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# Simulation of Some Options to Manage of Drainage Water from Irrigation of Sugarcane in Middle Part of Khuzestan Province, Iran

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**ABSTRACT**

Due to the shortage of water resources in country and adverse environmental effects resulting from the nonsystematic release of drainage waters, one of the necessary actions is to collect this water and reuse in agricultural and horticultural operations. So, in this research, the possibility of collecting the drainage water from sugarcane cultivation in the lands of middle of Khuzestan province and reusing it to cultivate barley and eucalyptus and final discharging into evaporation ponds or artificial wetlands is studied. In this regard, the best empirical model of soil desalinization is provided by using desalinization tests in studied area. Therefore, a simulation model, called leaching process, was prepared to determine the final values of salinity of soil (ECf) for applying the depth percolation from irrigation of sugarcane. The results indicated that, the drainage water from second year of sugarcane cultivation can be used to cultivate barley and eucalyptus. Then the area of barley-arable and eucalyptus- arable lands was determined based on critical month of water requirement of plants. Finally, the option to "collecting drainage water of sugarcane and reusing it to cultivate barley and using the residual drainage water of sugarcane and barley to irrigate eucalyptus and final discharging to wetland or evaporation pond" was determined as the best one. It’s because of less wasted drainage water, supplying a greater volume of irrigation water and the need to a smaller area to build the evaporation pond.
**KEYWORDS**: Artificial wetland, evaporation pond, management of drainage water, salts leaching.

## 1. INTRODUCTION

Increasing population rate and demand to water and food, in one hand, and adverse environmental effects of agricultural drainage water on natural habitats and susceptive water resources, on the other hand, has attracted experts' attention to reuse such waters. Presently, the public belief is that the drainage networks should be designed so that preserving life of residents of in habitats is insured and agricultural activities don't damage water quality [9, 12].

With regard to present reports, Iran is among the countries which is encountering this problems and many ponds and rivers are polluted because of drainage water entering neighborhood agriculture grounds [8].

Also in arid and semiarid regions where the problems of saline and sodic soils are often present and a lot of water is required to amend them through leaching, reuse of drainage water from drainage of these soils whether directly or indirectly is unavoidable [5, 2 and 13]. In some of these regions in where there are the levels of shallow water table, if these waters aren't used, the level of water table is raised which results in problem of salinity soil or it is possible for this water to infiltrate into beds of ground water with high quality and pollute this water [1, 3].

With regard to above descriptions and shortage of water sources, one of the necessary actions is to collect this water and reuse them in cultivation and reformation programs. Therefore, this research is aimed to offer suitable management strategies to reuse and remove the drainage water from sugarcane cultivation in middle parts of Khuzestan province.

In order to manage of drainage water in a system of agroforestry in California, Letey (2005) used the drainage water of a crop sensitive to salinity to irrigate the cotton, a crop tolerant against salinity. This cycle was repeated several times and resulted drainage water was discharged into evaporation ponds. The results indicated that the main advantage of this system is less waste of water in evaporation pond. But the costs associated with decreasing the environmental effects (because of the birds using the poison salts accumulated in evaporation pond) should be evaluated [7].

In a study by Jorgensen and Solomon (2006), the drainage water from carrot cultivation was applied to irrigate cotton. The drainage water of cotton, the volume of which became smaller and was more concentrated in terms of salt and poison elements such as selenium, was used to irrigate eucalyptus and resulted drainage water was used to irrigate a kind of Halophyte, named Atreplix. The final drainage water with high concentration was discharged into evaporation ponds. The results showed that this method is effective to reduce and use drainage water, but costs associated with transferring and discharging drainage water into evaporation ponds are high [4].

### Materials and Methods:

The studied area is a part of middle lands of Khuzestan province in southwest of Iran. This area is 12000 ha. From north, these lands are extended to Dez River, from east to Karoon River, from west to railroad of Ahvaz–Tehran, and from south to Ahvaz city. Based on the comprehensive classification of united state department of agriculture (USDA), the soils of studied region were generally silty clay and in term of classification they were Typic Haplosalid [10]. The main Limitation of these lands was salinity and sodicity and the level of ground water was high.

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In this research, in order to manage of sugarcane drainage water, the possibility of collecting and reusing this water was studied with four alternatives:

1- Collecting sugarcane drainage water, reusing it to cultivate barley, using residual drainage water of sugarcane and barley to irrigate eucalyptus and discharging final drainage water into evaporation pond or artificial wetland.
2- Collecting drainage water of sugarcane, reusing it to cultivate barley and finally discharging into artificial wetland or evaporation pond.
3- Collecting drainage water of sugarcane, using it to plant eucalyptus and finally discharge into wetland or evaporation pond.
4- Collecting sugarcane drainage water, using it to plant eucalyptus, using residual drainage water of sugarcane and eucalyptus to irrigate barley and finally discharging into evaporation pond or wetland.

The possibility of executing these models was studied on a 1000 ha plot of sugarcane-cultivated, with efficiency of 65 percent.

To study of these alternatives, the process of soil desalinization was initially studied. To do so, the "empirical model of desalinization" was obtained for soils of studied region as follow [11].

$$\left[\left(EC_f - EC_{eq}\right)/\left(EC_i - EC_{eq}\right)\right] = 0.222\exp\left[-1.047\left(f/\theta_v\right)/\left(D_{lw}/D_s\right)\right] \quad (1)$$

Where $EC_i$ and $EC_f$, are electrical conductivity values of saturated extract of soil before and after leaching, respectively (in this paper EC equals the salinity), $EC_{eq}$, is equilibrium salinity of soil saturated extract, ($D_{1w}/D_s$), is the ratio of leaching water depth to soil depth unit, (f), is efficiency coefficient of solution salts leaching from soil profile, ($\theta_v$), is the soil moisture content.

Then by using the equation 1, a simulation model as "Leaching process" was prepared. This model is able to predict the final salinity of saturated extract of soil ($EC_f$) for applying sugarcane drainage water. The input data of the model are as follow:

- The initial salinity of soil profile with 1.5 m thickness ($EC_i$) (dS/m),
- The leaching efficiency of soil profile (f),
- Equilibrium salinity of soil saturated extract ($EC_{eq}$= 2.2 dS/m),
- The average salinity of irrigation water equal to 1.37 dS/m,
- The soil moisture content ($\theta_v$),
- The values of monthly sugarcane drainage water are listed in table 1 (meter).

In this model, it's assumed that desalinization process is performed only through drainage water of irrigation water, and also to determine the final salinity of soil layers at the end of each month, the soil column up to 1.5 m depth was differentiated into six 0.25 m layers, and final salinity of soil layers at the end of each month is considered as initial salinity at beginning of next month.

Accordingly, with regard to value of $EC_f$ from the model of leaching process, and considering that the maximum potential of yield of barley and eucalyptus is obtained in salinity values of 8.0 and 6.0 dS/m, respectively [10], it can be said that, is the barley and eucalyptus cultivation possible by using the drainage water resulted from first and second year of sugarcane cultivation?

In next step, collecting information related to pure water requirement of sugarcane, barley and eucalyptus in different months of cultivation year was performed by CropWat software. Then through the values of required pure water and with regard to irrigation efficiency of 65% for sugarcane and that of 53% for barley and eucalyptus, the impure water requirement and values of depth percolation were calculated by considering control of water and salt balance in the region of plant roots growth.

With regard to obtained information and considering 28% losses of irrigation water for sugarcane and 38% losses of irrigation water for barley and eucalyptus, the value of consumed water, the application items of irrigation water and also the rate of drainage discharge (presented in tables 1 to 3) were calculated.

**Table 1. The cases of application of irrigation water and value of water wastes to plant one hectare sugarcane**

| Rows | Months of year | Volume of used water ($m^3$) | Depth of used water (m) | Depths of used water (m) | | Volume of drainage water (m3/day) |
|---|---|---|---|---|---|---|
| | | | | Water requirement (72%) | Depth percolation* (28%) | |
| 1 | Apr | 3507 | 0/35 | 0/25 | 0/10 | 31/6 |
| 2 | May | 4329 | 0/43 | 0/31 | 0/12 | 39/0 |
| 3 | Jun | 4347 | 0/43 | 0/31 | 0/12 | 39/3 |
| 4 | Jul | 3759 | 0/38 | 0/27 | 0/10 | 33/9 |
| 5 | Aug | 1764 | 0/18 | 0/13 | 0/05 | 15/9 |
| 6 | Sep | 1456 | 0/15 | 0/11 | 0/04 | 13/2 |
| 7 | Oct | 1415 | 0/14 | 0/10 | 0/04 | 13/3 |
| 8 | Nov | 859 | 0/08 | 0/06 | 0/02 | 8/0 |
| 9 | Dec | 331 | 0/03 | 0/02 | 0/01 | 03/1 |
| 10 | Jan | 411 | 0/04 | 0/03 | 0/01 | 03/7 |
| 11 | Feb | 1057 | 0/11 | 0/08 | 0/03 | 10/0 |
| 12 | Mar | 2251 | 0/22 | 0/16 | 0/06 | 21/7 |
| Total | | 25488 | 2/55 | 1/84 | 0/71 | - |

* 23%, the unavoidable wastes in method of surface irrigation and 5% for other depth wastes are considered.

**Table 2. The cases of application of irrigation water and value of water wastes to plant one hectare barley**

| Rows | Months of year | Volume of used water ($m^3$) | Depth of used water (m) | Depths of used water (m) | | Volume of drainage water (m3/day) |
|---|---|---|---|---|---|---|
| | | | | Water requirement (62%) | Depth percolation* (38%) | |
| 1 | Apr | 2000 | 0/2 | 0/12 | 0/08 | 24/5 |
| 2 | May | 283 | 0/03 | 0/02 | 0/01 | 3/5 |
| 3 | Jun | - | - | - | - | - |
| 4 | Jul | - | - | - | - | - |
| 5 | Aug | - | - | - | - | - |
| 6 | Sep | - | - | - | - | - |
| 7 | Oct | - | - | - | - | - |
| 8 | Nov | - | - | - | - | - |
| 9 | Dec | - | - | - | - | - |
| 10 | Jan | - | - | - | - | - |
| 11 | Feb | 226 | 0/027 | 0/01 | 0/01 | 2/9 |
| 12 | Mar | 868 | 0/09 | 0/05 | 0/04 | 11/4 |
| | Total | 3377 | 0/34 | 0/21 | 0/13 | - |

* 28%, the unavoidable wastes in method of surface irrigation and 10% for other depth wastes are considered.

**Table 3. The cases of application of irrigation water and value of water wastes to plant one hectare eucalyptus**

| Rows | Months of year | Volume of used water ($m^3$) | Depth of used water (m) | Depths of used water (m) | | Volume of drainage water (m3/day) |
|---|---|---|---|---|---|---|
| | | | | Water requirement (62%) | Depth percolation* (38%) | |
| 1 | Apr | 821 | 0/08 | 0/05 | 0/03 | 10/1 |
| 2 | May | 1419 | 0/14 | 0/09 | 0/05 | 17/4 |
| 3 | Jun | 1864 | 0/19 | 0/12 | 0/07 | 22/9 |
| 4 | Jul | 2411 | 0/24 | 0/15 | 0/09 | 29/6 |
| 5 | Aug | 2245 | 0/22 | 0/14 | 0/09 | 27/5 |
| 6 | Sep | 1759 | 0/18 | 0/11 | 0/07 | 21/6 |
| 7 | Oct | 1277 | 0/13 | 0/08 | 0/05 | 16/2 |
| 8 | Nov | 272 | 0/03 | 0/02 | 0/01 | 3/4 |
| 9 | Dec | 17 | 0/002 | 0/001 | 0/001 | 0/2 |
| 10 | Jan | - | - | - | - | - |
| 11 | Feb | - | - | - | - | - |
| 12 | Mar | 419 | 0/04 | 0/03 | 0/02 | 5/5 |
| | Total | 12504 | 1/252 | 0/78 | 0/471 | - |

* 28%, the unavoidable wastes in method of surface irrigation and 10% for other depth wastes are considered.

Then four alternatives were examined as follow:

In the first alternative, the area of barley–arable lands which can be irrigated by drainage water from one ha sugarcane (listed in table 1) and also area of eucalyptus-arable lands which can be irrigated by residual drainage water of sugarcane and barley (listed in table 5) are determined. The month with maximum water requirement of barley and eucalyptus (listed in table 2 and 3) has been the base of calculation.

In the second alternative, the area of barley–arable lands which can be directly irrigated by drainage water from one hectare of sugarcane is determined based upon the month with maximum water requirement of barley.

In third alternative, the area of eucalyptus-arable lands which can be irrigated by drainage water from one hectare of sugarcane are calculated, based upon the critical month of water requirement of eucalyptus.

In fourth alternative, the area of eucalyptus–arable lands which can be irrigated by drainage water from one hectare of sugarcane and area of barley–arable lands which can be irrigated by residual drainage water of eucalyptus and sugarcane were determined.

Then by preparing "calculation program", called evaporation pond, the area of wetlands and evaporation ponds were calculated to discharge residual drainage water from all cultivations. This program calculates the values of required water and area of drained lands for three modes: evaporation pond (zero water balance), wetland (with +0.25 m height of water table level) and wetland (with +0.5 m height of water table level) with area of one hectare.

The input data to execute this calculation program includes: the values of monthly drainage water, the values of monthly precipitation, the values of evaporation from water surface on evaporation pond or wetland, and also the values of depth infiltration (the infiltration from soil surface of pond or wetland into soil).

To perform this program for area unit of evaporation pond or wetlands, some of input and output data related to climate conditions (precipitation and evaporation of pond surface or surface of water laid on wetlands) and soil (the value of depth infiltration) during one year of cultivation were considered as constant values: 0.21303, 2.1505 and 0.5475 m, respectively [10], therefore, it is the value of drainage water that meets the conditions to maintain water balance (0, + 0.25, + 0.50 m).

Finally, the best alternative to manage of drainage water was selected according to following items:

- In which alternative, has less final drainage water discharged into evaporation pond or wetland.
- In which alternative, one hectare evaporation pond or wetland is required for larger area of drained lands.
- In which alternative, a larger part of lands which aren't used because of water shortage enters agriculture cycle.

**Discussions and conclusions**

**First option: collecting sugarcane drainage water, reusing it to barley and then eucalyptus and finally discharging to evaporation pond or artificial wetland.**

To study this option, the simulation model of leaching process was initially executed. In figure 1, it's shown that how the value of final salinity up to 1.5 m depth from soil surface is varied in the first year of sugarcane cultivation.

It should be noted that the results of studies in the second year of sugarcane cultivation showed that final salinity of saturation extract up to 1.5 depths of soil and throughout all months is equal to $EC_{eq}$, which 2.2 dS/m.

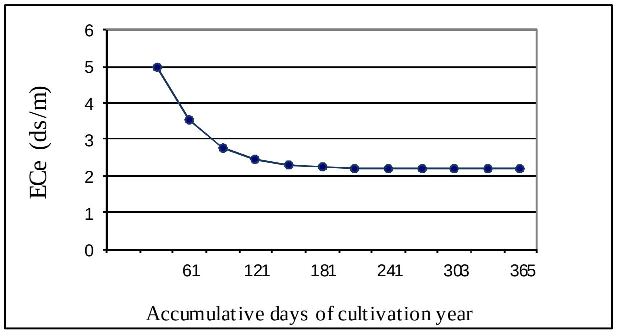


**Fig. 1.** The variations of EC up to 1.5 m depth from soil surface (first year of sugarcane cultivation)

To achieve final and actual salinity of drainage water, it was assumed that due to high level of saline ground water in the region, some of the salinity under the tile is entered into the drain and final salinity of the drainage water outflow the drain is in fact more than calculated values in figure 1. Then we calculated the coefficients to determine value of the salinity inflowing the drain, through drainage water, from the above and bottom of tile.

The results showed that the coefficient of ($C_t$) and ($C_b$) (coefficients to determine salinity value that enters drain from above and bottom of tile, respectively) are equal to 0.27 and 0.73 for drain distance of 45 m, 0.185 and 0.815 for drain distance of 55 m, 0.16 and 0.84 for drain distance of 65 m and 0.11 and 0.81 for drain distance of 102 m.

Then by using calculated coefficients and values of salinity in above the drain (listed in figure 1) and by using the relation of $EC = aEC_t + bEC_b$, where $EC_t$, is the salinity of above the tile, $EC_b$, is the salinity in bottom of tile and EC is final salinity of the drainage water out flowing the tile and by knowing that the salinity level of ground water is equal to 32.0 dS/m, we calculated final salinity of drainage water in first and second year of sugarcane cultivation. Obtained results are presented in figures 2 and 3.

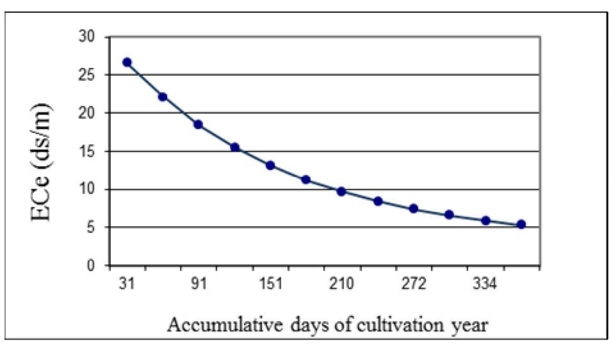


**Fig. 2.** The salinity variation up to 1.5 m depth from soil surface on the first year of sugarcane cultivation, after exerting, calculated coefficients

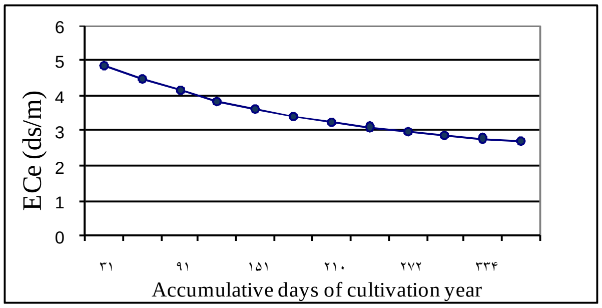


**Fig. 3.** The salinity variation up to 1.5 m depth from soil surface on the second year of sugarcane cultivation, after exerting, calculated coefficients

With regard to the values of final salinity of sugarcane drainage water on the first and second year, after exerting the calculated coefficients and by considering the maximum potential of yield of barley and eucalyptus, it's better to cultivate barley and eucalyptus by using drainage water from the second year of sugarcane cultivation.

In order for better management of drainage water, we can use the drainage water from the first year to prepare and reform the soils which are considered to be under cultivation of barley and eucalyptus.

In next step, the results of determining the area of barley–arable and eucalyptus– arable lands showed that 0.5 ha barley can be cultivated by using the drainage water from one hectare sugarcane, and 0.22 ha eucalyptus can be planted by using the residual drainage water of sugarcane and the drainage water of 0.5 ha barley. Obtained results are showed in tables 4 and *5*.

**Table 4. The variations of water balance in a combination of one ha sugarcane (main plant) and 0.5 ha barley (as second plant)**

| Rows | Studied factors | Variation of studied factors on different month (values are in m3) | | | | | | | | | | | | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | |
| 1 | Volume of used water by sugarcane | 3507 | 4329 | 4347 | 3759 | 1764 | 1456 | 1415 | 859 | 331 | 411 | 1057 | 2251 | 25488 |
| 2 | Volume of drainage water of sugarcane | 980 | 1210 | 1220 | 1053 | 494 | 408 | 400 | 240 | 93 | 110 | 300 | 630 | 7138 |
| 3 | Volume of used water by barley | 980 | 142 | - | - | - | - | - | - | - | - | 163 | 434 | 1718 |
| 4 | Residual drainage water of sugarcane | - | 1068 | 1220 | 1053 | 494 | 408 | 400 | 240 | 93 | 110 | 137 | 196 | 5420 |
| 5 | Volume of barley drainage water | 372 | 54 | - | - | - | - | - | - | - | - | 34 | 165 | 634 |
| 6 | Residual drainage water of sugarcane and barley | 372 | 1122 | 1220 | 1053 | 494 | 408 | 400 | 240 | 93 | 110 | 180 | 361 | 6054 |

**Table 5. The variations of water balance in a combination of one ha sugarcane (main plant), 0.5 ha barley (as second plant) and 0.22 ha eucalyptus (as third plant)**

| Rows | Studied factors | Variation of studied factors on different month (values are in $m^3$) | | | | | | | | | | | | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | |
| 1 | Residual drainage water of sugarcane and barley | 372 | 1122 | 1220 | 1053 | 494 | 408 | 400 | 240 | 93 | 110 | 180 | 361 | 6054 |
| 2 | Volume eucalyptus used water | 181 | 313 | 410 | 530 | 494 | 387 | 281 | 60 | 4 | - | - | 92 | 2751 |
| 3 | Residual drainage water | 192 | 810 | 810 | 523 | - | 21 | 119 | 180 | 89 | 110 | 180 | 269 | 3303 |
| 4 | Volume of eucalyptus drainage water | 69 | 119 | 156 | 202 | 188 | 147 | 107 | 23 | 2 | - | - | 35 | 1045 |
| 5 | Residual drainage water of sugarcane, barley and eucalyptus | 260 | 929 | 966 | 724 | 188 | 168 | 226 | 203 | 91 | 110 | 180 | 304 | 4348 |

Finally, the calculation program, called evaporation pond was applied to discharge residual drainage water of all cultivations. To maintain water balance (0, +0.25, +0.50 m), the values of the residual drainage water of sugarcane, barley and eucalyptus was used which was equal to 0.4348 m during one cultivation year (listed in table 5). Accordingly, the area of drained parts to create one hectare evaporation pond, wetland (with +0.25 m height of water table level) and wetland (with +0.5 m height of water table level) is equal to 5.715, 12.61 and 19.51 ha, respectively. On the other hand, the drainage water of mentioned areas should be collected and discharged into one hectare of evaporation pond or related wetland.

Applying mentioned areas, the water balance and related components were calculated by using calculation program. The results showed in figures 4 to 6.

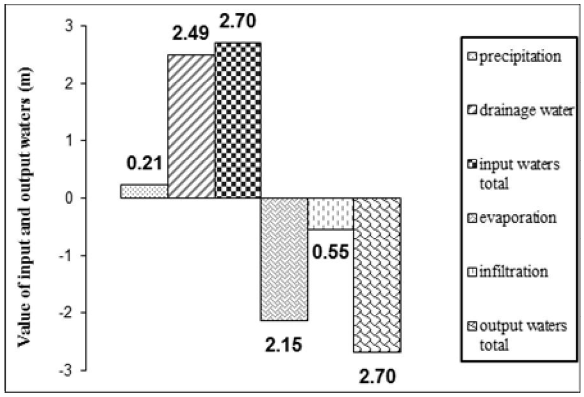


**Fig. 4.** The quantities of water balance to discharge drainage water, the studied area is 5.715 ha to build one hectare evaporation pond

Figure 4, Shows that under the conditions of building evaporation pond, a water volume equal to 26980.0 $m^3$/h is annually wasted through depth infiltration and surface evaporation, 24850.0 $m^3$ of which should be compensated through discharging the drainage water of 5.715 ha drained area. That is, an area of one hectare land is required per 5.715 ha of cultivated lands for the drainage water to be discharged, that desirable conditions aren't achieved in term of land utilizing.

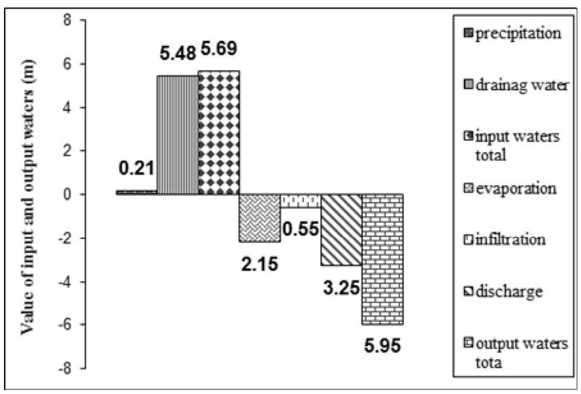


**Fig. 5.** The quantities of water balance to discharge drainage water, 12.61 ha drained area to build one ha wetland (with +0.25 m height of water table level)

Figure 5, shows that under the conditions of building wetland (with +0.25 m height of water table level), a water volume equal to 59462.0 $m^3$ is annually wasted through surface evaporation and depth infiltration and discharging of water from wetland, 54831.0 $m^3$ of which should be supplied through collecting drainage water of drained area (12.61 ha) to be discharged into one hectare land that by including precipitation values, the sum of inflowing water reaches 56961.0 $m^3$ annually, and by subtracting the sum of water out flowing the wet land (59462.0 $m^3$) from the sum of inflowing water, a water depth equal to + 0.25 m during year will be laid on wetland surface.

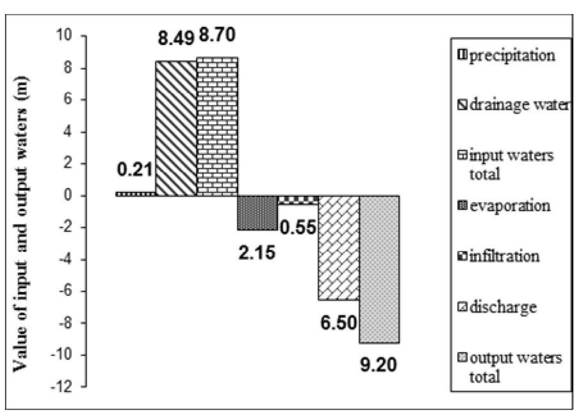


**Fig. 6.** The quantities of water balance to discharge drainage water, 19.51 ha drained area to build one ha wetland (with +0.5 m height of water table level)

Under the conditions of building a wetland, an area of one hectare land is required per 19.51 ha of cultivated lands for the drainage water to be discharged.

With maintaining water balance (+0.25, +0.50 m), because of preventing from concentrating of solution salts in drainage water, the quality of waters laid on wetland surface is gradually improved and the wetland becomes biological active. In these conditions, in term of land utilization, building wetland (with +0.5 m height of water table level) achieves more desirable conditions.

**Second option: collecting sugarcane drainage water, reusing it to barley and discharging into evaporation pond.**

The results of determining the area of barley-arable lands that can be irrigated by drainage water from one hectare of sugarcane (listed in table 2) showed that, 0.5 ha barley can be planted by using these values.

To discharge residual drainage water of cultivations into evaporation pond or wetland, the input data similar to first option and the values of residual drainage water of barley and sugarcane (0.6054 m) were used.

So, the area of drained parts to maintain water balance (0, +0.25 and +0.50 m) per area unit, is 4.10, 9.06 and 14.02 ha, respectively. The results of using calculation program with applying mentioned areas are similar to previous option.

**Third option: collecting sugarcane drainage water, reusing it to eucalyptus and finally discharging into evaporation pond.**

The results of executing this model indicated that, by using the drainage water from one hectare of sugarcane, 0.22 ha eucalyptus can be cultivated, and the area of drained parts to maintain water balance (0, +0.25 and +0.50 m) was equal to 4.57, 10.1 and 15.62 ha, respectively.

**Fourth option: collecting drainage water of sugarcane, reusing it to eucalyptus and then barley and finally discharging into evaporation pond.**

By using the drainage water from one hectare of sugarcane, we can cultivate 0.22 ha eucalyptus and by using the residual drainage water of sugarcane and the drainage water of 0.22 ha eucalyptus, 0.44 ha can be barley cultivated**.**

To discharge the residual drainage water, a calculation program similar to previous options was used. To maintain the water balance (0, +0.25, +0.50 m), from the values of residual drainage water of all cultivations (0.4478 m) were used. So, the area of drained parts to maintain of mentioned water balance is equal to 5.55, 12.25 and 18.95 ha, respectively.

## Conclusion

The studies indicated that based on following reasons, the first option (as mentioned) is the best one to manage of drainage water:

- Due to scarcity of water resources, less final drainage water is discharged into evaporation pond or wetland and waste of drainage water is less and also a part of water shortage in agriculture of studied region can be compensated.
- One hectare evaporation pond or wetland is required for a larger area of drained lands. Consequently, the area of the lands which aren't so used is less.
- A larger part of the lands which aren't optimally used because of water shortage can be brought in agriculture cycle.

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