Contrasting Furrow and Subsurface Drip Irrigation Effects on Groundwater Recharge

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Abstract:

Irrigation management is an increasingly popular topic in California. California is currently facing a severe drought, making it crucial for efficient water practices to emerge, especially in agriculture. In the upcoming summer months, agriculture will heavily rely on groundwater resources. Agriculture production is a large portion of the state's revenue, so proper water management is imperative. Different irrigation systems have been set up in an effort to manage water more efficiently. Drip irrigation offers concentrated, localized supply that can potentially increase productivity, whereas furrow irrigation offers a consistent flux of water flow that keeps the groundwater recharge consistent. The goal of this study is to understand the differences between these two types of irrigation and recommend the best solution to better water management. Upon further research, we are able to conclude that groundwater recharge is the key factor to better water management, however the method is not yet clear. In a mass balance equation performed by in this study, we calculate that furrow irrigation consistently offers higher groundwater storage as opposed to drip irrigation. Our calculations were based on numbers acquired from the Environmental Protection Agency. This study should be considered preliminary with a basic simulation and needs further field studies that incorporate several other factors in order to make better recommendations on better water management efforts.

Introduction:

There are 2 predominant types of agricultural irrigation in California; furrow irrigation and subsurface drip irrigation. Furrow irrigation is a method in which small parallel channels are created between the rows of crops in the direction of the predominant slope. Water is then fed into the higher end of the furrows and allowed to run under the influence of gravity down the furrow, providing water to the crops on either side. Subsurface drip irrigation uses a network of pipes and hoses to deliver water directly to the root zone.

Furrow irrigation has very low installation costs but involves a large quantity of standing water. Because of this standing water a large portion of the water used in furrow irrigation never makes it to the plant and is instead wasted due to evaporation and runoff. This standing water also leads to a high risk of leaching plant nutrients contained in the soil out of the root zone as the water percolates down. Acknowledgement of these downfalls has lead many to the conclusion that furrow irrigation is too water inefficient and an alternative must be implemented.

That alternative seems to be subsurface drip irrigation. Drip irrigation is more expensive to install because of the increased cost of setting up a complex hydraulic system that can deliver water directly to the root zone. This method provides water to crops exactly where they need it and results in very little wasted water, runoff, and leaching. Drip irrigation allows growers to water the same amount of crops while using around half of the supply. The increased water efficiency of drip irrigation has begun motivating irrigators to switch from furrow methods to the more efficient drip irrigation.

This switch is leading to a possible environmentally inefficient side effect: less groundwater recharge. While a high percentage of the “wasted” water in furrow irrigation not used by plants percolates down to recharge groundwater stores, drip irrigation eliminates this groundwater recharge capacity by increasing water efficiency. While both methods are pulling from the groundwater supply, recharge capacity is very important in making sure there is water for subsequent years of irrigation The low recharge rates of drip irrigation could be very environmentally inefficient when considering the economic incentive farmers have to use the increased water efficiency to double production while paying for the same amount of water. Essentially, they are using the same amount of water to produce double their yield and profits, and recharging a much smaller fraction of water. With many of California's groundwater basins already critically overdrafted, this could be hugely detrimental in the long run.

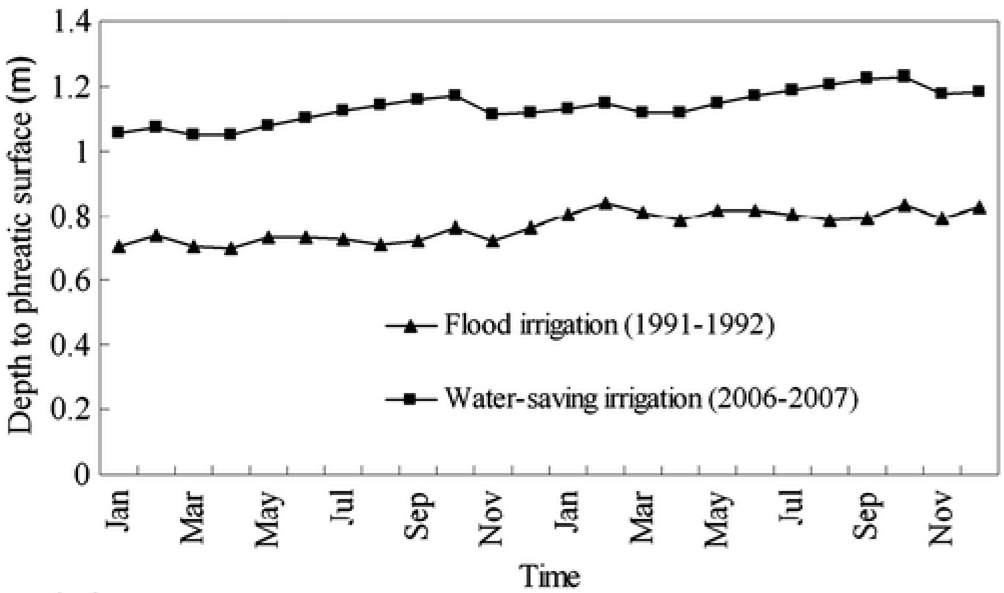
Objective:

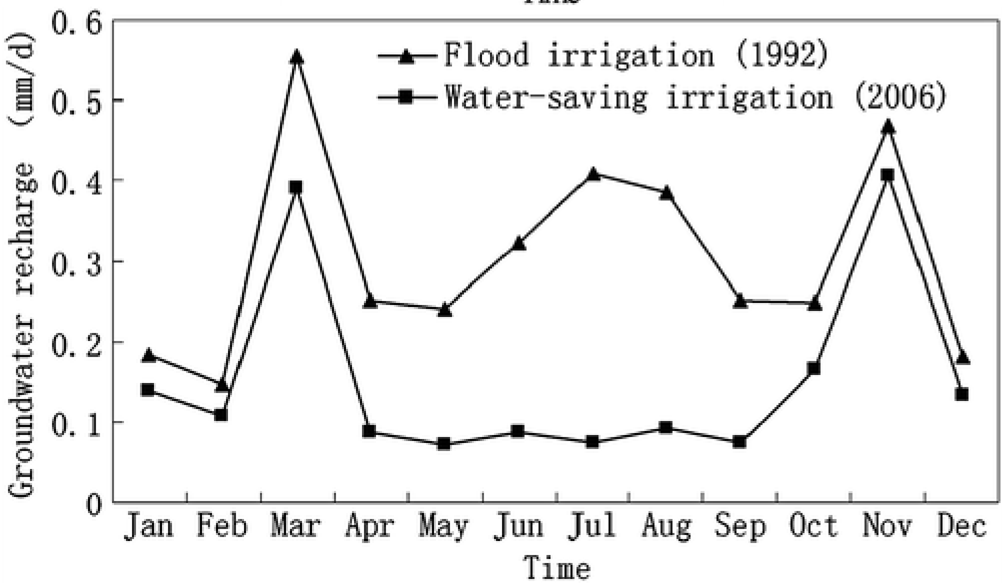
The objective of this study is to examine the impacts differing groundwater recharge capacities have on the environmental efficiency of furrow and subsurface drip irrigation methods using a mass balance approach. A mass balance analysis of the inputs and outputs of an irrigated system will be conducted and deduce the amount of water left over for recharge for the two irrigation methods. The goal is then to draw a conclusion from this simple model about the possible consequences to groundwater recharge that a definitive switch to drip irrigation might have and possible ways to make this increased water efficiency possible while still providing recharge.

Hypothesis:

Our hypothesis is that furrow irrigation will be more environmentally efficient on a long term time scale because of the method's higher infiltration rates. Subsurface drip irrigation may have a higher water efficiency, however the low infiltration rate creates a lack of excess water to provide for groundwater recharge unless other recharge methods are used.

Data Sources:





A study in Manasi Basin, China has been helpful for comparison of the mass balance simulation results. Although this region is a different temperature and moisture regime, the results can be compared because both regions are located on alluvial parent material, eliminating a few unknowns. The results showed that flood (furrow) irrigation consistently provides more groundwater recharge compared to water-saving (drip) irrigation, especially in the summer months (Figure 1). Especially in the summer months, irrigation managers rely more on groundwater because there is less precipitation.

The Manasi study also focuses on depth to the phreatic surface, which shows that water-saving irrigation greatly reduces the water table depth (Figure 2). This form of irrigation can be beneficial if managed effectively. Water-saving irrigation reduces potential drainage most effectively and can potentially increase production (Liu, 2012).

Methods and Assumptions:

This research project required the use of mass balance equations to determine the amount of water that was being used at different stages in the irrigation processes. However, this experiment is very complex in nature and requires extremely inclusive data, which wasn't possible to collect in the time frame given for the project and due to other limitations. To accommodate for the lack of data available for the topic, the team created a versatile mathematical model that would work with nearly any value of water that is available for irrigation and water that is required for the specific crop in question. In order to make the two irrigation methods more comparable, the group equated the amount of water that was available initially as well as the amount of water that was required in order for the plants to grow. Any numbers can be used for these values, as long as they are equal for both treatments. Also, there are no set units for the water quantities that are available or used, allowing for greater versatility.

The percentage values for these treatments were gathered from a table provided by the Environmental Protection Agency. According to this table, furrow irrigation (listed as "conventional furrow") is 60% efficient and allows for 17.5% of the water used to be recharged into the soil. Similarly formatted information can be collected for drip irrigation; this method is 95% efficient and allows for 1% of its water to be infiltrated. Each row in the table created by the group represents one growing season. For example, at the end of seven seasons, there would be 46.05 units of water infiltrated into the soil using the furrow irrigation method.

Due to the complexity of the research project, assumptions were made about irrigation behavior in an attempt to simplify the processes that were occurring. For example, how or if the runoff from these different methods could be reused in the research project was not considered. This is because it would require a concentrated effort for people to reuse this, and neither the efficiency nor regularity of this reuse method could were to be found. Another assumption was that the data represented in the table were gathered from experiments that were subjected to the same environmental conditions (temperature, soil type, plant type) and were repeatable for an environment similar to Davis, California.

Also left unconsidered were the affects these two methods of irrigation would have on the soils in which they were put into practice. For example, some types of irrigation strategies deposit salts in the soil, causing the field to become infertile. To remedy this phenomena, the field must be flushed with water. Whether or not this could increase the amount of groundwater recharge is unknown.

Our equations for these experiments are listed below:

$$Volume\ Available = 100$$

$$Required\ by\ Plants = 60$$

$$Extra_{farrow} = (0.6 * B2) - 60$$

$$Wasted_{farrow} = B2 - (0.6 * B2) - F2$$

$$Recharge_{farrow} = 0.175 * B2$$

$$Extra_{drip} = (0.95 * L2) - 60$$

$$Wasted_{drip} = L2 - (0.95 * L2) - P2$$

$$Recharge_{drip} = 0.04 * L2$$

Where the values for "Volume Available" and "Required by Plants" are variable from study to study. The results of implementing these experiments can be seen in the tables below.

Calculation/Results

Table 1: Farrow Irrigation After Seven Seasons

Furrow	Volume Avail	Required by I	Extra	Wasted	Infiltrated	Recharge
Season 1	100.00	60.00	0.00	22.50	17.50	17.50
Season 2	117.50	60.00	10.50	26.44	20.56	20.56
Season 3	138.06	60.00	22.84	31.06	24.16	24.16
Season 4	162.22	60.00	37.33	36.50	28.39	28.39
Season 5	190.61	60.00	54.37	42.89	33.36	33.36
Season 6	223.97	60.00	74.38	50.39	39.19	39.19
Season 7	263.16	60.00	97.90	59.21	46.05	46.05

Table 2: Drip Irrigation After Seven Seasons

Drip	Volume Available	Required by Plants	Extra	Wasted	Recharge
Season 1	100.00	60.00	35.00	1.00	4.00
Season 2	104.00	60.00	38.80	1.04	4.16
Season 3	108.16	60.00	42.75	1.08	4.33
Season 4	112.49	60.00	46.86	1.12	4.50
Season 5	116.99	60.00	51.14	1.17	4.68
Season 6	121.67	60.00	55.58	1.22	4.87
Season 7	126.53	60.00	60.21	1.27	5.06

Again, for the sake of this experiment, the units are left off of the values allowing the user of the spreadsheet to tailor the experiment to his or her own study. As shown by the charts, the amount of groundwater that is available after seven seasons of planting is substantially higher while the furrow irrigation method is in use than when drip is used.

Conclusions:

More emphasis needs to be placed on installing the necessary technology in all research sites, and then on as many irrigation districts as possible. From our mass balance model, we are able to infer that ground-water recharge would be greater with furrow irrigation, which is what we assumed. However, there are a great deal of external (possibly negative) effects that were not considered like water quality, nitrates, etc. California's current severe drought makes the issue of groundwater recharge even more relevant and it is imperative to put more focus on considering the questions asked in this study. Without further investigation, issues like subsidence, seawater intrusion, water quality declines, and loss of agricultural yields could become even more prevalent.

Recommendation/Limitations:

Many limitations affect our ability to make specific recommendations, especially tracking water inputs. The data is not there because laws and policies do not require accuracy in reports nor have the tools to enforce that, the tools for measuring inputs are very costly and difficult to install, and many unknowns still exist, like soil factors, ET and runoff (Carrillo-Cobo et. al. 2015). From our findings, we can recommend to scientists to further investigate the inputs and outputs of different irrigation systems, the water quality effects, and other methods of groundwater recharge while policy-makers enforce much stricter reporting requirements on growers. We can also encourage growers to report data to the best of their abilities, as it will not only benefit the research, but ultimately the individual farm's ability to utilize and release clean water.

References:

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