The Book-keeping Method of Irrigation Scheduling and its use for Turfgrass in Louisiana

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The book-keeping method of irrigation scheduling is based on the application of the water balance equation on a daily basis to the layer of the soil containing the roots of the crop.

The water budget equation for a place and a given time period (daily in this case) and specified depth of soil, is based on the conservation of matter (water) and may be written:

$$P = E + R + \Delta S \qquad \text{--- } 1$$

where P is incoming precipitation, E is evaporation, R is runoff and ΔS is change of soil water[1].

The steps in the method are as follows. First, the field capacity of the effective soil rooting zone is established or a value for this is assumed. The field capacity (or total evaporable water – TEW) is the quantity of water held in the pore spaces of an originally saturated soil after gravity drainage has terminated, and depends upon the depth of the root zone and the soil type. A clay soil can hold more soil water than a sandy soil. The

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[1] A more realistic expression would involve the concepts of effective precipitation, Pe, and evapotranspiration, ET, such that

$$Pe = P – R – Perc$$

where Perc is the amount of water that percolates out of the soil beyond the root zone and evapotranspiration is a combination of evaporation from the soil surface and transpiration from plants. Under these circumstances equation 1 could be rewritten as $\Delta S = P – R – Perc – ET$.

amount of water leaving the soil by evapotranspiration (ET, a combination of evaporation from the soil surface and the transpiration from plants) is estimated on a day by day basis. The amount of water entering the soil by precipitation is monitored[2]. We are interested in the amount of soil water in the soil and available to the roots of the plants on any given day. We are even more interested in soil water deficit i.e. the amount of (irrigation or rain) water required to bring the soil water to its maximum (field capacity) value. In its simplest form, an irrigation schedule involves setting up limits below which the soil water will not be allowed to fall and applying a measured and appropriate amount of water by irrigation to bring the soil water level back to the required level.

The graphs and tables below show how this concept could be applied to the soil in the rooting zone of the grass at Ben Hur Agricultural Station near Baton Rouge for the period June 9 through July 14, 2005. We obtain our rainfall and evaporation data from the Louisiana Agriclimatic Information System (LAIS – see http://www.lsuagcenter.com/weather/ (accessed 11/30/05) and click on Agriclimatic Tools for evaporation and rainfall data). Let us assume that the field capacity of the soil in the soil layers where grass roots penetrate (**the rooting zone or layer**) is 0.5 inches depth of water. We have chosen to begin on June 9 because we can assume the soil is saturated at this time following a period of several days of rain. We keep an accumulative tally of input (rain) and output (ET) for each day subtracting from that starting amount (0.5 inches) the amount of estimated ET and adding any[2] rainfall amount that might occur. When we reach June 12 (Day # 4), the soil water content becomes negative. Since the soil in the rooting layer can not hold less than zero water now (and on future similar

[2] In the simple example described here we will assume that all the rainfall enters the soil. More realistic calculations would involve the use of runoff/rainfall ratios which must be estimated for specific soil types, surface cover, and rainfall intensity. We will suggest how to monitor rainfall later in the discussion.

days) we will reset the soil water content to 0.0 inches and keep it at that point until there is some new input of water. When we get to June 17th (Day # 9) the 0.52 inches of rain that fell this day was not enough to bring the soil water back up to its maximum (because of the loss by ET on that day), but the 2.4 inches of rain that fell on the 18th (Day # 10) was enough to fully replenish the soil moisture. Without any adjustments our calculations would indicate there was 1.59 inches of soil water available on the 18th. But our soil can only hold 0.50 inches (excess rain is assumed to run off across the surface and be lost into nearby drains, rivers and streams, or to deep percolation). So we reset our accumulative tally to 0.5 inches on the 18th and continue our calculations.

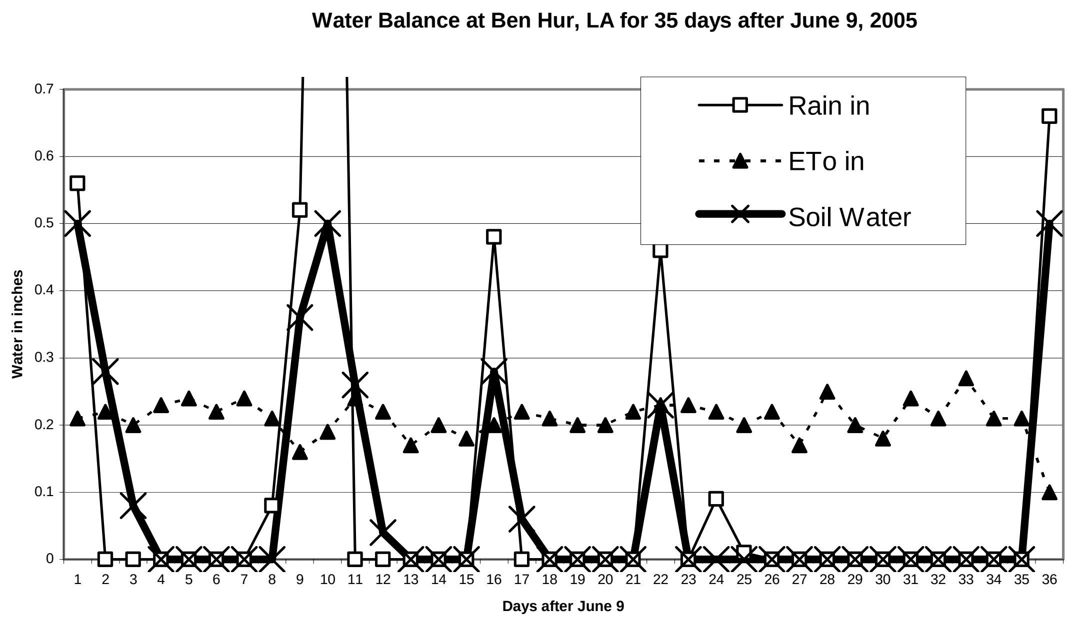
Table 1. Water balance calculations in inches for Ben Hur, La, in the absence of any irrigation.

Date	Day No	Rain in	ETo in	Soil Water
09-Jun	1	0.56	0.21	0.5
10	2	0	0.22	0.28
11	3	0	0.2	0.08
12	4	0	0.23	0
13	5	0	0.24	0
14	6	0	0.22	0
15	7	0	0.24	0
16	8	0.08	0.21	0
17	9	0.52	0.16	0.36
18	10	2.4	0.19	0.5
19	11	0	0.24	0.26
20	12	0	0.22	0.04
21	13	0	0.17	0
22	14	0	0.2	0
23	15	0	0.18	0
24	16	0.48	0.2	0.28
25	17	0	0.22	0.06
26	18	0	0.21	0
27	19	0	0.2	0
28	20	0	0.2	0
29	21	0	0.22	0
30	22	0.46	0.23	0.23
01-Jul	23	0	0.23	0
2	24	0.09	0.22	0

3	25	0.01	0.2	0
4	26	0	0.22	0
5	27	0	0.17	0
6	28	0	0.25	0
7	29	0	0.2	0
8	30	0	0.18	0
9	31	0	0.24	0
10	32	0	0.21	0
11	33	0	0.27	0
12	34	0	0.21	0
13	35	0	0.21	0
14	36	0.66	0.1	0.5

In this example, even despite some significant rainfalls, the soil water (without any irrigation) is at zero for much of the time examined. Grass would be highly stressed without irrigation. The value 0.5 inches minus the values in the Soil Water column indicates how much irrigation water on any give day should be added to bring the soil to it maximum moisture content. A deeper understanding of the situation may be gained by looking at the data presented graphically as follows.

Graph 1. Water balance calculations for Ben Hur, La, in the absence of any irrigation.



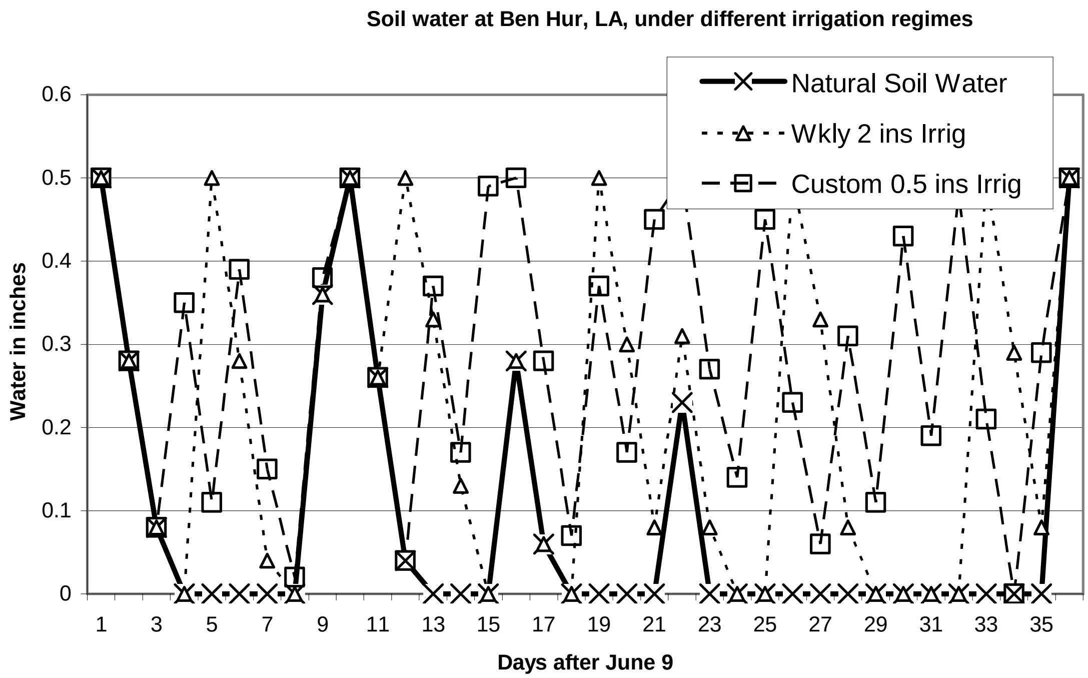
Obviously, in order to keep the grass healthy it would be advantageous to water the turf. But how much water should be applied and when? We will examine two scenarios. In the absence of any water balance concepts we might just decide to water the grass once a week with 2 inches of water. A second scenario would be to irrigate with 0.5 inches of irrigation water every time the soil water would otherwise become less than zero.

So first let us now see what effect the provision of 2 inches of irrigation every Monday (weekly irrigation) would have on the soil water status. In this case (see Table 2) we would have to add our irrigation water to the natural rainfall in order to keep our tally of available soil water. Once more, every time the soil water is calculated as exceeding 0.50 inches we enter 0.50 inches for that day and every day the soil water becomes negative we will set the value at 0.0 inches. With the weekly 2 inch watering regime there are still periods of zero soil water but the periods are not as prolonged as in the “natural” case (Table 2 and Graph 2).

Table 2. Soil water status (in inches) under three different irrigation regimes.

Date	Day No	Natural Soil Water	Irrig Applied	Wkly 2 ins Irrig	Irrig Applied	Custom 0.5 ins Irrig
09-Jun	1	0.5		0.5		0.5
10	2	0.28		0.28		0.28
11	3	0.08		0.08		0.08
12	4	0		0	0.5	0.35
13	5	0	2	0.5		0.11
14	6	0		0.28	0.5	0.39
15	7	0		0.04		0.15
16	8	0		0		0.02
17	9	0.36		0.36		0.38
18	10	0.5		0.5		0.5
19	11	0.26		0.26		0.26
20	12	0.04	2	0.5		0.04
21	13	0		0.33	0.5	0.37
22	14	0		0.13		0.17
23	15	0		0	0.5	0.49
24	16	0.28		0.28		0.5
25	17	0.06		0.06		0.28
26	18	0		0		0.07
27	19	0	2	0.5	0.5	0.37
28	20	0		0.3		0.17
29	21	0		0.08	0.5	0.45
30	22	0.23		0.31		0.5
01-Jul	23	0		0.08		0.27
2	24	0		0		0.14
3	25	0		0	0.5	0.45
4	26	0	2	0.5		0.23
5	27	0		0.33		0.06
6	28	0		0.08	0.5	0.31
7	29	0		0		0.11
8	30	0		0	0.5	0.43
9	31	0		0		0.19
10	32	0		0	0.5	0.48
11	33	0	2	0.5		0.21
12	34	0		0.29		0.00
13	35	0		0.08	0.5	0.29
14	36	0.5		0.5		0.5
		Total	10	Total	5.5	

Graph 2. Soil water in inches for Ben Hur, La, under natural conditions and two different irrigation regimes.



In this last example we used 5 weekly applications of 2 inches each of irrigation water i.e. 10 inches. Could we have used less?

Let us try the second scenario - adding 0.5 inches of irrigation water every time the soil water would otherwise become less than zero (Table 2). Once more, every time the soil water is calculated as exceeding 0.50 inches we enter 0.50 inches for that day. In this case we only used a total of 5.5 inches and the procedure kept the soil fairly moist throughout the period. The line with long dashes and square symbols on Graph 2 always falls within the lower and upper limits of soil water and this shows that custom irrigation keeps the soil fairly moist all of the time – but, of course, the custom regime uses much less water and therefore potentially saves money.

Now these are very simple examples. They raise many questions and contain oversimplifications. The calculations could be improved and made closer to reality in several ways. But the procedure does show a fairly simple way of keeping track of soil moisture and the potential to save money on irrigation water and energy costs. Let us look at some of the questions, oversimplifications, and caveats.

First, how do we know how much irrigation water we are adding? We could place an empty coffee can or similar home-made rain gage, or inexpensive commercially available rain gage, under the sprinkler system and observe when water level in the can reaches a depth of whatever amount of irrigation water we have decided to apply[3].

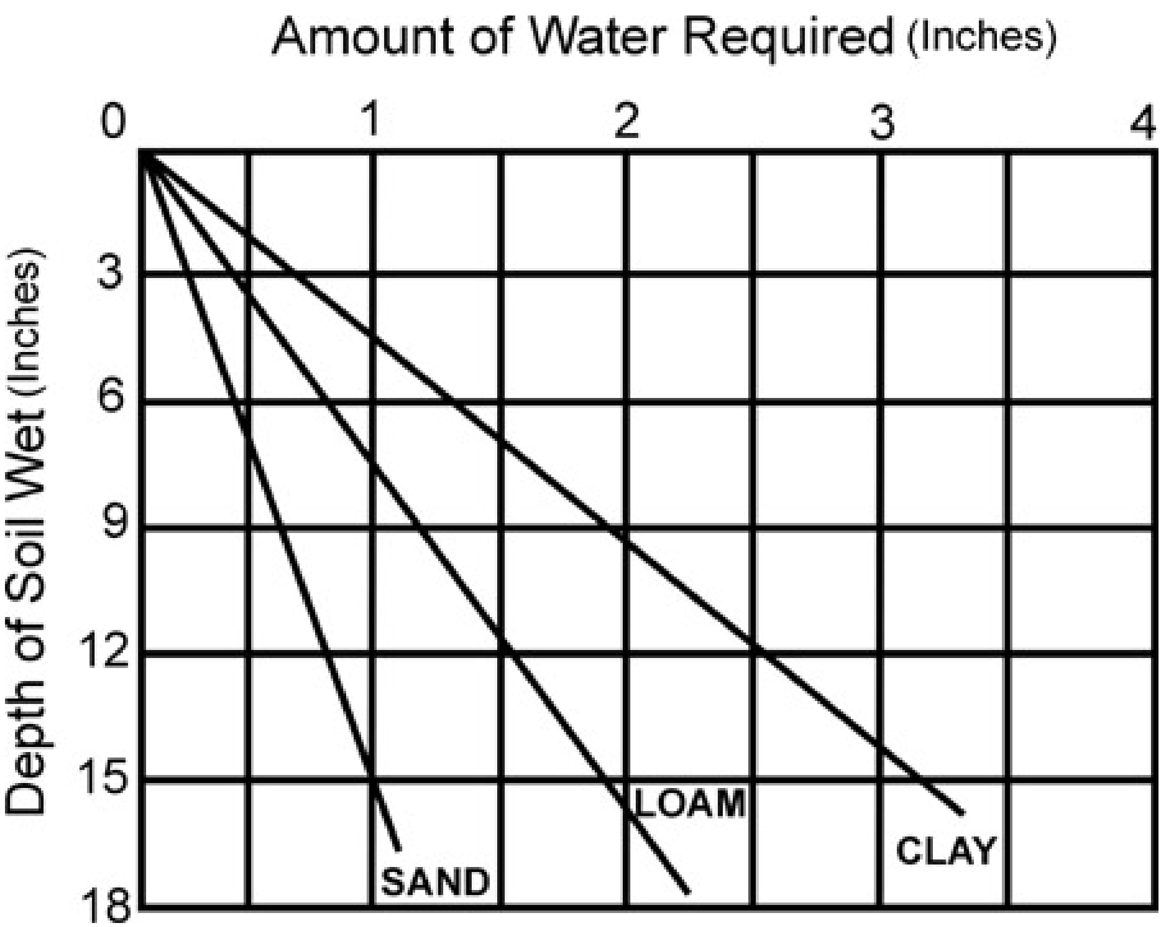
Two other important issues are the estimation of soil field capacity and the assumption that the radiation and rainfall values measured at the locations of the Louisiana Agriclimatic Information System (LAIS) also apply to the specific location of interest. Fortunately, the ET values on LAIS refer to a grass surface and so we do not have to adjust them further (with a crop coefficient) as we might with a crop of larger size such as cotton.

Possibly the most simple way of approaching the field capacity estimation might be to start with assuming it is 0.5 inches and using the system described above for a while and observing if it seems to be working, or over- or under- estimating. Often there are vertical profiles through the grass such as at sand traps on golf courses or the edges of lawns near pathways, where you can see if the soil under the grass is moist or not. A very useful approximate guide to the field capacity of sandy, loamy, and clayey soils of different depths is given in Figure 1 of the Georgia Extension Service document found at

[3] For large areas where flood irrigation is used, the LSU AgCenter is using commercially-available water flow meters to measure water use in flood and furrow irrigation of agronomic crops.

http://pubs.caes.uga.edu/caespubs/pubcd/L399.htm (accessed 01/06/06) and reproduced here with permission as Graph 3 below.

Graph 3. Approximate amounts of water required to bring varying layers of different soil types to their field capacity. *Example:* 1 inch of water will wet a clay soil to more than 4 inches deep, a loam soil to 8 inches deep, and a sand soil to more than 15 inches deep. Alternatively, it takes about 0.2 inches of water to wet the top 3 inches of a sandy soil, while for a loam and clay it takes respectively about 0.45 inches and 0.7 inches. The Graph is reproduced with permission of the Georgia Extension Service.



In addition, Louisiana Extension Agents have access to Natural Resources Conservation Service/LSU AgCenter-generated parish soil surveys which give soil property values for various locations in their parishes. These surveys often give data on available water capacity in inches/inch(depth) for various soil horizons for each soil[4]. A scientific method of estimating the soil field capacity is to take several samples of the soil the day after a major rainfall or irrigation event, place the soil in metal containers, and dry the soil in a laboratory oven (don't try this at home – never put metal in a microwave oven!) and weigh the soil sample(s) before and after drying. The difference in weight gives the water lost (and formerly contained) from the weight of the soil sample. The final value has to be adjusted to one cubic inch of volume of soil, so that the value relates to the depth of water in the soil sample[5].

Spatial variability of solar radiation (upon which the ET estimates are very dependent) and rainfall are also potential problems. Summer rainfall in Louisiana is very "spotty". The values of rainfall from rain gage measurements may not be valid for locations more than ¼ mile away from the point where the rain gage is located. Not much can be done about this unless the user makes measurements of local rainfall and substitutes these local values in the calculations instead of using the LAIS values. The same coffee-can irrigation amount measurers could serve also as rain gages and provide local data. Solar radiation receipt at the surface strongly depends on local cloud cover and the slope of the land. The ET estimates given here are for a horizontal surface at the LAIS

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[4] A listing of Louisiana soil surveys and their general availability status is given at http://soils.usda.gov/survey/printed_surveys/louisiana.html (accessed 11/30/05)

[5] Precise methods of determining the amount of water in a soil using this drying approach is provided in a Purdue University laboratory exercise at http://pasture.ecn.purdue.edu/~eql/Gravimetric.doc (accessed 11/30/05)

observing site. A north facing slope would have much less and a south facing slope would have much more radiation. Areas shaded by buildings and vegetation also would have less radiation.

Another incorrect assumption made in the above calculations is that the loss of water by evapotranspiration is always at the rate shown in the calculation, i.e. the maximum rate for that day. In reality, if the soil water is below its field capacity, some lesser rate of evapotranspiration will occur. This lesser rate is determined by the drying curve applicable to a particular soil and the ability of the plant roots to access the water and use it. In similar vein, the proportion of rainfall that runs off from the surface of the soil when large rainfalls occur also, to some degree, depends on the soil type. There are numerous steps one could take in order to obtain more accurate estimates of required irrigation amounts. For more detail one could consult the following web document http://www.fao.org/docrep/X0490E/x0490e0e.htm#chapter%208%20%20%20etc%20under%20soil%20water%20stress%20conditions (accessed 11/30/05). The Extension Services of other states have also addressed the issue. See for example suggestions from the Florida Extension Service at http://edis.ifas.ufl.edu/AE111 (accessed 11/30/05). As with most things, there exists a large amount of published research on the topic of estimating irrigation needs and their scheduling. The above approach is meant to be a first, and as simple as possible, step.

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