# Recharge assignment

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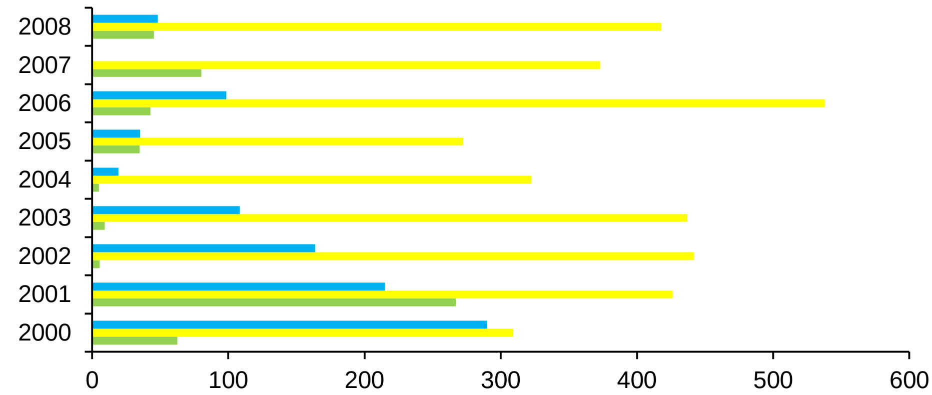
**a) Why do you think we opted for a daily time step in the model instead of a monthly time step? What could be the problem of calculating recharge using a monthly water balance?**

The daily step is more suitable for the scale of the progress, which is described by this model than the monthly time step. The time scale of the important process in this model is on a small scale, such as precipitation, evaporation, and infiltration. These factors can change dramatically in a short period of time, so if using monthly data, many parts of the changes such as the change of infiltration are implicit, not be shown. In conclusion, it is obvious that using a daily step can get more accuracy and realistic result. Of course, daily data will also increase the amount of calculation. However, these calculations are done by the computer repeated calculations, will not add too much burden to the computer.

When using a monthly water balance, the change of soil moisture is neglected. The influence of rainfall intensity and change of daily evaporation also are neglected. So we will ignore some important processes in the water balance and get an inaccurate result of recharge.

**b) Calculate the annual runoff, actual evapotranspiration (ET), and recharge for the period of 2000-2008 under natural conditions (i.e., no irrigation), in mm/a (using no decimals) and as % of rainfall (using one decimal). Do this by entering the necessary data into the spreadsheet model and using the default parameters. Group the data using a Pivot table in Excel (already provided, but you need to refresh the results every time you change the input). Present the values in a table and a bar diagram (one graph for all three parameters in mm/a vs. time). Give some general observations of the temporal distribution of the three parameters.**




| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|
| Recharge | 289.8 | 214.8 | 163.8 | 108.3 | 19.2 | 35.3 | 98.5 | 0.0 | 48.2 |
| Actual Evapotranspiration | 309.0 | 426.1 | 441.7 | 436.9 | 322.5 | 272.4 | 537.8 | 372.9 | 417.7 |
| Runoff | 62.5 | 267.1 | 5.5 | 9.2 | 4.9 | 34.7 | 42.8 | 80.2 | 45.3 |

*Figure b Recharge, actual evapotranspiration, runoff versus time*

The peak of recharge occurred in 2000 with a high value of 289.9 mm/year followed by a significant annual decline until 2004 with a low value of 19.2 mm/year. And then recharge increased in 2005 and 2006. 2007 was the extreme year when there was no recharge in the whole year, and again in 2008, there was a small amount of recharge.

The interannual variation of actual evapotranspiration is not very dramatic relative to the other two factors. The peak was 537.8 mm/year in 2006, the two low value was in 2004 (272.4 mm/year) and 2000 (309 mm/year), and the evapotranspiration of rest years were around 400.

The annual variation of runoff is very large. The peak was 267.1 mm/year in 2001, three times the second-highest in 2007 (80.2 mm/year). There were continuous dry years for the surface stream from 2001 to 2007, and the runoff depth was less than ten during the three years from 2002 to 2004. In 2000 and 2008, the recharge was around 50.

**c) Assess the correlation between annual rainfall and recharge (both in mm) in a graph. What does it tell you? What is the minimum rainfall needed to produce recharge according to this relationship? Provide one possible explanation for each of the outliers between 2000 and 2007.**

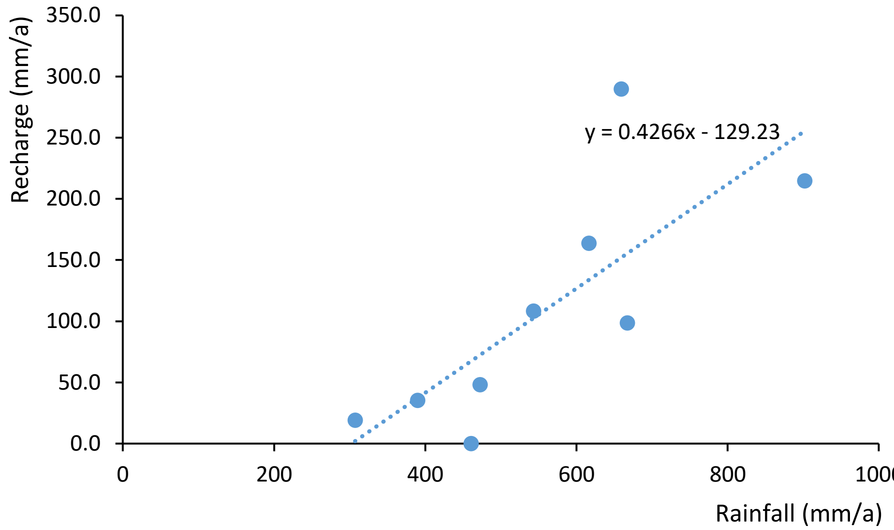



*Figure c Relationship between rainfall and recharge*

We can get the correlation between annual rainfall and recharge. The recharge is proportional to the rainfall. This is consistent with our basic understanding.

Due to the trendline and the function y=0.4266x-129.23, rainfall is equal to 303 mm/year when the recharge is equal to 0. So the minimum rainfall need to produce recharge is 303 mm.

There are two possible reasons for the occurrence of the extreme situation in 2007. The first reason is that although the total amount of rainfall is larger than the minimum rainfall needed to produce recharge, the rainfall may be relatively dispersed, causing soil moisture always to fail to reach the field capacity and produce supply. The second reason is that there is less effective rainfall, which is the real cause of groundwater recharge. The rainfall with a short duration of rain and strong intensity is much, resulting in a decrease of effective precipitation. It may also be the reason for the whole year of 2007 without a recharge.

We use calendar years to analyze the relationship between rainfall and recharge, not hydrological years. It is obvious that the relationship between rainfall and recharge in hydrological years will be stronger and more regressive. This is another reason for the extremes of 2000 and 2007.

**d) Next, assess the correlation between monthly rainfall and recharge in a graph. What is the minimum monthly rainfall needed to produce recharge according to this relationship? Why are there some months of rainfall higher than 100 mm that do not produce recharge?**

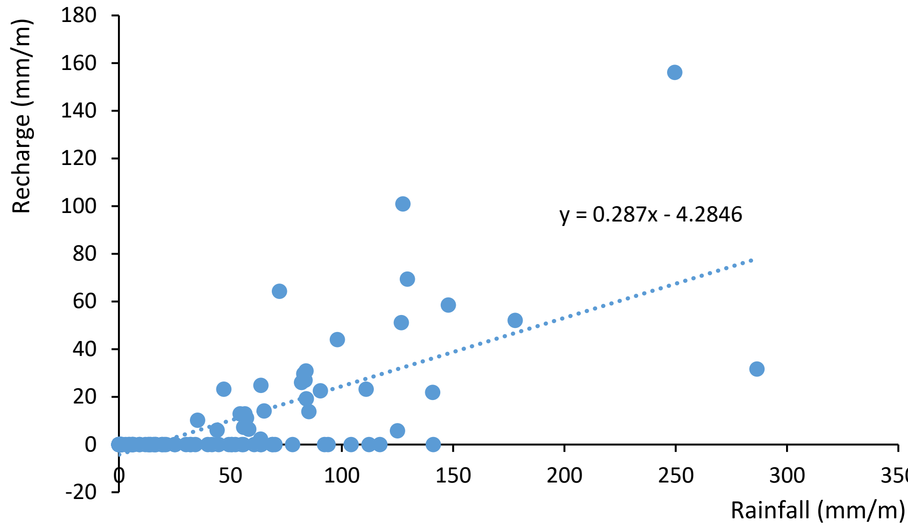



*Figure d Relationship between monthly rainfall and recharge*

Due to the trendline and the function $y = 0.278\text{x} - 4.2846$, rainfall is equal to 14.9 mm/month when the recharge is equal to 0. So the minimum monthly rainfall need to produce recharge is 14.9 mm.

We can get the date that rainfall is higher than 100 mm but doesn't produce recharge (Table ? ). There are two possible reasons for the situation of no recharge for high rainfall. The first reason is the lack of moisture. These four months all are at the beginning of the hydrologic year, which means it is at the end of the dry season. In the months leading up to these four months, rainfall has been very low. Because of the low moisture, the water infiltrating into the subsurface zone is stored and can't get the water table. This is the general reason for no recharge. The second reason is specific to these four months. When the rainfall intensity is greater than the runoff threshold, some rainfall produces runoff directly. For these four months, all of them have day rainfall is larger than the runoff threshold (30mm) (i.e., 22/09/2001 72.8mm). The effective rainfall is equal to the actual rainfall minus runoff. In other words, for these months, the effective rainfall is not larger than 100 mm/month. This is another reason for no recharge.

*Table d Rainfall over 100 mm with no recharge*

| Date | Rainfall(mm) | Recharge(mm) |
|---|---|---|
| Sep/01 | 117.1 | 0.0 |
| Oct/03 | 104.2 | 0.0 |
| Oct/06 | 141.1 | 0.0 |

| | | |
|---|---|---|
| Dec/07 | 112.2 | 0.0 |

**e) Now add irrigation to the calculations and compare the annual values of recharge and actual ET to those calculated under natural conditions (question b). Briefly explain the observed differences in recharge and actual ET.**

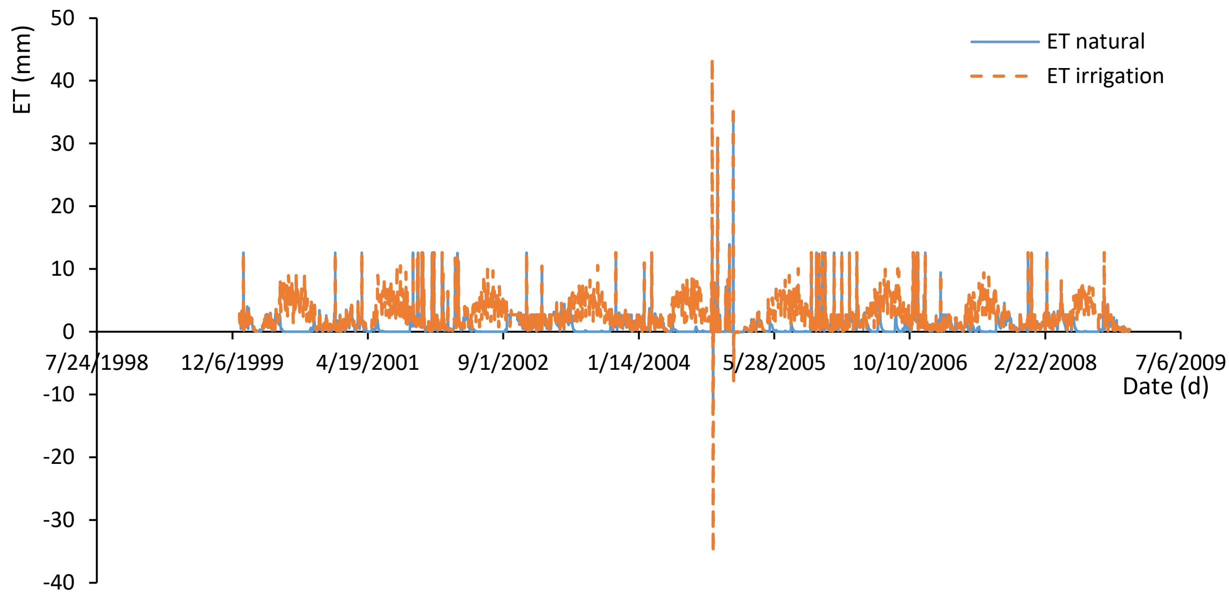



*Figure d.1 ET natural and ET irrigation for the long period*

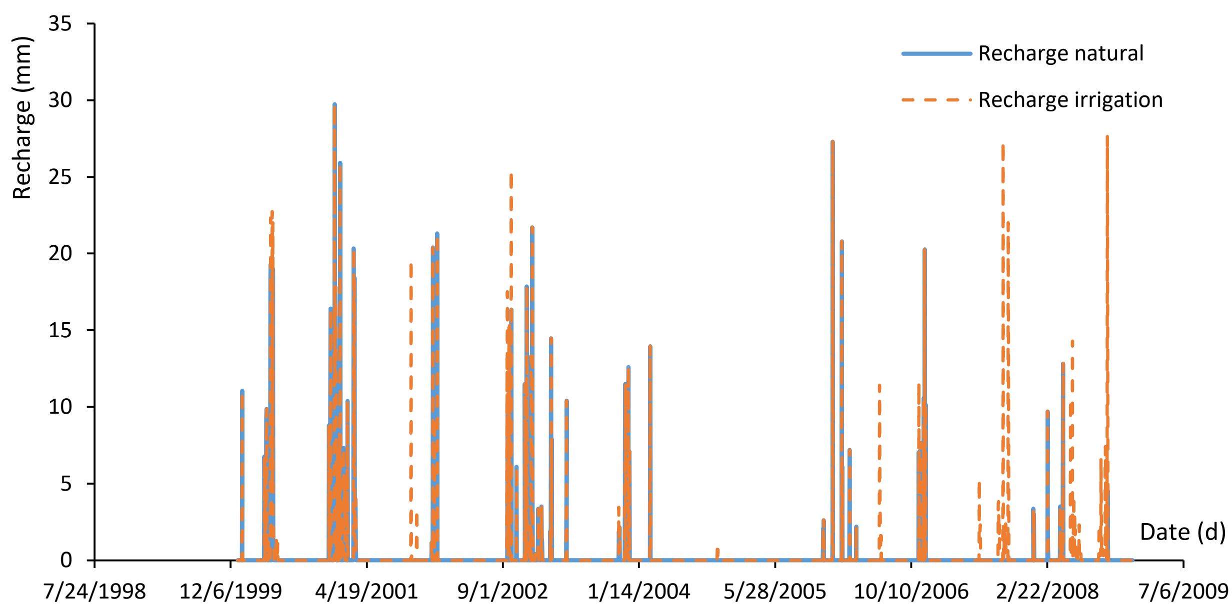



*Figure d.2 Recharge natural and recharge irrigation for a long period*

After irrigation, evapotranspiration and groundwater recharge are both increased than under natural conditions. It can be seen that evapotranspiration increases significantly in the dry season, and the image of groundwater recharge also shows that recharge occurs at times that are not recharged under natural conditions. The sum of both differences in total evapotranspiration (5357 mm) and recharge (410 mm) is almost equal to the water of irrigation (5787 mm). This indicates that the increased evapotranspiration and groundwater recharge are from irrigation. Irrigation increases the soil moisture in the root zone and the supply to the soil, so that moisture is always higher than the natural condition, so the actual evaporation is closer to the potential evaporation. Similarly, the increase of soil water content leads to the recharge of rainfall, which cannot produce groundwater recharge under natural conditions, so the groundwater recharge also increases.

**f) Going back to the original model (without irrigation), change the available moisture in the soil at field capacity to 25% of total volume. What could this indicate regarding soil characteristics? Recalculate recharge and actual ET and briefly explain the results.**

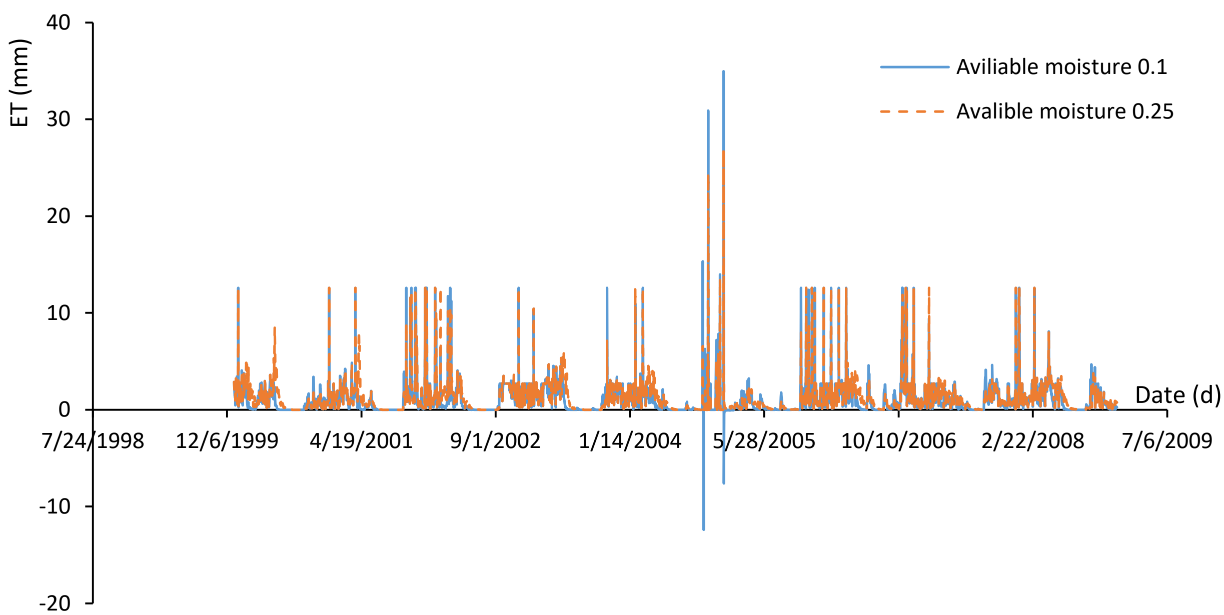



*Figure f.1 ET with different available moisture*

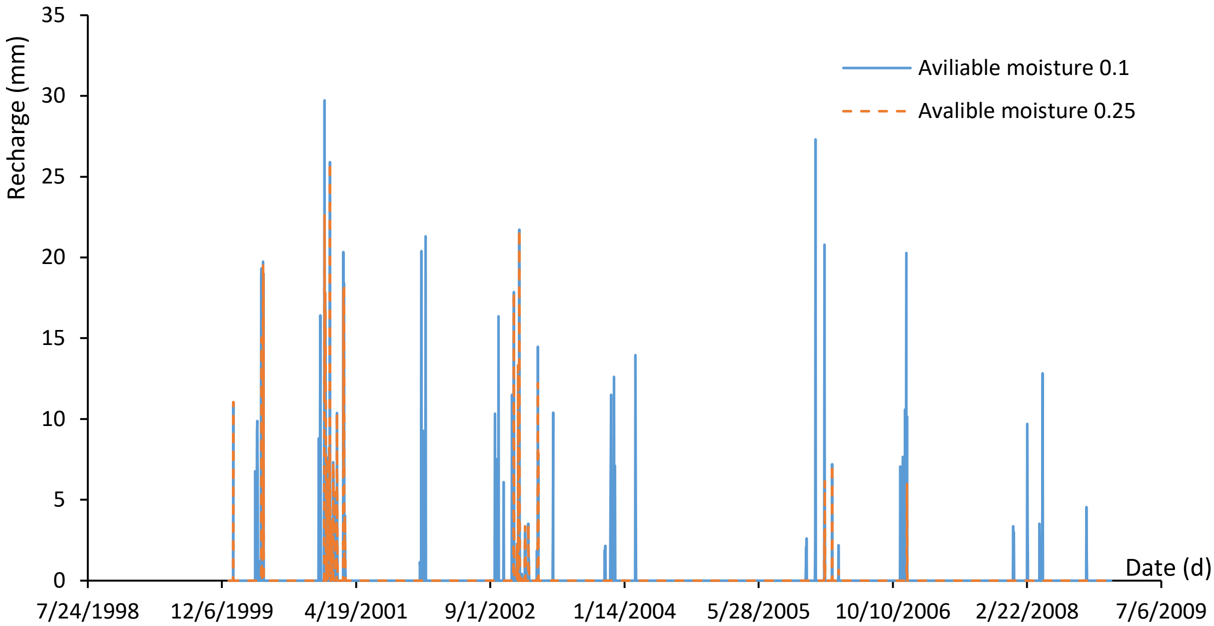



*Figure f.2 Recharge with different available moisture*

Field capacity represents the moisture of the soil after drainage of the water contained in the macropores by gravity action. It can reflect the water capacity of the soil and is the upper limit of soil water available to most plants. This parameter can be used to calculate the maximum available soil moisture. The value of 0.25 is better than 0.1 because 0.25 means the soil can hold more water.

With the increase of field capacity, the amount of evaporation increased, but the peak value decreased obviously. Therefore, water deficit declines. As can be seen from the diagram of recharge, a significant decrease in recharge is due to the increased water-holding capacity of the soil, with more water stored in the soil rather than percolating into the groundwater.

**g) Assess the correlation between annual rainfall and newly calculated recharge by adding the data to the graph of question c. What does it tell you? Has the minimum annual rainfall needed to produce recharge changed in the new situation? Why (not)?**

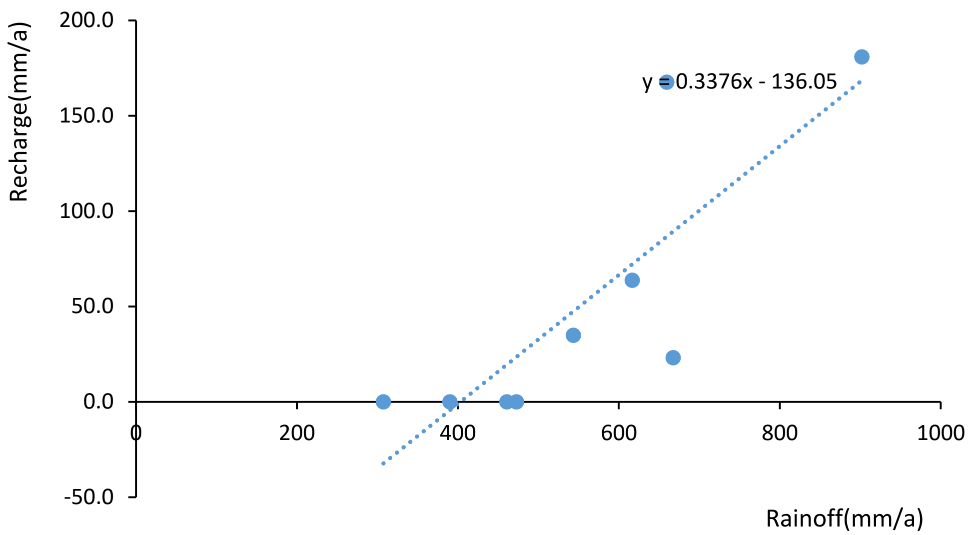



*Figure g Recharge with different available moisture after changing field capacity*

From the figure, we can see that there are more years without groundwater recharge, and the relationship between rainfall and recharge is consistent with the trend in question c. The minimum annual rainfall needed to produce recharge has increased in the new situation (from 303 mm to 403 mm). With the field capacity increasing from 0.1 to 0.25 and the depth of soil keep constant (50 cm), the maximum moisture increase from 50mm to 125mm. More precipitation is stored in the root zone rather than percolating into the groundwater, so it takes more rain to recharge the groundwater.

**h) For a clay the available moisture at field capacity (field capacity minus wilting point) can also be 10%, due to a high wilting point. This parameter would therefore remain unchanged with respect to the original model. Notwithstanding, clay has a much lower infiltration capacity than sand. What other parameter can you change in the original model to account for this?**

Runoff threshold.

The lower infiltration capacity means that it is harder to seep in during rainfall and more likely to produce runoff, so the runoff threshold should be smaller.

**i) Decrease the parameter found in question h) by a factor 3 and recalculate recharge. Assess the correlation between rainfall and newly calculated recharge by adding the data to the graph of question g. Briefly explain the results.**

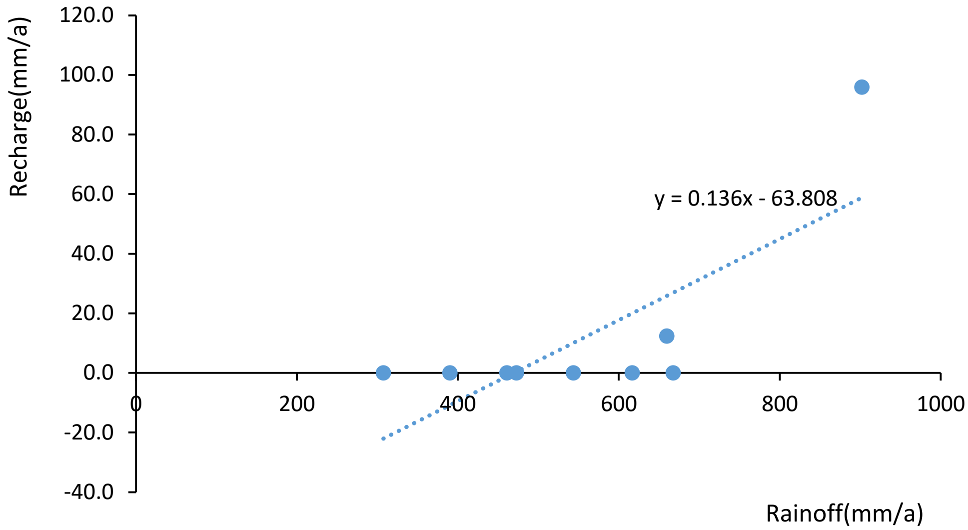



*Figure i Recharge with different available moisture after changing runoff threshold*

More years without groundwater recharge occurred relative to question g. The minimum rainfall needed to produce the recharge also increased. This is because the rate of infiltration is slow, resulting in more rainfall to form runoff rather than infiltration into the soil. On the other hand, an increase in the runoff threshold means a decrease in the maximum effective rainfall, which is the only source of groundwater recharge.

**j) Going back to the original model (question b), change the depth to the root zone to 1 m and the extinction depth to 2 m. When could this be the case? Calculate the annual recharge from rainfall (Qprec), net recharge (Qprec - Qcap), and actual evapotranspiration and compare with the original values (of question b). Briefly explain the results.**

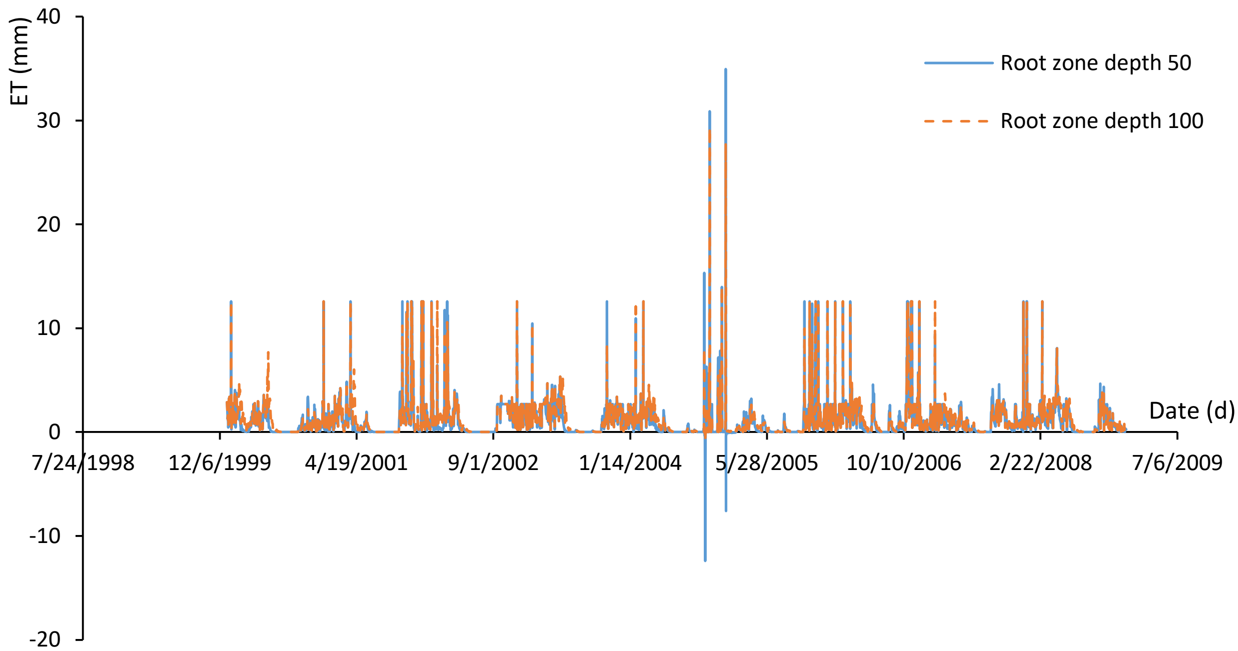



*Figure j.1 ET with different root zone depth*

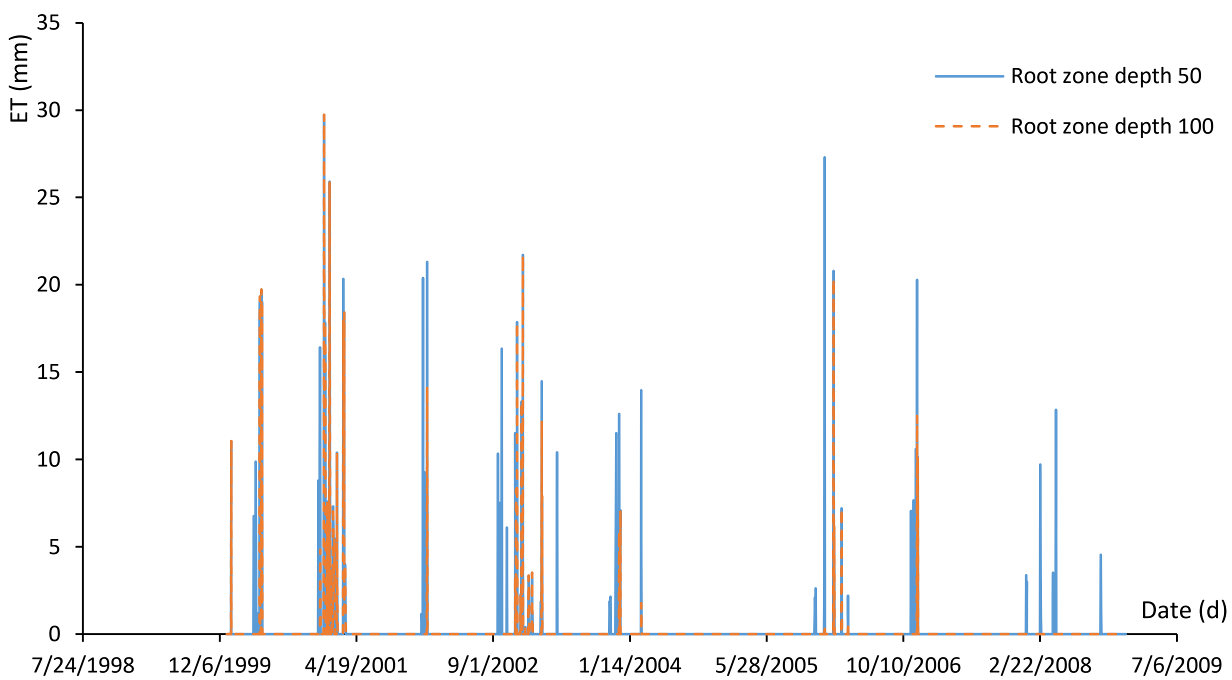



Figure j.2 ET with different root zone depth

As the plant grows, the depth of the root zone increases. Or artificially increasing the soil suitable for planting will also increase the depth of the root zone.

I think the effect of increasing root zone depth is the same as that of increasing field capacity in question f. Because the capacity of water storage in the root zone is increased, more water is stored in the root zone, so the evapotranspiration is increased, but the recharge of groundwater is decreased. The results confirmed my idea. From the figure, we can get that the total value of evapotranspiration increased, but the peak value decreased, and the groundwater recharge decreased.