboratory techniques between sample periods. The water samples were analyzed for NO_3-N, NH_4-N and PO_4-P using calorimetric techniques.

The sample data for each water quality parameter was statistically analyzed between sites with new Duncan multiple range test (DMR) at the 0.05 level of significance.

Table 1. Water quality sampling locations for Plasa farm study

Sampling		Location
Site	Type	
1	Grab	Southeast corner of the experimental area in sump outlet
2	Well	In the CD-SI plot, centered between drain laterals
3	Well	In scrub forest section
4	Well	In the cleared, unirrigated grassland area
5	Grab	Discrete samples from the reservoir within 5 m of the dam. Samples are at the surface (Site 5), and at depth of 0.5 m (Site 5.1), 1.0 m (Site 5.2), and 1.5 m (Site 5.3). Composite sample (Site 5.4) was obtained by moving the sample bottle back and forth from the surface to the 1.5 m depth until full.
6	Grab	In the ditch, but 200 m downstream from Site 1
7	Grab	Water from the channel at the inflow to the initial control structure head tank

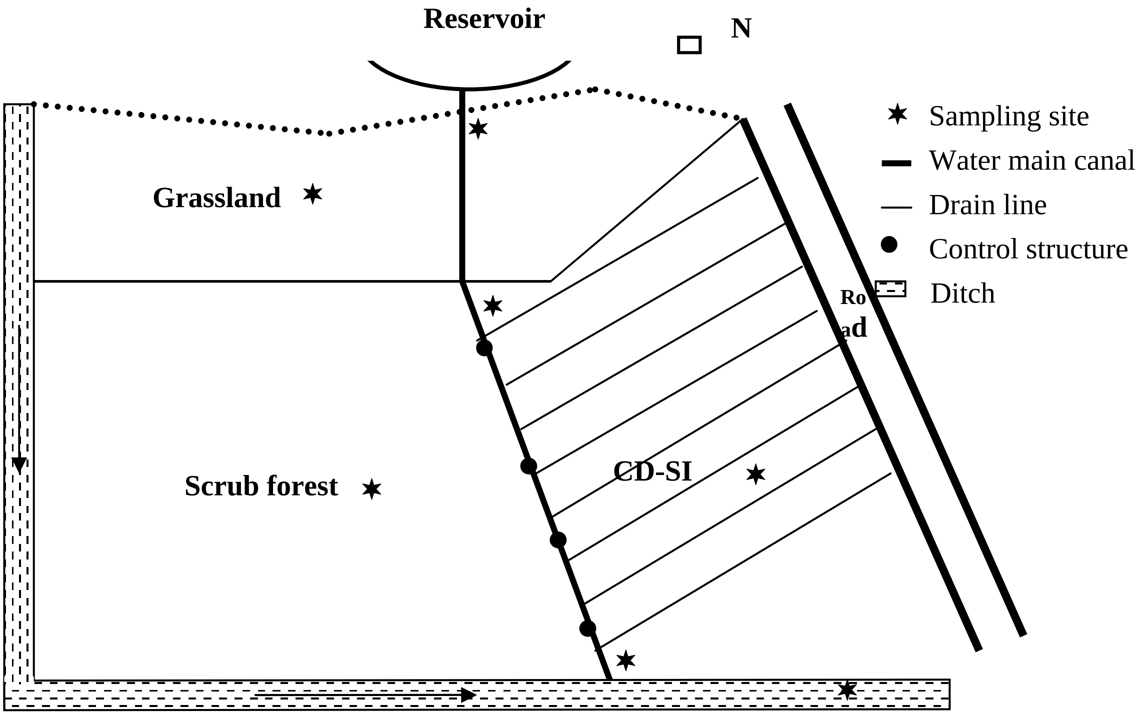

Figure 1. Layout of Plasa farm experiment with water sampling locations (not to scale)

RESULTS AND DISCUSSION

Statistics of the water quality measurements of Plasa County experiment (maximum, mean, standard deviation and DMRT) are presented in Table 2. One important characteristic must be emphasized when interpreting the statistical results. The sample size is relatively small. This fact along with the unusual weather conditions implies that all results may not be absolute indicators of long term conditions. The results are presented down here by each individual water quality parameter (Table 2).

Nitrate-N

In the statistical analysis, the CD-SI samples had significantly higher nitrate-N concentrations than most of the other sites. In all four years the nitrate-N concentration was highest following the fertilizer application in early March. The nitrate-N concentrations remained high in the CD-SI area during the drought period of May and June. The increased water input (subirrigation) during the summer months reduced the nitrate -N concentrations until the next fertilizer application in August.

A comparison between CD-SI site and forested site shows the marked increase in nitrate -N concentration of the CD-SI area. Only five of samples from the forested area had nitrate-N concentrations exceeding 5 mg L^{-1} .The potential exists for shallow well concentrations in the forested and CD-SI areas to be greater, since the sampling interval was every two weeks.

Site 3 (CD-SI), site 2 (Scrub forest), and site 5.4 (Open ditch composite) all had at least one sample in which the concentration exceeded 10 mg L^{-1}. However, no samples had concentrations above 28 mg L^{-1}. Based on the all samples obtained from the CD-SI area, the concentration exceeded 10 mg L^{-1} on less than ~12% of the samples. The high nitrate-N concentration from the scrub forest site occurred during the October and May and have been the result of lateral movement from the adjacent field or an increased concentration of soil water nitrate due to evapotranspiration from the forested area. N-mineralization would be enhanced during the low water table period in October, thus, higher levels of nitrate -N would be present when the water table rises.

The high nitrate-N concentration from the open ditch has been caused by a disturbance in the plant and particulate material at the base of the ditch during the sampling process. The low concentrations from the other ditch samples on the same date indicate some disturbance must have been occurred during the sampling process. The samples from the open ditch exhibit a slight decrease in maximum NO_3-N concentration as the depth increases.

The Table 2 illustrates one of the most beneficial characteristics of CD-SI as related to off-site water quality impacts. Even though the nitrate-N concentration below CD-SI area exceeded 10 mg L^{-1} on over 12% of the samples, the outflow (site 1) concentrations remained below 8 mg L^{-1} in all the samples. Mean nitrate-N concentration was near 1.5 mg L^{-1}. This phenomenon is related to timing and control scenario of CD-SI. During the periods of fertilizer application, the outlet is controlled and the system is in the subirrigation mode most of the time. Therefore, the irrigation water supply and the gravity flow mainline distribution system are of similar quality since the water moves through the distribution system, and back into the field. The water at the outflow is the minimum overflow required maintaining the water level at the last control device and is also of similar quality to the well-water quality. This system effectively reduces the potential influx of high nitrate-N concentrations into surface waters. In each of the four years, nitrate -N concentrations in the shallow wells were high during subirrigation (May-September). The outflow concentrations decreased during this period and were similar to the inflow concentrations.

⇒ ⇒ *Table 2*

The instream samples, which were obtained 200 m downstream from outflow, also had fairly low nitrate-N concentration (average 1.26 mg L^{-1}) and did not exceed 5.32 mg L^{-1} in any of the samples obtained.

Nitrate-N concentrations in the shallow ground water below an agricultural production area would be expected to increase above 10 mg L^{-1} whether a WTM system was present or not. The high leaching potential of these sandy soils in combination with only one split nutrient application would results in high nitrate-N leaching losses. Improved nutrient management with increased split application should provide additional reduction in leaching losses. Ferguson et al. (1990) and Thomas et al. (1990) give similar conclusion.

Denitrification may be enhanced with the use of CD-SI systems when the water table is raised during particular periods of the year. The lack of organic matter in these soils does reduce the potential for denitrification. Insufficient data are available in this study to evaluate this effect.

Ammonium -N

In the decomposition of nitrogenous organic substances in this type of soils, the release of ammonia (NH_3) equilibrates to ammonium (NH_4). In the sample results, site 2 (scrub forest), site 5.3 (1.5 m depth in the open ditch), and site 4 (grassland) had ammonium-N concentrations excess of 2 mg L^{-1}. A ditch sample at the 1.5m depth showed the highest ammonium -N concentrations of 12.3 mg L^{-1} (Table 2). This value may have been caused by disturbance of the sediment on the bottom of the ditch since the ammonium -N concentrations from other levels in the ditch were similar.

None of outflow samples had ammonium-N concentrations exceeding 1.41 mg L^{-1}. The well aerated water and natural gravity flow characteristics of controlled drainage -subirrigation systems may reduce ammonium -N concentrations by nitrification, the conversion of ammonium to nitrate. It appears that the natural gravity flow characteristics of CD-SI systems may reduce the potential for increased ammonium-N by the conversion to nitrate-N. Obviously, the sampling period of this study is not sufficient to draw specific conclusions. In the statistical analysis, no significant differences in ammonium -N concentrations were detected between any of the sites. A decrease in the sampling interval might have produced different results.

Ortho-P

The low ortho-P concentrations of the outflow samples (only one sample at 2.84 mg L^{-1} all other samples were below 1 mg L^{-1}) indicates that CD-SI systems may not increase dissolved ortho-P concentrations in streams, based on the limited data. The combination of the clay and silt particles in the soil and the low slope will limit ortho-P movement even without CD-SI system. In the statistical analysis, no significant differences in ortho-P concentration were exhibited between sites, but the sample size may have been insufficient to detect a significant difference if it existed.

CONCLUSIONS

Associated water management practices as CD-SI also have effect on the rate, the route and the quality of drainage water leaving a field. The outflow water from the CD-SI system is of good quality with respect to nitrate - N, ammonium - N, and ortho-P concentrations. The benefit of this particular CD-SI system is the reduction in nutrient concentrations to off-site surface waters. As a result of this study the poorly drained soils lost fewer nitrates to drainage water than well-drained soils. Improvements in nitrogen management are required to reduce the potential impacts of agriculture and water management on shallow ground water quality. It appears the levels of ammonium-N and ortho-P concentrations from the CD-SI systems are not severe and are comparable to concentrations from the forested and grassland areas.

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Table 2. Statistics values for nutrients concentrations at water-sampling locations for Plasa County farm study, 1992 - 1995

Site No.	Sampling			NO_3-N (mg L^{-1})					NH_4-N (mg L^{-1})					PO_4-P (mg L^{-1})			
	Sites	Number		Max	Mean	SD[1]	D[2]		Max	Mean	SD[1]	D[2]		Max	Mean	SD[1.]	D[2]
1.	Drain outflow	76		7.98	1.52	1.73	cd		1.41	0.20	0.03	a		2.84	0.18	0.28	a
2.	Scrub forest	61		22.29	0.98	2.56	cd		3.54	0.46	0.76	a		0.70	0.13	0.19	a
3.	CD-SI	64		27.92	3.78	7.37	abc		1.64	0.69	0.14	a		0.51	0.12	0.18	a
4.	Grassland	59		5.09	0.62	1.04	cd		2.36	0.23	0.27	a		0.80	0.14	0.22	a
5	Open ditch, surface	78		8.91	0.96	1.72	cd		1.52	0.18	0.34	a		0.88	0.16	0.31	a
5.1	Open ditch, 0.5m depth	75		8.14	1.01	1.78	cd		1.62	0.15	0.65	a		0.98	0.16	0.28	a
5.2	Open ditch, 1.0m depth	74		7.84	0.94	1.59	cd		1.57	0.13	0.54	a		0.86	0.11	0.27	a
5.3	Open ditch, 1.5m depth	54		6.22	0.48	1.04	d		12.3	0.58	1.34	a		0.46	0.15	0.24	a
5.4	Open ditch, composite	77		13.52	1.46	1.81	cd		0.82	0.19	0.41	a		0.91	0.16	0.25	a
6.	In stream	69		5.32	1.06	0.97	d		0.35	0.16	0.08	a		0.85	0.14	0.26	a
7.	Inflow	71		6.38	1.22	0.90	d		1.37	0.13	0.12	a		1.09	0.11	0.13	a

[1] Standard Deviation

[2] Duncan new multiple range test. Means followed by the same letter are not significantly different based on a 0.05 level of significance