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Design of edges in contour and half moons from edaphoclimatic parameters, for the endorrheic basin of lagunas de tajzara - ramsar site 1030

Diseño de bordes en contorno y medias lunas a partir de parámetros edafoclimáticos, para la cuenca endorreica de las lagunas de tajzara - sitio ramsar 1030

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Abstract

The collection of water is proposed from the design of contour borders and half moons, green infrastructure measures, to reduce surface runoff and increase the availability of water for vegetation. The contour and crescent ridges have land ridges with a trapezoidal section, which follow the contour lines, to compartmentalize the slope into smaller hydrological units, the ends of which are located on contour lines. With the data of maximum rainfall every 24 hours and parameters of Gumbel's Law modified, the equations of maximum daily rainfall height (hdT), rainfall height for a duration ´´t´´ (htT), and the Intensity Duration Frequency curve (ItT), for a duration of t <2h. Then considering the values of basic infiltration, vegetation cover, soil type and hydrological condition, the curve numbers were determined for different soil moisture conditions, later the separation length (L) between the Half Moons, and the borders was calculated. in contour, which were designed by means of 10 configurations between diameter and height, for the two infrastructures, being in Copacabana Valle, the greatest separation distance.

Infiltration, Crescent moons, Borders in contour

Resumen

Se plantea la captación del agua a partir del diseño de bordos en contorno y media lunas, medidas de infraestructura verde, para disminuir el escurrimiento superficial e incrementar la disponibilidad de agua para la vegetación. Los bordos en contorno y media lunas presentan caballones de tierra con sección trapezoidal, que siguen las curvas de nivel, para compartimentar la ladera en unidades hidrológicas más pequeñas, cuyos extremos se sitúan sobre curvas de nivel. Con los datos de precipitaciones máximas cada 24 horas y parámetros de la Ley de Gumbel modificada, se obtuvieron las ecuaciones de altura de lluvia máxima diaria, (h_{dT}), altura de lluvia para una duración ´´t´´(h_{tT}), y la curva Intensidad Duración Frecuencia (I_{tT}), para una duración de t<2h. Luego considerando los valores de infiltración básica, cubierta vegetal, tipo de suelo y condición hidrológica, se determinaron los números de curva para diferentes condiciones de humedad del suelo, posteriormente se calculó la longitud de separación (L) entre las Media Lunas, y los bordos en contorno, mismas que se diseñaron mediante 10 configuraciones entre el diámetro y la altura, para las dos infraestructuras, encontrándose en Copacabana Valle, la mayor distancia de separación.

Infiltración, Media lunas, Bordos en contorno

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1. Introduction

The high animal load supported by water recharge areas in the endorheic Tajzara basin has produced considerable degradation of the soil and vegetation, with a worrying decrease in water recharge flows. [10] Causing the ecological imbalance in the different ecosystems, which are manifested in: a) the gradual disappearance of desirable plant species, b) the decrease in plant cover, c) slow recovery of flora. As an ecosystem response to the aforementioned disturbance, invasive plant species of low nutritional value appear (successional regression), the consequence of which is the loss of forage capacity and the quality of native pastures, which is manifested in the weakness of the animals and their little resistance against diseases and low production of meat and wool [14].

[8] In the case of degraded grasslands in the basin, they mention, surface runoff can be managed to increase water availability, and promote the development of grasslands and shrubs with higher forage value, favor infiltration and increase recharge flows. subsurface and underground hydric. In addition, it is essential to know the autoecology of the species, which is associated with climatic and edaphological conditions, as well as the altitudinal distribution. [15]

On the other hand [3] they explain that this is achieved by concentrating and storing rainwater in the form of runoff in a certain space. According to [9], runoff collection systems consist of an impluvium area, which generates runoff, and a reception area, which receives runoff water. In the case of the endorheic basin of Tajzara, tholares and pastures of higher forage value will be planted in the reception area, whose water needs will be satisfied by the surface runoff captured in the impluvium area, contributing to increase the useful life of the land. that every year decreases and this is due to natural phenomena and human activity. [1]

According to [13], the water storage capacity is given mainly by the height of the board, and by the volume excavated to form the small dam, to mitigate the fact that the board has to support the entire volume of interior water. In addition, Analyze the challenges of adaptation in the framework of water management in the face of climate change [12]

2. Methodology

The Lagunas de Tajzara endorheic basin, internationally known as the Ramsar 1030 site, is located in the second municipal section of the Avilés province of the Tarija department, Bolivia, it has an area of 47,233.20 ha. At an altitude of 3,400 meters above sea level [11].

Climate exerts great influence on the environment, acting as an interaction factor between biotic and abiotic components [6]. Among the criteria, they consider texture as a parameter related to the water retention capacity and its permeability [2], in the face of the erosion process in the adopted hydrological design, for infiltration ditches, because it is a water collection system oriented to redistribute surface runoff towards water recharge, while Bordos en Contour (BC) and Media Moons (ML) are systems to retain runoff and increase water availability in the restoration of vegetation cover, based on the following calculation sequence:

- Obtaining the curves I-D-F, for rains of maximum intensity.
- Calculation of the design rain for a certain duration and return period.
- Quantification of surface runoff, according to the hydrological conditions of the soil, infiltration capacity and vegetation cover.
- Determination of the length of separation between the collection systems, considering the magnitude of the surface runoff and the dimensions of its storage area, based on the “non-exceedance” criterion.

The intensity of the design rain is determined by applying the equation of the I-D-F curve, obtained by the method of Modified Gumbel's Law according to the methodological criteria suggested by [10-7].

$$I_{t,T} = \frac{E_d}{t}(\frac{t}{t_d})^{\beta} \cdot (1 + K \log T) \qquad (1)$$

Where:
Ed: Modal value of the maximum daily rainfall height (mm).

$\bar{h}_{d,T}$: Average daily rainfall height (mm).

Sd: Standard deviation of maximum daily rainfall height (mm)

t: Duration of rain (h).
td: Maximum duration of rain (h), for the region td = 3 h was determined.
β: Coefficient of the slope of the curve that is 0.2 for a t <2 h.
K: Modified Gumbel's Law distribution characteristic.
ni: Number of years with maximum daily rainfall for each season considered.
N: Total number of years with maximum daily rainfall of all the stations considered.
T: Return period in years.

According to the criteria of [8], a return period T = 10 years is assumed, which corresponds to a probability of occurrence of 90%, which is consistent with the useful life of the collection systems considered. Likewise, the intensity of rainfall is calculated for a duration t = 1 h, due to its magnitude is representative when incorporating maximum events to the hydrological design of the collection systems. The incorporation of events of less than 1 hour implies designing high cost systems that do not conform to an adequate cost / benefit ratio.

For the calculation of runoff from the impluvium, the suggested criterion [5] was applied, based on the methodology of the Curve Number of the US Soil Conservation Service. When P> 0.05 S, then:

$$Q = \frac{(P - 0.05 \cdot S)^2}{P + 0.95 \cdot S} \qquad (2)$$

With an initial abstraction S equal to:

$$S = \frac{25400}{CN_{II}} - 254 \qquad (3)$$

Being:

Q: Drain runoff from the collection system (mm / h)
P: Maximum rain height for one hour duration (mm / h)
CNII: Curve number value for antecedent moisture condition II (USDA-NRCS, 2004).

Considering the type of vegetation, soil tillage (if necessary), hydrological condition, basic infiltration, and / or soil texture, the Curve Number (CNII) was determined by applying the computer program, Determination of Curve Numbers, designed by [7].

To calculate the length (LIII) of separation between water collection systems, they are deduced from the following expressions:

According to the principle established by [4], to size a water collection system, the continuity equation is considered; contribution - reception (Va = Vr), whose volumes of water are the following:

Volume of impluvium water:

$$V_i = Q \cdot A_i \qquad (4)$$

Geometric volume of the collection system:

$$V_{SR} = h_{SR} \cdot A_{SR} \qquad (5)$$

Volume of precipitation inside the collection system:

$$V_P = I_{t,T} \cdot t \cdot A_{SR} \qquad (6)$$

Volume of infiltration in the reception area of the collection system:

$$V_{INF} = f_c \cdot t \cdot A_{SR} \qquad (7)$$

Where:

Vi: Impluvium volume in m³.
Q: Surface runoff from implude in meters
Ai: Impluvium area in m².
V_{SR}: Volume of the collection system in m³.
h_{SR}: Height of the board in the storage of the collection system in m.
A_{SR}: Storage area of the collection system in m².
V_P: Volume of precipitation in the storage of the collection system in m.
$It_{,T}$: Rain intensity in m / h, for a duration "t" in hours and a return period "T" in years.
V_{INF}: Infiltration volume in the collection system storage area in m³.
fc: Basic infiltration in m / h.

The individualized equations for each of the selected collection systems are the following:

a) Half Moons

For the impluvium area (Ai_{ML}) we have:

$$A_{iML} = D \cdot L + \frac{D^2}{2} \cdot \left(1 - \frac{\pi}{4}\right) \qquad (8)$$

The volume of water generated in the impluvium area (Vi$_{ML}$) between Half Moons, will be:

$$V_{iML} = Q \cdot \left[D \cdot L + \frac{D^2}{2} \cdot (1 - \frac{\pi}{4}) \right] \qquad (9)$$

The geometric volume in the storage area of the crescent (V$_{ML}$), is determined by:

$$V_{ML} = \frac{\pi}{8} \cdot D^2 \cdot h_{ML} \qquad (10)$$

Where:

Q: Surface runoff generated in the implude in m.
D: Diameter of the crescent, which is equal to the width of the beam in m.
L: Horizontal length of separation between half moons in m.
h$_{ML}$: Height of the storage edge of the crescent in m.

Applying the equation of contribution - reception to the collection of water by the Crescent, we have:

$$V_{iML} + V_{PML} = V_{ML} + V_{INF} \qquad (11)$$

In its developed expression it remains:

$$Q \cdot \left[D \cdot L + \frac{D^2}{2} \cdot (1 - \frac{\pi}{4}) \right] + (I_{t,T} \cdot t \cdot \frac{\pi}{8} \cdot D^2) = \frac{\pi}{8} \cdot D^2 \cdot h_{ML} + \frac{\pi}{8} \cdot D^2 \cdot f_c \cdot t$$

Where the separation length (L) between Half Moons can be obtained.

$$L = \frac{\pi \cdot D\left[h_{ML} + t \cdot (f_c + I_{t,T})\right]}{8 \cdot Q} - (1 - \frac{\pi}{4}) \quad (12)$$

The correction to calculate the length (Li) on a slope when θ >0 is:

$$L_i = \frac{L}{\cos\theta} \qquad (13)$$

a) Borders in Contour

The impluvium area for Contour Borders (Ai$_{BC}$) is:

$$A_{iBC} = D \cdot L \qquad (14)$$

The volume of runoff generated in the impluvium (Vi$_{BC}$) is determined by the expression:

$$V_{iBC} = Q \cdot D \cdot L \qquad (15)$$

The geometric volume in the Contour Board (VBC) storage area is expressed as:

$$V_{BC} = h_{BC} \cdot D \cdot d \qquad (16)$$

Where:

Q: Surface runoff generated in the implude between the contour edges in m.
D: Distance between the lateral edges, of the edge in contour, which is equal to the width of the implude in m.
L: Horizontal length of separation between edges in contour in m.

Considering the expression contribution - reception, we obtain:

$$V_{iBC} + V_{PBC} = V_{BC} + V_{INF} \qquad (17)$$
$$Q \cdot D \cdot L + I_{t,T} \cdot t \cdot D \cdot d = h_{BC} \cdot D \cdot d + f_c \cdot t \cdot D \cdot d$$

From where the horizontal length (L) of separation between edges in contour, is equal to:

$$L = \frac{d \cdot \left[h_{BC} + t \cdot (f_c - I_{t.T})\right]}{Q} \qquad (18)$$

The inclined length (Li) for a slope when: θ >0 is:

$$L_i = \frac{d \cdot \left[h_{BC} \cdot t \cdot (f_c - I_{t.T})\right]}{Q \cdot \cos\theta} \qquad (19)$$

The application of all the methods with their respective calculation equations, allowed the dimensioning of the proposed collection systems.

3. Results

For a design rain intensity, I1.10 = 23.1 mm / h, considering a return period T = 10 years, the horizontal separation distances (L), for Half Moons and Contour Borders, with different heights of the border and water storage areas are as follows:

In order to have a safety margin, it is assumed that the length calculated for pre-saturation humidity conditions (LIII), in addition to rounding to the smallest whole number, which will allow meeting the non-exceedance conditions, in both water collection systems. The magnitudes of LIII, considered in the horizontal distance, were adjusted to the slope conditions, according to equation (13), to obtain the inclined separation length (Li), allowing the correct location and implementation of the mentioned collecting measures.

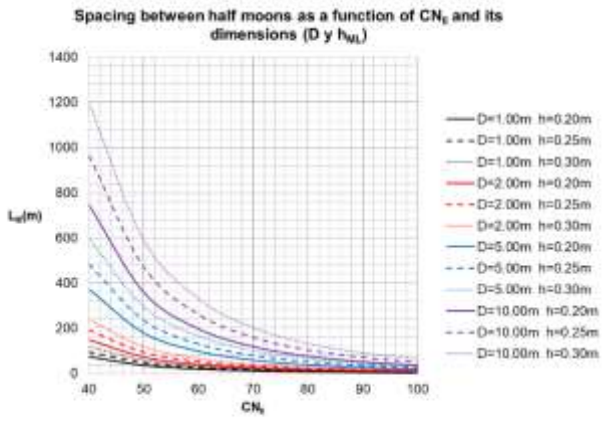

Figure 1 Spacing between half moons

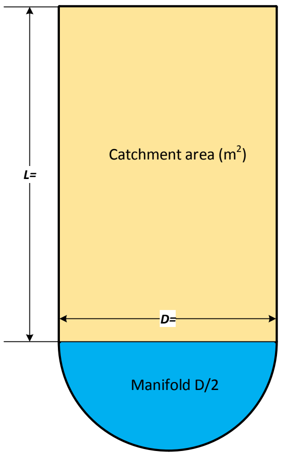

Figure 2 Catchment area between half moons

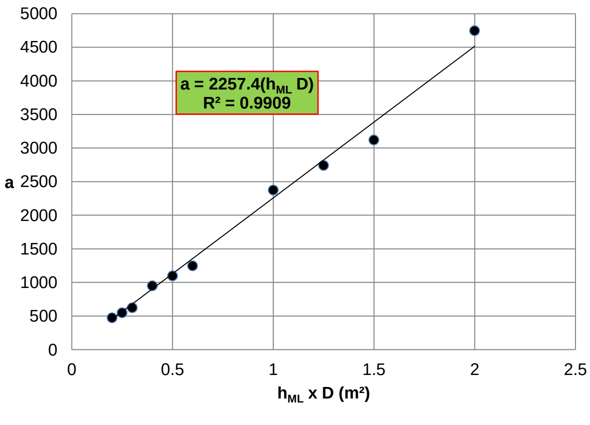

Figure 3 Ratio Coefficient 'a' - (hML x D)

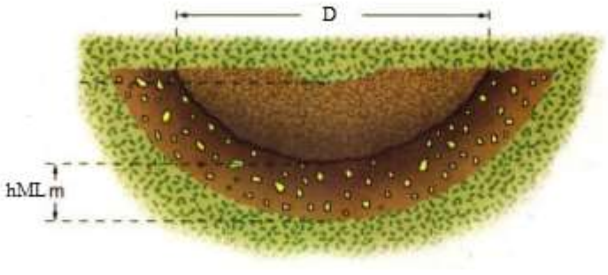

Figure 4 Plan View of (hML x D)

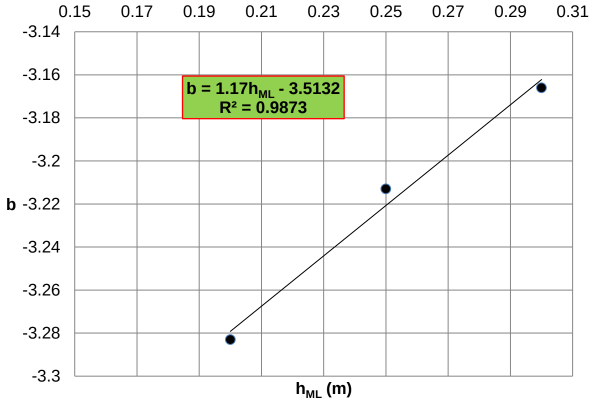

Figure 5 Coefficient 'b'- hML relationship

It can be interpreted in Figures 1,3 and 5, that the amount of surface runoff is subject to the soil conditions and characteristics of the vegetation, which define the infiltration capacity of the impluvium. This explains that, for a greater length of separation between collection systems, the soil and vegetation conditions are favorable for infiltration and water availability, the opposite being the case when there is a shorter separation distance. There is a direct relationship between the storage capacity of the collection system and the surface runoff from the impluvium. Therefore, the greater the geometric dimensions of the water storage, the greater the separation between collection systems.

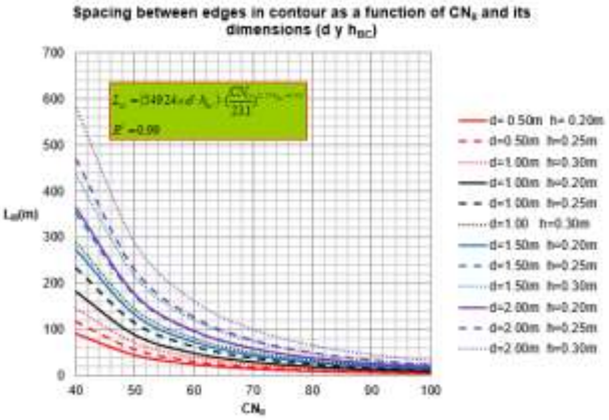

Figure 6 Edge Spacing in Contour

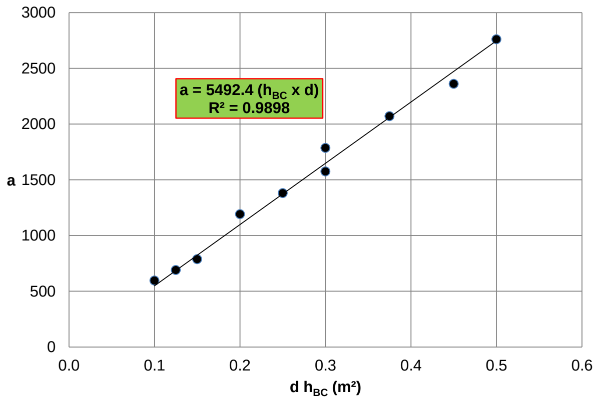

Figure 7 Ratio Coefficient 'a' - (hBC x d)

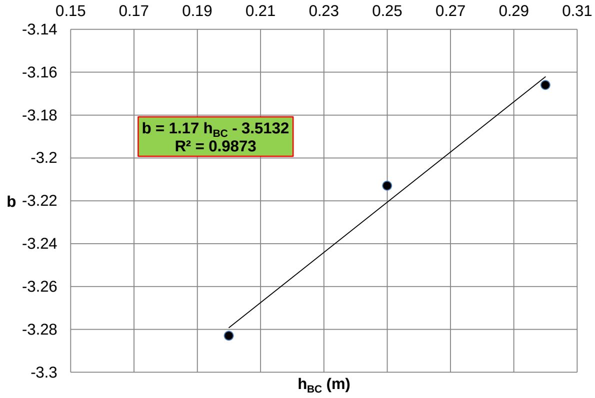

Figure 8 Relationship Coefficient 'b' - (hBC)

In the same way, it can be interpreted in Figure 6, 7 and 8, that the amount of surface runoff is conditioned to the type of soil and characteristics of the vegetation in the area, parameters that define the infiltration capacity of the impluvium. Therefore, it is explained that, for a greater length of separation between collection systems, the soil and vegetation conditions are favorable for infiltration and water availability, the opposite being the case when there is a shorter separation distance. There is a direct relationship between the storage capacity of the collection system and the surface runoff from the impluvium. In other words, the larger the geometric dimensions of the water storage, the greater the separation between collection systems.

The aforementioned is valid for all the HEUs of the basin and for the two collection systems (ML and BC), considered.

Finally, from the aforementioned relationships, the following expressions were obtained for the two water collection systems, which are expressed by the following regression equations.

a) Half Moons

$$L_{III} = \left(2257.4 \times D \cdot h_{ML}\right) \cdot \left(\frac{CN_{II}}{23.1}\right)^{(1.17 \cdot h_{ML} - 3.51)} \tag{20}$$

b) Edges in contour

$$L_{III} = \left(5492.4 \times d \cdot h_{BC}\right) \cdot \left(\frac{CN_{II}}{23.1}\right)^{(1.17 \cdot h_{BC} - 3.51)} \tag{21}$$

Where:

L_{III}: Length of separation between collection systems in m. Considering conditions of antecedent humidity in soil saturation.
D: Diameter of the Half Moons in m.
d: Length of the lateral edge in the BC system in m.
h_{ML}: Height of the ML edge in m.
h_{BC}: Height of the BC in m.
CN_{II}: Curve number for antecedent humidity condition II.

The equations described, constitute expressions of a regionalized model for the dimensioning of the collection systems, from variables of simple determination from the characterization of the site of its location. It should be noted that the regionalization is valid for all the HEUs, considering a design rainfall of 23.1 mm / h at a return period of 10 years.

Figure 9 Photograph of Ramsar Site 1030

4. Conclusions

Overgrazing in the endorheic basin of Tajzara, has caused considerable physical degradation of the soil, with the compaction of the same and the depletion of the vegetation, which, due to the reduction of infiltration and the permanent browsing of the pastures, have led to degradation in the composition of species, the reduction of protection to the soil against the impacts of raindrops, the start of particles and soil erosion, which in synergy alter the hydric flows of recharge to the water sources and wetlands of the basin.

The Water Harvest, expressed by two Water Collection Systems: half-moons and Edges in Contour, constitute green infrastructure measures, which will make viable the restoration of pastures and shrubs with forage value, because before the capture and storage of surface runoff, It will increase the infiltration and the storage of the water available for the development of the plants, in addition to favoring the hydric recharge to springs, wetlands, rivers and wetlands.

For the correct operation of the water collection systems, the hydrological design must consider the criterion of "no exceedance", considering the runoff generated for maximum intensity rain events, with a return period of 10 years. The dimensions of the geometric storage of the collection system must retain runoff volumes from impluvium with adequate lengths of separation between systems, to avoid considerable environmental and landscape alterations, as well as optimizing construction and maintenance costs for Media Moons and Bordos. in Contour.

Regionalized design criteria were obtained, valid for the soil, vegetation and relief conditions that are expressed in the Curve Number (CNII), with a design rainfall of 23.1 mm / h, calculated for a return period of 10 years. which is only applicable to the twelve UEH, of the basin. The regression equations obtained (20 and 21) make it possible to estimate the separation length between collection systems and define the implude area.

For the construction of the collection systems, the construction engineers can design them, considering the geometric dimensions for the storage of water, determining the curve number, from direct observations of the conditions of the soil, vegetation and slope of the construction site, which will enable the correct execution and implementation of the systems, based on easily quantified variables.

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