Chapter 14
Rainwater Collection and Storage

Many regions have a high water surplus for the irrigation of plants during rainy seasons and a deficit of water in dry seasons. When growing plants in greenhouses, the rainwater running off the roofs of greenhouses can be collected and used for irrigation. If salty water is available, this can be mixed with rain water and then used as irrigation water. It is necessary to build greenhouses with sufficiently large gutters and storages for the collection of rain water. The crop water requirement has to be known in order to calculate the storage for rainwater and for irrigation systems.

The crop water requirement CWR can be calculated by use of the reference evapotranspiration ET0 (mm/day) according to FAO–Penman–Monteith with adapted parameters for unheated greenhouses (see Chap. 13).

The actual evapotranspiration AET of the crop inside the greenhouse is

$$\mathrm{AET_C} = \mathrm{ET0} \times k_C \quad (\mathrm{mm/day} = \mathrm{l/m^2 day}). \tag{14.1}$$

The daily crop water requirement is.

$$\mathrm{CWR_d} = \mathrm{AET}(1 + l_\mathrm{I}) \times A_\mathrm{crop}/A_\mathrm{G} \quad (\mathrm{mm/day}), \tag{14.2}$$

where

$l_\mathrm{I} = 0.03$–0.1 loss factor for the drip irrigation system.
$A_\mathrm{crop}/A_\mathrm{G} = 0.9$ for vegetables and flowers on ground beds.

The monthly crop water requirement CWR is

$$\mathrm{CWR_m} = \mathrm{CWR_d} \times d_\mathrm{m} \quad (\mathrm{mm/month}), \tag{14.3}$$

d_m = days in the month

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14.1 Calculation of the Storage Volume

The following points have to be considered for the design of the storage basin:

- The area of greenhouses and the vacant area available for a storage basin.
- The distribution of precipitation and the amount of rainfall.
- The crop water requirement.
- Whether the storage basin is only to be used for storing rainwater or for mixing rain and salty water.

Normally, daily frequencies of precipitation should be taken into consideration for the calculation of the storage volume. Those values are unknown in most cases. Therefore, monthly precipitation can be used to estimate the storage volume in a first approximation.

The monthly collected amount of precipitation is.

$$CV_m = Pre \times f_C \quad (l/m^2 month), \tag{14.4}$$

where

Pre (l/m^2month) = mean monthly precipitation
$f_C = 0.9$: Collecting factor for greenhouse roofs.

The collecting factor is the ratio of possible amount of collected rain water to the precipitation.

If rain water is to be used for irrigation, the monthly storable precipitation is:

$$STP_m = CV_m - CWR_m - EV_{pond} \quad (l/m^2 month). \tag{14.5}$$

The evaporation of the storage basin surface EV_{pond} can be neglected if the basin is covered by a swimming plastic cover, for example.

If STP_m is positive, the storage will be filled, if STP_m is negative, the storage will be emptied.

The yearly storable precipitation is:

$$STP_y = \sum \text{positive } STP_m \quad (l/m^2 month). \tag{14.6}$$

The yearly deficit is:

$$Def_y = \sum \text{negative } STP_m \quad (l/m^2 month). \tag{14.7}$$

The yearly storage balance is:

$$STB_y = STP_y - Def_y \quad (l/m^2 month). \tag{14.8}$$

The following cases have to be distinguished:

1. If $STB_y > 0$ or $STP_y > Def_y$, the storable precipitation is sufficient for irrigation throughout the year. The storage volume becomes:

$$VST = Def_y \quad (l/m^2).$$

One can enlarge the volume, if the monthly variation of precipitation is high. The storage volume is:

$$VST = Def_y(1 + V_C),$$

V_C = coefficient of variation for precipitation (see Chap. 2).

2. If $STB_y < 0$ or $STP_y < Def_y$, the storable precipitation is not sufficient for irrigation. two cases have to be distinguished:
   (a) If the storable precipitation is higher than the maximum monthly collected precipitation CV_{mmax}
   If $STP_y > CV_{mmax}$, then

$$VST = STP_y$$

or

$$VST = STP_y(1 + V_C) \quad (lm^2)$$

   (b) If $STP_y < CV_{mmax}$, then

$$VST = CV_{mmax}$$

or

$$VST = CV_{mmax}(1 + V_C)$$

14.2 Example 1: Storage Volume for Climate Conditions in Bangalore (India)

Table 14.1: Calculation of the storage volume for collecting rainwater for irrigation in Bangalore (India). Precipitation Pre (Müller 1996); Monthly storable precipitation STP_m with (14.5) and $EV_{pond} = 0$; ET0 see Fig. 13.1;

$CWR_m = ET0 \times k_C(1 + l_i) \times A_{Cr}/A_G \times d_m$

For tomato, mean $k_C = 1.1$; $(1 + l_i) = 1.05$; $A_{Cr}/A_G = 0.9$

$k_C(1 + l_i) \times A_{Cr}/A_G = 1.04$;

$CWR_m = 1.04 \times ET0 \times d_m$

From Table 14.1 can be seen:

$STP_y = \Sigma pos\ STP_m = 164.9\ l/m^2$ year

$Def_y = \Sigma neg\ STP_m = 371.2\ l/m^2$ year

Table 14.1 Data for the calculation of the storage volume in Bangalore (India)

Month	Pre l/m^2 month	CV l/m^2 month	d_m	ET0 l/m^2 day	CWR_m l/m^2 month	STP_m l/m^2 month	STP_m accumulated
Jan	5	4.5	31	2.38	76.7	−72.2	+23.1
Feb	8	7.2	28	2.8	81.4	−74.2	−51.1
Mar	10	9	31	3.35	108	−99	−150.1
Apr	41	37	30	3.3	103	−66	−216.1
May	107	96.3	31	3.3	106.3	−10	−226.1
Jun	74	66.6	30	3.3	103	−36.4	−262.5
Jul	99	89.1	31	3.26	105.1	−16	−278.5
Aug	127	114.3	31	2.9	93.5	+20.8	+ 20.8
Sep	170	153	30	2.34	73	+80	+100.8
Oct	150	135	31	2.2	70.9	+64.1	+165.2
Nov	69	62.1	30	2.13	66.5	−4.4	+160.8
Dec	10	9	31	2.3	74.2	−65.2	+95.6

Case 2(a): Storage volume per m^2 greenhouse area VST $= STP_y = 165(l/m^2)$

The storage is empty from February until July.

Looking at the accumulated sum of STP_m, starting in August, the crop water requirement can be covered for 6 months from August to January by rainwater with a storage volume of 0.165 m^3 per m^2 greenhouse area.

14.3 Example 2: Storage Volume for Climate Conditions in Antalya (Turkey)

Table 14.2: Calculation of the storage volume for the collection of precipitation in Antalya (Turkey). Precipitation Pre (Müller 1996); STP_m with (14.5) and $EV_{pond} = 0$; ET0 from Fig. 13.1. $CWR_m = 1.04 \times ET0 \times d_m$ (see Example 1)

$STP_y = \Sigma pos\ STP_m = 608.2\ l/(m^2\ year)$

$Def_y = \Sigma neg\ STP_m = 1{,}651.4\ l/(m^2\ year)$

$STP_y > CV_{mmax}$:

Case 2(a): Storage volume VST $= STP_y = 608\ l/m^2$

The storage is empty from July until October. The crop water requirement can be covered for 8 months from November to June by rainwater with a storage volume of 0.61 m^3/m^2 greenhouse area.

14.4 Design of Rainwater Storage Basins

Different types of storage basins can be built, if enough space is available near the greenhouse:

- Simple basins, dug in the soil, if the soil at the bottom of the basin is sufficiently watertight.

Table 14.2 Data for the calculation of the storage volume in Antalya (Turkey)

Month	Pre l/m^2 month	CV l/m^2 month	d_m	ET0 l/m^2 day	CWR$_m$ l/m^2 month	STP$_m$ l/m^2 month	STP$_m$ accumulated
Jan	259	233	31	0.86	27.7	+205.3	+495.8
Feb	175	157.5	28	1.55	45.1	+112.4	+608.2
Mar	79	71	31	2.24	72.2	−1.2	+607
Apr	38	34	30	3.5	109.2	−75.2	+531.8
May	33	30	31	4.75	153.1	−283.1	+248.7
Jun	13	12	30	5.9	184.1	−172.1	+76.6
Jul	3	2.7	31	6.4	206.3	−203.6	−127
Aug	3	2.7	31	5.6	180.5	−177.8	−304.8
Sep	15	13.5	30	3.82	119.2	−105.7	−410.5
Oct	53	48	31	2.25	72.5	−24.5	−435
Nov	119	107	30	1.11	34.6	+72.4	+72.4
Dec	267	240	31	0.68	21.9	+218.1	+290.5

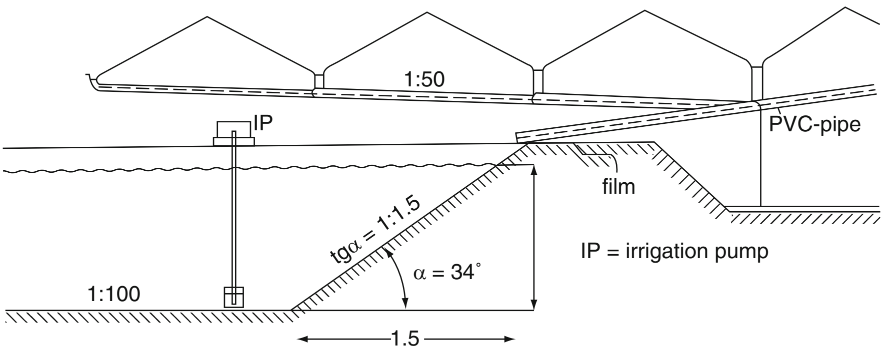

Fig. 14.1 Rainwater basin and rainwater run off from greenhouse gutters

- Earth basin lined with plastic film.
- Concrete basins; durable, need less maintenance, but are very expensive.

All storage basins should be covered at the surface by swimming plastic film, for example, to avoid too high evaporation.

Figure 14.1 shows the arrangement of a plastic-film water basin with water tubes from the gutters to the basin (von Zabeltitz and Baudoin 1999). To collect heavier rainfall, the gutters and tubes leading to the storage basin must have an adequate diameter. The tubes leading the water to the basin should have a slope of about 1:50–1:100. The following diameters are recommended:

Greenhouse floor area (m^2)	Tube diameter (mm)
<400	100
400–700	125
700–1,200	150

If the level of the storage basin is deep enough, the rainwater can be led via open gutter lined with plastic film.

The basin has to be situated at the deepest point of the site. If this is not the case and the greenhouses are placed deeper than the basin, the rainwater can be conducted into the basin by a siphon system (Fig. 14.2). Watertight tubes are installed

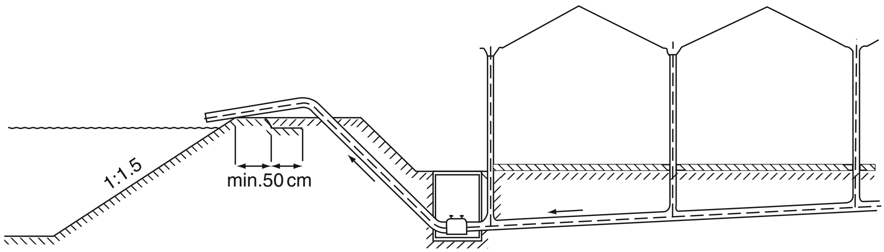

Fig. 14.2 Rainwater conducted to the basin by a siphon system

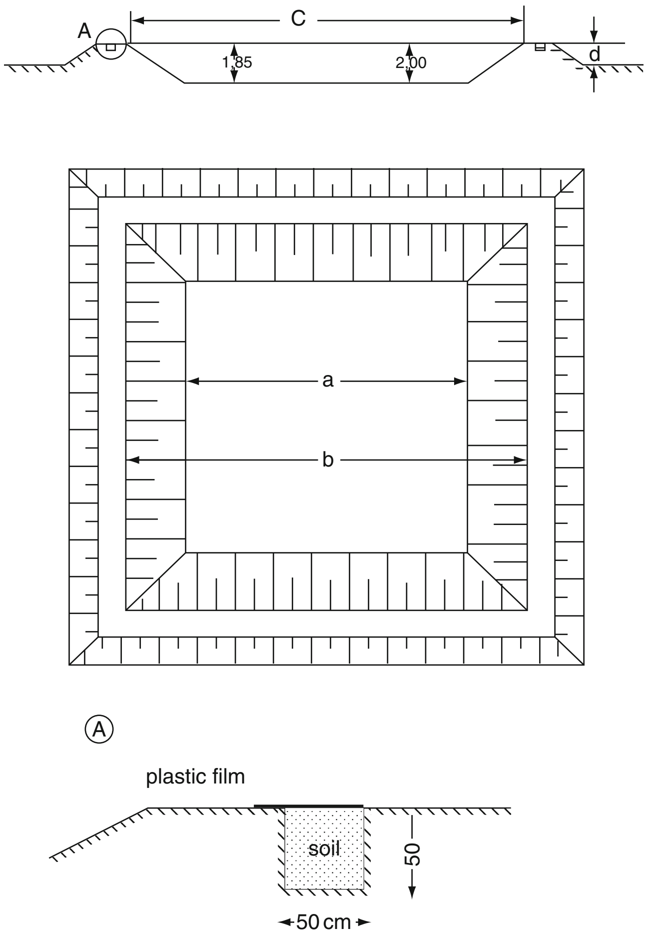

Fig. 14.3 Measurements of a rainwater basin

sloping downward to a deepest point near the basin, and from there into the basin. The gutters have to be above the water level of the basin. When rainwater in the tubes rises above the water of the basin, positive pressure develops, and the water flows from the tube into the basin.

When digging out the basin, the soil is thrown up around the basin as an embankment (Fig. 14.3).The angle of the embankment is about 34°, or it has a ratio of 1:1.5. Thus it is within the range of frictional angles of most types of soil.

In the case of a 2 m-deep square basin, the measurements a, b, c and d have the following values (m) for different quantities of water:

Water quantity(m^3)	a(m)	b(m)	c(m)	d(m)
200	7.25	13.03	12.8	0.75
400	11.7	17.5	17.25	09
600	15.05	20.8	20.6	1.0