

Combining water and fertilizer management for high productivity, low water degradation

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Between 1880 and 1930, increased agricultural productivity in the United States was directly related to increased land area brought into production. Since 1930 cultivated land area has diminished slightly, while agricultural production has continued to increase rapidly. Increased production on the same or less total land area has been brought about by a number of factors, including significant increases in fertilizer application. For example, 1.8 million metric tons of fertilizer nitrogen were used in 1955 and 9.4 million metric tons were applied in 1976.

Nitrogen is a fertilizer element essential for high agricultural productivity. However, nitrogen may stimulate excessive algal or weed growth in lakes and streams resulting in significant negative environmental impacts. Also it must not be overlooked that the present drinking-water standard specifies a nitrate-nitrogen concentration less than 10 ppm.

A research program was undertaken to measure nitrate-nitrogen leached from agricultural systems and to determine factors that affect the amount of leaching. With such information, management strategies that increase agricultural productivity while maintaining low water degradation in irrigated agricultural systems could be devised.

Investigations were carried out on commercial farms in important agricultural areas of California. Fields that were drained by tiled systems—as well as lands naturally drained by free drainage—were selected.

The free drainage studies involved drilling on specifically chosen agricultural sites and analyzing the soil removed at various depths. The depth of drilling was 50 or more feet except in cases where sand or rocks obstructed machinery or a saturated zone was reached. The fraction of irrigation water which passed below the root zone (leaching fraction) was estimated from the ratio of the chloride concentration in the soil-water below the root zone. Multiplying the leaching fraction by the amount of water applied provided estimates of the amount of water leached beyond the root zone each year. Multiplication of the quantity of water leached by the nitrate-nitrogen concentration in the drainage water provided an estimate of the quantity of nitrate-nitrogen leached beyond the root zone.

Water was collected from tile outlets periodically and analyzed for nitrate-nitrogen concentration. The volume of effluent was also measured so that total nitrate-nitrogen quantities could be calculated.

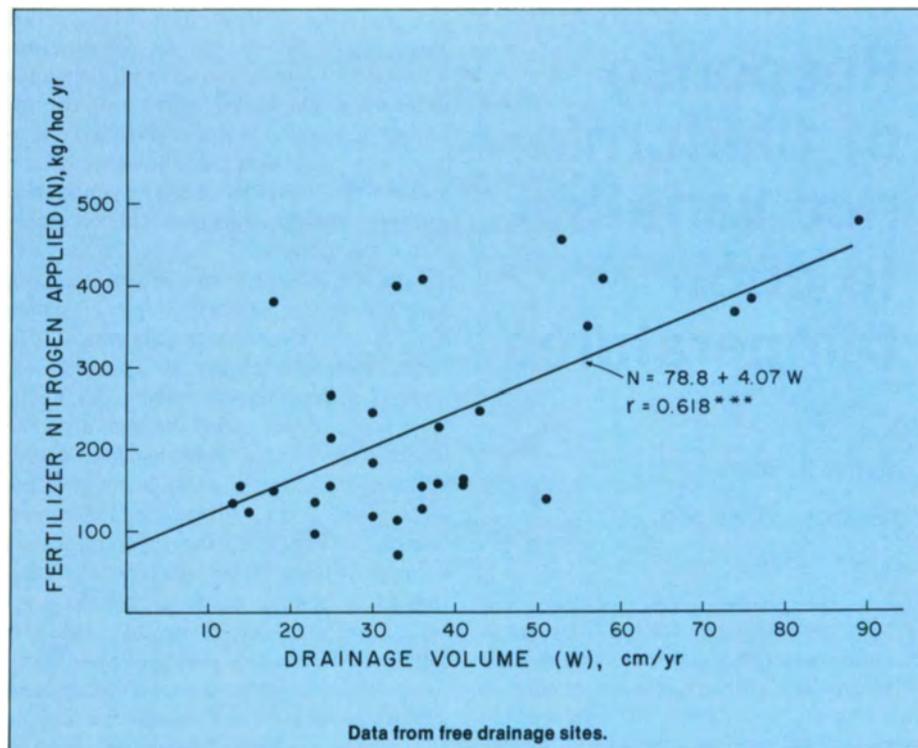
Drilling rig used to obtain soil samples for nitrate analysis.

Linear regression analysis was done on accumulated data. The same general results were achieved from both the free and tile drainage systems. The amount of nitrate-nitrogen leached beyond the root zone was found to be related to the amount of drainage water and the amount of fertilizer nitrogen applied. The highest correlation coefficient was obtained between amount of nitrogen leached and the product of the drainage volume and fertilizer nitrogen application. The second highest correlation coefficient was obtained between nitrate leached and drainage volume, followed in significance by the correlation between nitrate leached and fertilizer input. There was very poor correlation between the concentration of nitrate-nitrogen in the drainage water and either applied fertilizer or water leached.

It must be recognized, however, that the correlations were carried out between two variables with all other variables being uncontrolled. For example, one would expect a higher nitrate concentration in the leachate with increased fertilizer nitrogen input if all other variables were constant. The lack of correlation between concentration and nitrogen inputs simply means that in the systems investigated other variables are acting on the same system to remove the significant correlation. One would also expect lower nitrate-nitrogen concentration with increased drainage volumes simply because of dilution. The fact that this was not observed again indicates that there are other interacting variables in the system.

It is conceivable that water management resulting in high drainage volumes would remove considerable nitrogen from the root zone. A grower may learn from experience that he needs to apply higher amounts of nitrogen under his management system to compensate for the leached nitrogen in order to maintain top crop production. Insofar as we had data on drainage volumes and fertilizer input, we were able to determine if there was a significant relationship between these two factors. Data from the free drainage sites are illustrated in the figure. A linear regression analysis resulted in the equation $N = 78.8 + 4.07 W$, with $r = 0.618$ (significant at the 0.1 percent level), for the free-drainage sites. Tile drainage sites yielded $N = 275 + 2.85 W$, with $r = 0.524$ (significant at the 5 percent level). N represents the amount of fertilizer applied and W represents the drainage volume.

The analysis shows that the significant trend is to apply more fertilizer nitrogen on fields with higher drainage volumes. These results clearly demonstrate that fertilizer



management and water management are interlinked: one cannot be evaluated separately from the other.

Because the amount of nitrogen leached is correlated with the amount of fertilizer nitrogen applied, one may choose to decrease the amount of nitrate leached by decreasing the fertilizer input. This could, however, lead to the undesirable side effect of decreased crop production, unless more nitrogen had been applied than was necessary for maximum crop production. It is difficult, however, to establish what excessive fertilization might be, because water management plays a key role in fertilizer movement. A water management system leading to considerable leaching would undoubtedly require higher fertilizer input, to maintain good production, than water management leading to low leaching. Therefore, a grower applying considerably more fertilizer than another farmer is not necessarily applying excess for maximum production.

Developing water management to have very low leaching would result in low nitrogen flow beyond the root zone, and, in principle, reduce the need for applied fertilizer. Some leaching, however, must still occur to maintain salt balance.

Changing water management may not always be simple or inexpensive. For example, one of the cooperators on the tile drainage project had very high drainage volume and nitrate loss through leaching. He irrigated his sandy soil by rapidly applying water at one end of the field and shutting it off as soon as it reached the

other end of the field. Because of the very high hydraulic conductivity of the soil, considerable amounts of water passed through the soil profile during the period that was required to get the water across the field. Only a different irrigation system—such as sprinkler or drip—could decrease the leaching. This change would require considerable capital investment and perhaps supplemental energy to create the pressure needed for the new systems. From an environmental point of view there might be a transfer of problems from nitrate leaching to inefficient energy use—a limiting factor in the future.

Amount of leaching is determined largely by soil profile characteristics. Good water management can control the amount of leaching independent of soil profile; however, under very sandy profiles, instrumentation and possibly special application techniques are necessary.

Our findings also point out the importance of considering water management in fertilizer research. Experiments that are conducted to determine optimum fertilizer application are done under a given water management system. The results of these studies are valid only for other systems where similar water management practices are used. Growers with vastly different water management may require more or less fertilizer than the amount indicated by research.

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The research reported was supported by Grant GI-34733X of RANN of the National Science Foundation.