Fate of Precipitation Falling on Oklahoma Cropland

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Precipitation falling to the land surface can be classified into three primary categories: blue water, green water, and white water. As illustrated in Figure 1, blue water flow is that portion of precipitation which runs off or drains through surface soils. Blue water recharges aquifers and rivers and sustains human and ecological water needs. Green and white water flows are consumptive water uses that return to the atmosphere and are lost from the watershed unless re-precipitated. Green water flow is the productive portion of this consumptive use which drives plant growth. White water flow is non-productive evaporation from the land surface.

Oklahoma's Water Budget

Oklahoma receives on average 34 inches of rainfall annually, with a strong gradient of increasing precipitation from the northwest to the southeast. Totaled across our 45 million

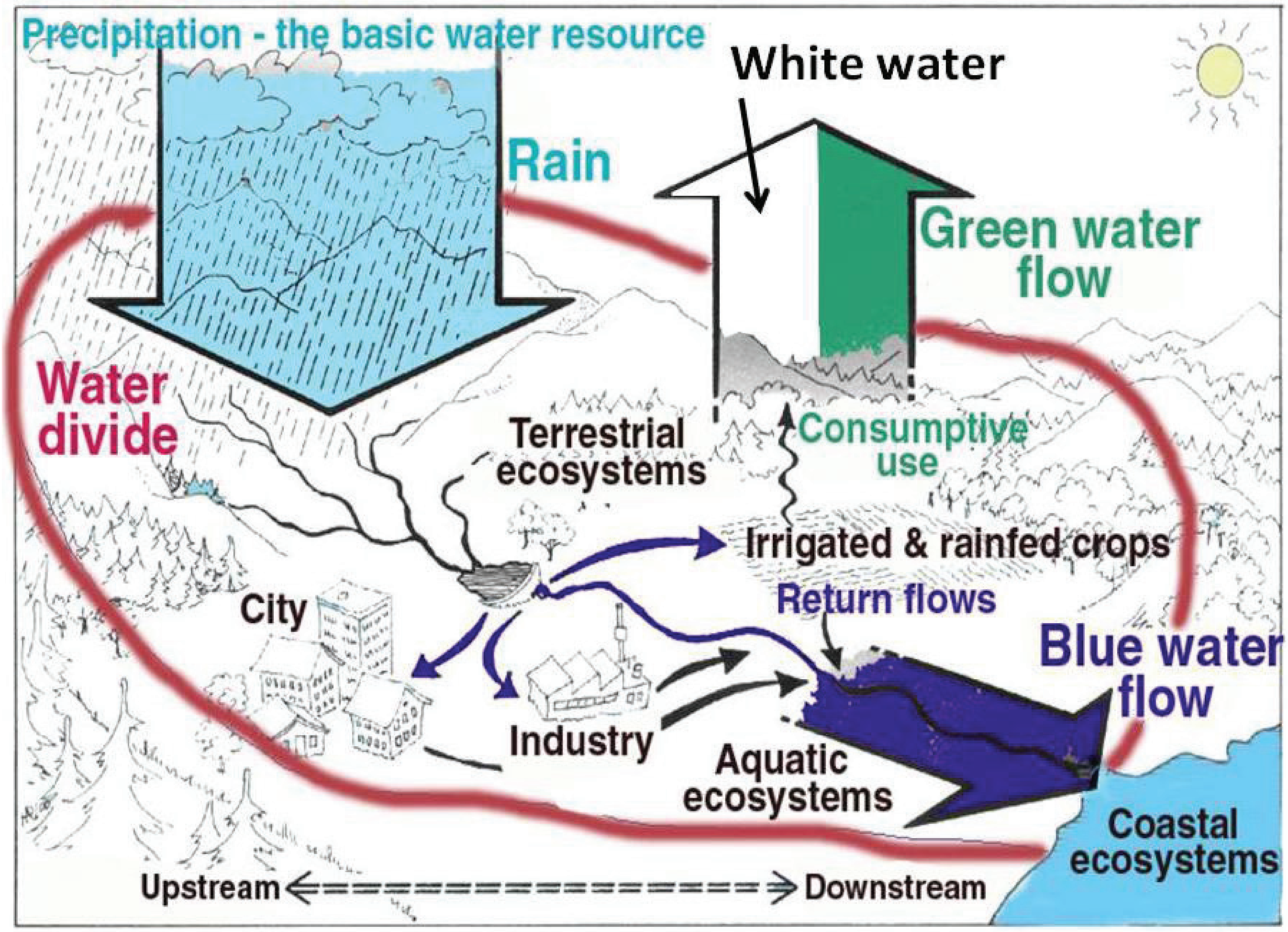

Figure 1: Precipitation is the renewable water resource. It is partially consumed by plant transpiration (green water) and by land surface evaporation (white water). The surplus goes to recharge aquifers and surface water systems (blue water). Adapted from Falkenmark and Lannerstad (2005).

acres this rainfall provides 127 million acre-feet of renewable water annually. This is the state's annual water 'income' and the foundation of the state's water budget.

Some of this rainfall is diverted into our surface waters, either through direct runoff or via discharge from shallow groundwater. This blue water flow supplies important beneficial uses including: maintenance of aquatic and riparian ecosystems; household and industrial water supply; recreation; power generation; irrigation; and transportation of commodities. With the exception of irrigation, these uses are not consumptive. Using annual mean discharge of the Arkansas and Red rivers near the Oklahoma-Arkansas border, and correcting for river inflows at the Kansas and Texas borders, it is estimated that on average, 7.7 inches of Oklahoma's annual precipitation is directed into blue water flow. This represents 23 percent of the Oklahoma's annual water budget.

Nearly all the remaining 77 percent of Oklahoma's annual rainfall returns to the atmosphere through evapotranspiration, which is the sum of green and white water flows. Across Oklahoma's diverse landscape, this consumptive water use accounts for on average 26.3 inches annually. Green water flow (transpiration) is inseparable from plant growth and produces valuable economic and ecological benefits including: crop production and livestock gain; timber production; wildlife habitat; recreation; and soil conservation. The same cannot be said for white water flow (evaporation) where no benefit is realized.

The distribution of precipitation falling onto Oklahoma's cropland into the blue, green and white water flows can have significant impacts on its productivity. The remainder of this fact sheet will focus on how crop management practices influence this distribution. Understanding the interaction between crop management and the movement of water within cropland systems is vital to improving water use efficiency and overall productivity of Oklahoma cropland.

Blue water flow

As mentioned, blue water is generally a small component of the water budget in Oklahoma, accounting for approximately 23 percent of the average rainfall. Blue water flow from cropland is likely larger as a percent of total rainfall in the eastern part of the state, becoming a smaller component farther west.

Blue water flow from cropland can be partitioned into surface runoff and subsurface drainage. Some management strategies aimed at reducing runoff may in turn increase subsurface drainage. Although we perceive a reduction in blue water flow from our cropland, we have simply redirected flow of water from the surface to the subsurface.

Structural alterations such as terraces aimed at reducing water erosion can divert surface runoff to subsurface drainage. Alterations in tillage such as the conversion from conventional tillage to reduced tillage or no-till can result in the diversion of surface runoff to subsurface drainage. Reduced tillage or no-till allows for more crop residue on the soil surface. Crop residue protects the soil surface from raindrops. This prevents surface crusting which can limit water infiltration in conventional tillage systems.

Green and White Water Flow

Green and white water that is transferred to the atmosphere through transpiration or evaporation is a much larger pool of water accounting for 77 percent of the total average rainfall. However, a simple analysis of the water use of crops commonly grown in Oklahoma shows that in general only a small portion of this water is utilized for crop production with the remaining lost as evaporation. To understand the magnitude of the evaporative losses from Oklahoma cropland, we must consider the water use efficiency of the crops grown.

Water use efficiency (WUE) is defined in various ways depending on the context. For the sake of this discussion, we define WUE as the harvestable yield of a crop produced per unit of water transpired. Table 1 shows the 10-year average yields for crops commonly grown in Oklahoma and their estimated WUE. Among the grains, corn and sorghum are most efficient at converting water to crop yield, wheat and rye have intermediate WUE's, and soybean has the lowest WUE. The WUE for a forage like alfalfa cannot be directly compared to the WUE of a grain crop, because less than half of the biomass is harvested in the grain crop. Although, alfalfa has the highest transpiration, the fact that most of the above ground biomass is harvested gives it an intermediate water use efficiency value. In, contrast, the harvested biomass from a cotton plant is relatively low and therefore it has a low water use efficiency.

Using the average yields and the WUE, the amount of water transpired by these various crops was calculated by dividing the crop yield (lbs per acre) by the WUE. This shows that crops commonly grown in Oklahoma use 3.6 to 14.0 inches of water or 11 to 41 percent of the average Oklahoma rainfall (34 inches).

An average wheat crop of 33 bushel per acre transpires 6.2 inches of water or 18 percent of the average rainfall. Recall that on average approximately 23 percent of rainfall is lost from cropland as blue water. **Therefore, roughly 59 percent of the precipitation falling on cropland utilized for continuous winter wheat in Oklahoma is lost as unproductive evaporation.** This evaporative water loss represents inefficient utilization of rainfall in our crop production systems. Of course much of this water loss cannot be avoided because of the nature of Oklahoma's climate. The hot, dry and generally windy summer months of Oklahoma provide ideal conditions for evaporative water loss. However the magnitude of this loss does suggest that controlling evaporative water loss from Oklahoma cropland may provide the greatest opportunity to improve rainfall utilization in crop production systems.

Table 1. Oklahoma 10-year (1997 to 2007) average yields, water use efficiencies (WUE), and annual transpiration estimates for crops representing more than 1 percent of total cropland area.

	Average yield	*Average yield lbs acre^{-1}*	*WUE lbs acre^{-1}inch^{-1}*	*Transpiration inches*
Winter wheat	33 bu	1980	317	6.2
Alfalfa	3.3 tons	6600	473	14.0
Corn	90 bu	5040	580	8.7
Sorghum	45 bu	2520	435	5.8
Soybean	23 bu	1380	240	5.8
Cotton	0.75 bale	360	100	3.6
Rye	20 bu	1120	310	3.6

Controlling White Water Losses

Maintaining crop or residue cover on the soil surface minimizes evaporative water loss from soil. Residues effectively insulate the soil surface and protect it from solar radiation that drives water evaporation. Residue also reduces the wind speed at the soil surface, providing a more humid environment above the soil surface. This humidity at the soil surface also limits water evaporation from the soil surface. This influence of crop residue on evaporative water losses allows for surface soil moisture in no-till soils to be higher than the moisture content of conventional tillage soils.

Figure 2 shows that the soil water storage to 4-foot depth under no-till wheat at Lahoma, OK was consistently 18 percent higher than in conventionally tilled wheat. This greater water storage under no-till results from improved water infiltration and a reduction in evaporative water loss.

In cultivated systems, maintenance of crop residue through reduced tillage practices will also reduce evaporative water loss. However each tillage pass will stimulate evaporative water losses by exposing moist soils to the surface. Tillage practices such as delayed tillage will allow for a greater level of subsurface soil water recharge. Of course, if delayed tillage is followed by intensive tillage for seed bed preparation, the surface soils can be dried significantly prior to planting, and rainfall will be required for crop emergence.

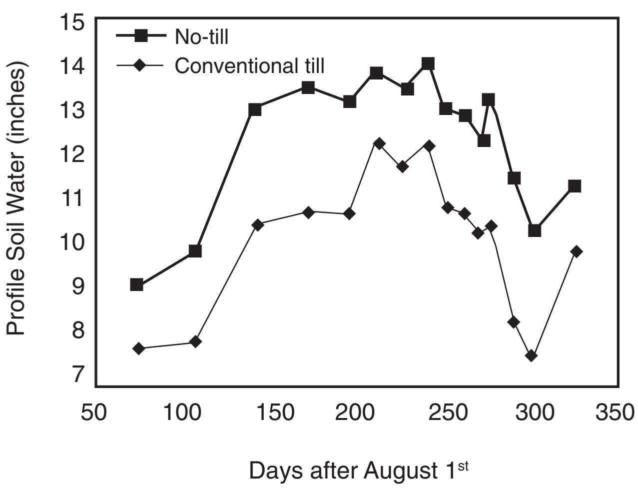

Figure 2: Profile soil water content of No-till and conventionally tilled wheat at Lahoma OK during the 1984-85 growing season.

Maintenance of crop residue on the soil surface is only effective in minimizing white water losses. In order to convert this water to productive green water, crop yields must be increased. In a continuous winter wheat production system this can be done by providing optimum soil fertility and minimizing yield reductions due to disease and pest damage. However, a 20 percent increase in the average Oklahoma wheat yield from 33 to 39 bushels will still only require 7.4 inches of transpiration, which will allow for 18.8 inches or 55 percent of the average annual rainfall to be lost as white water.

Another option to increase transfer of white water flow to the productive green water flow is intensification of the cropping system. This can take on many forms and the success of various crop intensification strategies will depend on site specific weather conditions and soil characteristics. Crop rotations that include three crops in two years have a great deal of potential for central and eastern Oklahoma. However, moving westward producers must be more cautions and may want to utilize less intensive rotations such as four crops in three years.

Conclusion

Oklahoma's climate is ideal for white water losses (evaporation) from cropland, especially during summer fallow periods. White water loss is the single greatest loss of water from Oklahoma cropland and therefore even small reductions in this loss may significantly increase the productivity of our cropland. Maintenance of crop residue will minimize the base evaporative water loss; however, crop productivity must at the same time be increased. This can be done through management practices to improve crop yields or through intensification of the cropping system.

References

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