Infiltration and Surface Hardness at 21 Acres Farm

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**Abstract:**

Irrigation at 21 Acres Farm has been accomplished in the past through a combination of private well water and city water. In an effort to conserve water resources, it is important for farm management to understand how well the land is using the water it is fed. Measurements of infiltration and surface hardness can be one means to understanding. After taking a number of measurements throughout the farm we found the mean infiltration rate to be 1.09 cm/min with a standard deviation of ±4.61 cm/min. Field conditions varied widely throughout the farm, leading to high variability amongst the readings. No correlation was evident between surface hardness and infiltration rate. Measurements taken during the growing season may prove to be a more accurate indicator of actual irrigation needs.

**Introduction:**

The ability of 21 Acres to irrigate their crops in the most efficient way can critically affect the operating costs of the farm. The farm has one well capable of extracting 5000 gallons of ground water per day. During the growing season this is not enough to meet watering demands with current practices. Once their quota is used up the farm must buy water from the city (Muehleisen 2010). With the added cost of city water, it is important to make sure the water is being applied effectively, without waste. In order to develop a more efficient irrigation plan, it is important to understand soil properties such as infiltration and compaction (Arriaga et al. 2010).

In addition to determining irrigation needs, infiltration is also a key factor in delivering nutrients to the plants. The nutrient’s ability to penetrate the soil drastically affects the field’s ability to retain them. Without good infiltration, many of these applied nutrients will end up in runoff instead of plant roots (Brooks et al. 2003). Infiltration is the first line of defense against surface water pollution, which may be a concern to 21 Acres due to their proximity to the Sammamish River.

The ability of water to penetrate soil is contingent upon many factors such as texture, pore size, vegetation, organic matter content, surface conditions, and land use (Brooks et al. 2003) to name only a few. Some of these have been investigated by other groups. Our focus was solely on the rate at which water entered the soil and the compaction readings associated with each rate. We examined infiltration rates using a flooding-type, double-ringed infiltrometer. A penetrometer was also used to judge surface hardness at the infiltration measurement locations.

With this infiltration and compaction information 21 Acres will be able to more accurately assess their irrigation needs. Since its start, 21 Acres has been known as a place that leads by example. This will be an added educational resource for the community. How to manage irrigation properly is a lesson that will go a long way towards a more sustainable future.

**Methods and Materials:**

The equipment used to gather surface hardness readings was a Geotest pocket penetrometer, which measures hardness in kilograms per square centimeter of the top ¼” of soil. We also used a Turf-Tec double ringed infiltrometer equipped with a timer, which measures the infiltration rate of water into the soil in millimeters per minute. Infiltration readings were later converted into centimeters per minute prior to our analysis.

A total of 39 locations were chosen in twelve different fields. Two fields were much bigger than the others, so they were further sub-divided into two fields. Test sites within each field were chosen by dividing the field into even portions and locating plots across irrigation lines rather than down the rows. Different numbers of infiltration readings were taken from each field depending on the size and layout. At each location, five penetrometer readings were taken at random from within two feet of the infiltrometer.

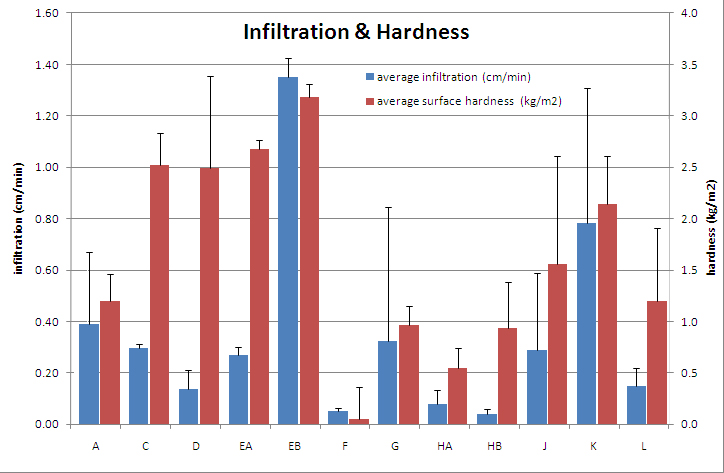
Once a flat area was found at each site the infiltrometer was inserted into the soil until the horizontal flange was even with the plane. Both inner and outer rings were then filled with water. The height of the needle was noted since the device did not register zero when the reservoir was full. The timer was then set to run at ten minute intervals. The type of measurement taken was a falling head measurement. In a few instances the reservoir drained before the ten minutes was up and needed to be refilled. In this situation the level was noted, and then the device was refilled to finish the time interval. Penetrometer readings were then taken around each site by inserting the device about ¼” into the ground, perpendicular to the soil surface.

Readings were taken on three days in February and one day in March under varying weather conditions. Conditions on the day of and the days leading up to visits were noted in the event that they affected our readings.

**Results:**

The total average infiltration rate from the 12 fields was 1.09 cm/min with a standard deviation of ±4.61 cm/min. Our results are further broken down in figure 1 which shows the average infiltration rates and surface hardness for each field. Eleven of the twelve fields had an average of less than .080cm/min. The remaining field (EB) had the highest rate at 96% greater than field HB with the lowest infiltration rate (Figure1). Within field K, two of the test plots had 83.6 % higher infiltration than the third. The average infiltration rate in field J was 0.29 cm/min, however, the readings ranged from .08 to 0.50 cm/min.

Eleven of the twelve fields had an average surface hardness measurement that was less than 3.0 kg/m2. Surface hardness in field F was 98.4% less than the highest reading in field EB, which also had the highest infiltration rate. (Figure1). Fields EA, C, and D had the highest compaction readings after EB, measuring between 2.50 and 2.68 kg/m². However, their infiltration rates were markedly lower than EB, measuring below 0.295 cm/min.



**Figure 1.** Average infiltration rate and surface hardness measured in 12 different fields on February 15, 20, and 26, and March 1, 2010 from 21 Acres Farm, in Woodinville, WA. Means and sample sizes vary for each field. (See Tables 1 & 2 in Appendix)

**Discussion:**

Mean soil infiltration rates were lowest in fields F, HA, and HB. Fields F and HB had been previously tilled and HA had a young cover crop of rye grass indicating that it may have also been tilled. HA had the highest infiltration and highest compaction of the three, which seemed contradictory to what we expected. Additionally, the soil in all 3 fields may have already been saturated by heavy rains the night before, leading to lower than normal readings.

Although these three fields had the lowest mean readings, it should be noted that field G had one reading of 0mm, which could account for the high standard deviation in this field and may be of some concern for irrigation purposes. Weather conditions were drizzly and wet on the day of and the days leading up to the reading, so the soil may have already reached capacity by the time we took the reading.

The fields with the highest infiltration rates were EB and K. Of the two, EB was much higher. Field EB had been tilled and had full vegetation, while field K had previously been used as a chicken coup and was largely abandoned at the time of the readings. Rain was noted on the days leading up to both readings. It could be expected to see low infiltration after rainfall, but both the 2 highest and the 3 lowest readings occurred after days of rainfall, indicating that other factors are influencing the rates.

Overall we found no correlation between surface hardness and soil infiltration rates (Figure 2), which was contrary to what we expected. The high rate of infiltration in field EB seemed an anomaly when compared to all other readings. However, it is extremely difficult to read these instruments incorrectly, so the anomaly was probably not the result of user error. Mathematical errors cannot be counted out, though.

**Figure 2.** Average infiltration rate and surface hardness measured in 12 different fields on February 15, 20, and 26, and March 1, 2010 from 21 Acres Farm, in Woodinville, WA. Means and sample sizes vary for each field. (See Tables 1 & 2 in Appendix)

**Conclusions:**

Based on these findings, there is high variability in soil infiltration at 21 Acres. Comparison of these results to those of the soil hydraulic qualities group may illuminate things more. Our study was limited by time and schedule availability. We suggest that a longer term, more controlled study be undertaken in the future. Such a study should take infiltration readings during the actual growing season, when rain is scarcer. We believe this would alter the findings significantly. More accurate readings could be obtained by taking sustained readings of hour-long, instead of ten-minute intervals.

**References:**

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**Appendix:**

**Table 1.** Average Infiltration rate\* and Surface hardness\*\* measured at 12 different

fields on February 15, 20 and 26, and March 1, 2010 at 21 Acres Farm, in

Woodinville, WA. Sample size varies for each field. (See Table 2)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Infiltration rate (cm/min) | | | | Surface Harness (kg/m2) | | |
| Date | **plot #** | **Mean** |  | **SD** | **Mean** |  | **SD** |
| 3/1/10 | A | 0.39 | ± | 0.28 | 1.2 | ± | 0.26 |
| 3/1/10 | C | 0.295 | ± | 0.02 | 2.53 | ± | 0.310 |
| 3/1/10 | D | 0.138 | ± | 0.08 | 2.50 | ± | 0.892 |
| 3/1/10 | EA | 0.27 | ± | 0.03 | 2.68 | ± | 0.082 |
| 3/1/10 | EB | 1.35 | ± | 0.07 | 3.18 | ± | 0.126 |
| 3/1/10 | F | 0.053 | ± | 0.01 | 0.05 | ± | 0.311 |
| 2/20/10 | G | 0.323 | ± | 0.52 | 0.96 | ± | 0.190 |
| 2/15/10 | HA | 0.08 | ± | 0.05 | 0.54 | ± | 0.196 |
| 2/15/10 | HB | 0.04 | ± | 0.02 | 0.93 | ± | 0.454 |
| 2/26/10 | J | 0.29 | ± | 0.30 | 1.56 | ± | 1.047 |
| 2/20/10 | K | 0.78 | ± | 0.52 | 2.14 | ± | 0.467 |
| 2/26/10 | L | 0.15 | ± | 0.07 | 1.20 | ± | 0.707 |

**Table 2.** Individual infiltration readings and mean surface

hardness per test plot. \*(n=5 per plot)

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| Date | **Plot #** | **Infiltration (cm/min)** | **Surface Hardness (kg/m²) Mean\*** |
| 2/20/10 | A1 | 0.30 | 1.0 |
| 2/20/10 | A2 | 0.17 | 1.10 |
| 2/26/10 | A3 | 0.70 | 1.50 |
| 3/1/10 | C1 | 0.29 | 2.92 |
| 3/1/10 | C2 | 0.28 | 2.58 |
| 3/1/10 | C3 | 0.29 | 2.42 |
| 3/1/10 | C4 | 0.32 | 2.18 |
| 3/1/10 | D1 | 0.03 | 1.40 |
| 3/1/10 | D2 | 0.2 | 3.42 |
| 3/1/10 | D3 | 0.18 | 2.98 |
| 3/1/10 | D4 | 0.14 | 2.18 |
| 3/1/10 | EA-1 | 0.28 | 2.58 |
| 3/1/10 | EA-2 | 0.24 | 2.68 |
| 3/1/10 | EA-3 | 0.31 | 2.78 |
| 3/1/10 | EA-4 | 0.25 | 2.68 |
| 3/1/10 | EB-1 | 1.27 | 3.26 |
| 3/1/10 | EB-2 | 1.36 | 3.02 |
| 3/1/10 | EB-3 | 1.44 | 3.14 |
| 3/1/10 | EB-4 | 1.31 | 3.3 |
| 3/1/10 | F1 | 0.05 | 1.16 |
| 3/1/10 | F2 | 0.04 | 1.68 |
| 3/1/10 | F3 | 0.07 | 1.38 |
| 3/1/10 | F4 | 0.05 | 1.86 |
| 2/20/10 | G1 | 0.05 | 0.95 |
| 2/20/10 | G2 | 0.92 | 0.78 |
| 2/20/10 | G3 | 0 | 1.16 |
| 2/15/10 | HA-1 | 0.12 | 0.75 |
| 2/15/10 | HA-2 | 0.10 | 0.52 |
| 2/15/10 | HA-3 | 0.02 | 0.36 |
| 2/20/10 | HB-1 | 0.04 | 0.6 |
| 2/20/10 | HB-2 | 0.02 | 0.75 |
| 2/20/10 | HB-3 | 0.06 | 1.45 |
| 2/26/10 | J1 | 0.08 | 2.3 |
| 2/26/10 | J2 | 0.50 | 0.82 |
| 2/15/10 | K1 | 0.92 | 2.02 |
| 2/15/10 | K2 | 0.20 | 1.75 |
| 2/20/10 | K3 | 1.22 | 2.66 |
| 2/26/10 | l1 | 0.10 | 0.7 |
| 2/26/10 | l2 | 0.20 | 1.7 |

**Table 3.** Documented weather conditions on days of infiltration and surface hardness

readings. Also included are weather conditions for the 2 days prior to each reading.

From <http://www.beautifulseattle.com/mthsum.asp>

|  |  |  |  |
| --- | --- | --- | --- |
| Date | Temperature | Weather | Precipitation |
| 2/13/10 | 53-45 degrees F | cloudy, rain | 0.20 inches |
| 2/14/10 | 53-42 degrees F | cloudy, rain | 0.42 inches |
| 2/15/10 | 55-37 degrees F | partly cloudy, rain | 0.07 inches |
| 2/18/10 | 59-39 degrees F | sunny | 0.00 |
| 2/19/10 | 59-39 degrees F | sunny | 0.00 |
| 2/20/10 | 57-39 degrees F | sunny | 0.00 |
| 2/24/10 | 51-42 degrees F | cloudy, rain | 0.33 inches |
| 2/25/10 | 54-44 degrees F | mostly cloudy, rain | 0.05 inches |
| 2/26/10 | 52-46 degrees F | cloudy, rain | 0.44 inches |
| 2/27/10 | 54-46 degrees F | cloudy, rain | 0.44 inches |
| 2/28/01 | 56-46 degrees F | cloudy, rain | 0.44 inches |
| 3/01/10 | 57-42 degrees F | cloudy | 0.00 |