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Investigation of Soil-Water Erosion in Surface Irrigation System of a Forest Plantation in Libya

Untersuchungen zum Problem der Wassererosion in einer Aufforstungsfläche bei Anwendung der Oberflächenbewässerung

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1. **Introduction**

Soil water erosion is a natural process affected by the velocity of flowing water and the characteristics of the soil. The important of this process is related to the loss of the so-called »relatively rich« surface layers of the soil and the disturbance of even water distribution on arable land.

The current investigation was made on four-years old forest plantation characterized by its sand loam soil. The plantation is part of BIR AYD PROJECT located in GEFARA PLAIN in Libya.

1.1. Geomorphological Description of the Area

The project area streches along the southern side of the main road Tripoli – Gadamis from Km 117 to Km 133. The altitude of the area varies from 140 to 800 m above sea level. Within the project area, 5000 ha are chosen for eucalyptus plantation. It has a gentle slope from southeast toward northwest having a maximum difference in altitude of about 66 m.

There are two different geological conditions which effect the formation of water bearing reservoirs. The deep one is unexplored. The shallow one, which is well-known and used widely, is the Quarternary aquifer and has a good possibility of recharge. Water quality of this aquifer, however, is very poor and not recommanded for direct utilization.

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1.2 Climate

The area is distinguished by its wet season which starts from September to May. In general it is bounded between 200 and 250 mm isohyets. The distance between those two isohyets is 7.5 km. The mean multiannual rainfall is 182.9 mm while the free water evaporation is estimated as 84.9 mm.

Temperature gradually changes from one month to another. The hotest month is August with a mean max. of 32°C while the coldest is January with a mean min. of 9°C. However, the range between absolute max., 50°C, and absolute min., -2°C is very wide. The mean yearly value of relative humidity is about 50%.

1.3. Water resources and means of utilization

Due to the poor quality of groundwater forest plantation must depend upon rainfall and supplementary irrigation. It has been stated that excellent forests in Libya require a mean yearly precipitation from 225 to 350 mm [3], while the mean multiannual rainfall in the project area is 182.9 mm. Therefore, the deficit must be compensated by irrigation water which is collected in a 332 km^2 catchment area. The estimated available volume of runoff in the catchment area is 3.125 Mill. m^3. This volume yields an equivalent depth of 64.3 mm irrigation water delivered to the forest plantation by means of main and lateral asbestos-cement pipelines. Manual gates were installed on the laterals every 7.50 m. In front of each gate a trapezoidal irrigation canal (furrow) was constructed. All canals are parallel and nearly perpendicular to the lateral pipes. Consequently the distance between the laterals determine the length of each canal. The functions of the irrigation canals are mainly distributing water to the end of the field as well as saturating the soil with moisture by means of vertical and horizontal water movement.

2. **Materials and methods**

2.1 Mechanical Analysis of the soil

Four soil samples where collected from the bottom of four canals chosen at a random. The samples were subjected to the mechanical analysis using the hydrometer method as described by Black [1]. The texture of each sample was determined as described in USA-Handbook No. 18 [6].

2.2 Infiltration rate

Infiltration test was carried out using the double ring infiltrometer method as outlined by Black [1]. The test was made on the predominat soil texture of the area under study.

2.3. Surveying of irrigation canals

Due to the large number of irrigation canals in the project only 5% sample was considered for this investigation. Sampling technique was made as follows:

The first canal was chosen at 75 m from the first valve located on every lateral pipeline. The distance between every two successive canals was 150 m. All investigated canals were subject to longitudinal and lateral surveying at every 50 m and 150 m from the intake respectively. The slopes of all segments were grouped into four classes namely reverse slope (less than zero), medium slope (0–0.4%), steep slope (0.4–0.8%), and very steep slope (greater than 0.8%). The observations of the lateral elevation were used to estimated the hetrogenity of the various shapes of the canal bottoms.

2.4. Flow rate of the pipeline

The flow velocity of water in the pipeline has been measured using the Price Current Meter and taking into consideration that the diameter is 200 mm and the pipe has full active cross-sectional area. The discharge was then calculated using the continuity equation:

$Q = av$...............(1)

where
Q = discharge of the pipeline in m^3/sec.
a = cross-sectional area of the pipe in m^2
v = flow velocity in the pipeline in m/sec

3. **Results and Discussion**

3.1. Mechanical Analysis

Due to the fact the bottom of the irrigation canals is the subject of this erosion study, four samples were collected and analysed to evaluate the soil texture. The results show that three samples are sandy loam, whereas the fourth is sandy clay loam. Weighed averages for the various soil flactions separates were calculated and are presented in table 1.

Table 1: Weighed Averages of the Mechanical Separates of BIR AYAD SOIL

Fraction	Diameter (mm)	Per cent
Sand	2.000 – 0.020	64.8
Silt	0.020 – 0.002	20.0
Clay	less than 0.002	15.2

3.2. Infiltration Rate

For furrow irrigation it is well-known that the depth of irrigation water should not be greater than the basic intake rate in order to avoid the susceptibility of the irrigation furrows to erosion. Concerning the slope of the instantenous intake rate (m-value), limits were made by [4] for the suitability of the soil for surface irrigation. Therefore an infiltration test was carried out and the result of this test shows that the basic intake rate equals to 2.0 cm/hr. which classied as moderately slow [1]. The data were plotted on log-log paper in order to derive the n-parameter from equation (2).

$D = cT^n$...............(2)

where
D = accumulated intake of the soil in mm
c = accumulated intake intercept at unit time, 2.31 mm
T = time that water is on the soil surface in min.
n = slope of the curve, 0.47
$m = n - 1.00 = -0.53$
= slope of the curve of instantaneous intake-rate

As m-value lies between 0.4 and 0.7 thus the soil is suitable for surface irrigation.

3.3. Surveying of the Canals

According to the sampling technique, 1203 observations were made on 118 canals. The length of the surveyed canals widely vary from 50 m to 1240 m. Regardless of the degree of slope, only 28 canals were shorter than 250 m which is considered as the allowable length in sandy loam soil [2]. The analysis of the longitudinal slopes show that 2.58% of the total canal length have reverse slope and 40.04% have medium slope while 57.38% have steep and very steep slopes.

Although the segments of the canals which have steep and very steep slopes must be rejected, yet the most serious problem will be caused from reverse slope segments. The lateral slopes of the canal bottoms have various shapes such as concave, convex, horizontal and evenly sloped towards the right or left. These variations are attributed to the two-dimensional uneven construction of the canals.

3.4. Flow Rate of the Pipeline

The value of the measured velocity of the water outflow from the pipeline through the gate (v) is 0.89 m/sec. As the cross-sectional area of the outlet is 0.0314 m^2, hence the discharge of each gate (Q) equals 28 l/sec. This value will not be considered harmful to soil erosion [7].

3.5. Mechanism of Soil-Water Erosion

The mechanism of soil-water erosion is mainly dependent upon the interaction of the most important two parameters namely degree of slope and horizontal length of the canal as expressed in equation (3):

$Y = f(S, L)$ ....(3)

where
Y = soil loss
S = degree of slope
L = horizontal length of the canal

The S-variable is a parabola-type equation as it fits the data better than other suggested equation. Based on this, the expression: $0.18 + 6.84\ S + 112.51\ S^2$ is substituted for S in the basic function for computing soil loss. On the other hand, L-variable is an exponential type equation. For simplicity a value of 0.5 could be used for the exponent of L [5]. Taking into consideration the base table given by Richey [5] for up and down hills equation [4] was derived for the soil loss in the following type:

$$Y = c\ [(0.18 + 6.84\ S + 112.51\ S^2)\ L^{0.5}] \ldots\ldots (4)$$

where
Y = soil loss, ton/ha. year
c = constant, 2.471
S = degree of canal slope, per cent
L = horizontal length of canal, meter

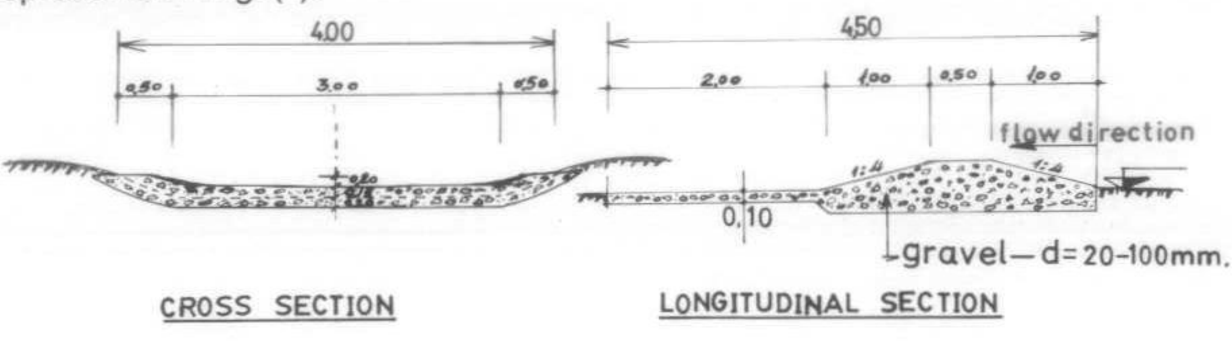
The permissible soil loss should not exceed 7.413 ton/ha and year. Accordingly the relationship between the degree of slope and length of canal can be presented as follow:

L (m)	50	100	150	200	250	278
S (%)	2,53	1.43	0.83	0.44	0.14	0.00

Appling equation (4) it is found that the soil loss for only 7 out of 118 investigated canals is below the permissible limit. The expected soil loss for the other canals is twice the permissible limit.

4. Conclusion

Since the flow rate is below the permissible limit and as the result of the infiltration test reveals the soil is suitable for surface irrigation, therefore the degree of the slope and length of canal were combined in an equation for computing the expected soil loss. Upon application of the derived equation, it is found that only 6% of the canals in the project area give soil loss below the permissible limit. For the remaining canals, it is recommanded to construct stills in order to minimize the effect of the slope and length of the canals. The suggested design of the sill is represented in fig. (1).



5. **Summary**

A investigation of the nature of soil water erosion was carried out on a four-year old forest plantation in the Bir Ayad Project Libya characterized by its sandy loam soil and surface irrigation system. The data obtained form infiltration tests reveals that the soil is suitable for surface irrigation. The inflow rate into the cannals lies below the erosive velocity. Regarding the degree of slope only 28 out of 118 investigated canals could be accepted. On the other hand, upon the application of an equation which was derived for the calculation of the expected soil loss, only 7 canals were below the permissible limit. It is recommanded to construct sills in order to minimize the negative effect of the slope and length of the canals.

Zusammenfassung

In der vorliegenden Arbeit werden Untersuchungen zum Problem der Bodenerosion in den Furchen eines Oberflächenbewässerungssystems in Libyen dargestellt. Bei der Versuchsfläche handelt es sich um eine aufgeforstete Fläche von 5000 ha im Rahmen des Bir Ayad Project. Die Infiltrationsmessungen des sandigen Lehmbodens haben ergeben, daß der Boden zur Oberflächenbewässerung geeignet ist. Die Zuleitungsrate liegt nach den vorliegenden Berechnungen unterhalb des errechneten Grenzwertes. Unbefriedigend sind die Gefälleverhältnisse in den »Bewässerungsfurchen« nur 28 der 118 untersuchten Furchen entsprechen den Anforderungen. Unter Anwendung der bekannten Bodenverlustformel wurde der zu erwartende Bodenverlust kalkuliert. Hier zeigte sich, daß nur 7 Bewässerungsfurchen unterhalb der zulässigen Bodenverlustwerte liegen. Um dem Bodenerosionsproblem zu begegnen, schlagen die Autoren den Einbau von Schwellen vor.

6. **Reference**

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