Design and Construction of Negarim Micro-Catchment System for Citrus Production

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Abstract

Negarim Micro-Catchment system was designed and constructed in the study , and Catchment Run-off Coefficient was evaluated based on the actual field measurements of rainfall and runoff for the period of three months, using Rainguage and collection Tank installed within the study area. The results of the evaluation revealed that, the average of crop water requirement of Citrus is 3.63mm/month .That on average, an annual rainfall of 1162mm or higher can be expected at 50% probability of occurrence and at an average frequency of occurrence of 3 years. The average catchment-cultivated area ratio (C:CA) estimated is 1.0478. The chemical analysis test carried out on the soil samples of the study area reveralled that, the salinity, infiltration rate, toxicity and fertility level of the soil in the study area are at satisfactory level based on the guideline for the interpretation of water quality(FAO) . Finally,the mean Catchment Run-off coefficient estimated throughout the period of observation is 3.85.

Keywords: Water harvesting, Runoff -Coefficient, Micro -Catchment, Catchment area, Cultivated area, Catchment area, Infiltration Pit.

1. Introduction

Harvesting runoff is a process of collecting runoff on the field and simultaneously conserving it for use by crop.The importance of collecting and conserving runoff cannot be over emphasized in our society especially, in the semi-arid drought prone areas where it is already practiced, it is a directly productive form of soil and water conservation.Crop yields and reliability of production can be significantly improved with this system. Negarim Micro-catchment is one of the water -harvesting schemes for tree production and are diamond – shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each (FAO 1991). Runoff is collected from within the basin and stored in the infiltration pit. Micro-catchments are mainly used for growing trees or bushes. This technique is appropriate for small-scale tree planting in any area which has a moisture deficit. Besides harvesting water for the trees, it simultaneously conserves soil. Negarim micro-catchments are neat and precise, and relatively easy to construct.

Pacey and Cullis (1986) described Micro-catchment techniques for tree growing, use in Southern Tunisia, which were discovered in the nineteenth century by travelers.Critchley and Reij (1989), observed that a number of water harvesting projects have been set up in Sub-Saharan Africa during the past decade and their objectives have been to combat the effect of drought by improving plant production (usually annual food crops), and in certain areas, rehabilitation abandoned and land degraded.

It is in the light of the above that, this project work is aimed at design and construction of Negarim Micro-Catchment , and evaluation of Run-off co-efficient for the study area.

2. Material Selection and Constructional Procedure

Material selected for this system was based on some factors and Engineering requirements. Such factors include: soil texture, soil structure, soil depth, soil fertility, soil salinity and sodicity, infiltration rate , available water capacity and availability of materials.

The constructional procedure mainly involves clearing land, field layout and formation of bunds. In the construction of the component part, the tracing were first made on the paper before it was transferred to the field .The bunds were constructed with Hoes and Spade. After the construction, seedlings (Citrus) were planted immediately after the first rainfall in the season.

3. Methodology

The study was carried out at the department of Agricultural Engineering and Water Resources Experimental plot, Kwara State Polytechnic, Ilorin ($08^o36'$N and 04^o29E) at an elevation of approximately 344.13m and the total area of the field used is $292.74m^2$.

3.1 Determination of crop water requirements

It is necessary to assess the water requirement of crop intended to be grown (citrus). Ten years of climatic data (evaporation rates) were obtained (1992-2002), from National Centre for Agricultural Mechanization, Idofian, Kwara State. The daily evaporation values obtained were summed and averaged to obtain the mean daily and monthly evaporation rates. The monthly evaporation rates (E_{pan}) have to be multiplied by pan coefficient (K_{pan}) to give reference evapotranspiration. Thus:

$$ET_o = E_{pan} \times K_p \tag{1}$$

Source: Jacob and Satti (2001)

For class A evaporation Pan, K_{pan} varies between 0.35 and 0.85, with an average value of 0.70 (FAO,1991). The average K_{pan} was multiplied by mean monthly evaporation rates to determine the mean monthly reference evapotranspiration (ET_o). This was finally multiplied by the crop coefficient to get the crop water requirement.

2.3.2 Soil physical and chemical analysis

Nine soil samples were randomly collected at the depth of about 30 – 55cm using soil auger and were taken to soil laboratory for both physical and technical analysis.

Triaxial texts were performed using sieves of various pores diameters and sizes from 0.0 – 0.2, in order to evaluate the suitability of the in-sity soil for water harvesting system.

Parameters evaluated include; Electrical Conductivity (ECw), Cations and Anions (Ca^+, Mg^{++}, Na^+, CO_3, HCO_3, Cl^-, SO_4), Nutrients (Nitrate – Nitrogen NO_3 – N, Ammonium – Nitrogen NH_4^- - N, Phosphate – Phosphorus PO_4 – P, Potassium K^+), Acidity/Basicity (PH) and Sodium Adsoprtion Ratio (SAR). Soil salinity was also measured using saturated paste method.

2.3.3 Probability analysis

The design rainfall is usually assigned to a certain probability of occurrence or exceedence. The design rainfall was determined by means of a statistical probability analysis. Ten years of annual rainfall totals (from NCAM; 1992 – 2002) were used for this analysis. The probability of occurrence P(%) for each of the ranked observations were calculated as thus:

$$P(\%) = \frac{M - 0.375}{N + 0.25} \times 100 \quad (2)$$

(Source: FAO (1991))

where,

P = probability in (%) of the observation of rank (m)

M = the rank of the observation and

N = total number of observations used.

Then, ranked observations were plotted against the corresponding probabilities, using normal probability paper and the curve generated was straight line in nature. Finally, the return period (T) was then derived, since the exceedence probability P(%) was known;

$$T = 100/ P \text{ (years)} \quad (3)$$

2.3.4 Design model for catchment-cultivated area ratio:

For an appropriate design of a (WH) system it is required to determine the ratio between catchment (C) and cultivated area (CA). This can be computed using the following equation:

Catchment Area/Cultivated Area = Crop Water Requirement – Design Rainfall/ Design Rainfall x Run-off Coefficient x Efficiency Factor (4)
Source: FAO (1991)

The run off coefficient value ranges between 0.1 and 0.5 with average value of 0.3 and efficiency factor ranges between 0.5 and 0.75 with average value of 0.625 were used to determine C:CA by substituting the known value of crop water requirement and design rainfall in equation 4.

2.3.5 Field layout and construction

The first step is to establish the contour line and the ground slope which was done using a line level (FAO 1991). By means of a measuring tape, the tips of the bunds were marked along the 'straightened contour'. The first line was open – ended. The distance between the tips (a – b) is 4.2cm which depends on the selected catchment size of 3m x 3m (Table 1).

A piece of string as long as the side length of the catchment (4.2m for a 3m x 3m) was held at one tip (a) and a second string of the same length at the other tip (b).

3. Results

An analysis of Rainfall – Runoff relationship and subsequently an assessment of relevant runoff coefficient (k) for the catchment was based on actual simultaneous measurements of both rainfall and runoff in the project area.

Rainfall and runoff readings taken after every rainfall event were averaged and used to compute runoff co-efficient for the catchment. The average runoff co-efficient across the period of observations is 3.85 and presented in table 4.

4. Conclusion

Negarim Micro-catchment system is appropriate for small scale tree planting, especially relevant to semi-arid and avid areas where the problems of environmental degradation, moisture deficit, drought and population pressures are most evident.

It is an important component of the package of remedies for these problem zones and therefore, there is no doubt that implementation of water harvesting techniques will expand in Nigeria.

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Table1: Crop water requirement

Year	ETc (mm/month)
1993	3.43
1994	3.50
1995	3.55
1996	3.85
1997	3.51
1998	3.69
1999	3.13
1999	4.08
2001	3.53
2002	4.15
Total	36.32
Mean	3.63

Table 2: probability analysis

Year	R (mm)	M	P (%)	T (year)
1993	1501	1	6.1	16.00
1994	1392	2	15.9	6.00
1995	1349	3	25.6	4.00
1996	1253	4	35.4	3.00
1997	1145	5	45.1	2.00
1998	1095	6	54.9	2.00
1999	1079	7	64.6	2.00
2000	1072	8	74.4	1.00
2001	1015	9	84.1	1.00
2002	721	10	93.9	1.00
Total	11620		500	38
Mean	1162		50	3.0

Table 3: Catchment-cultivated area ratio

Year	C:CA
1993	0.84
1994	-0.13
1995	-0.30
1996	1.82
1997	-0.52
1998	0.89
1999	-1.39
2000	1.90
2001	1.398
2002	1.97
Total	10.478
Mean	1.0478

Table 4: Runoff coefficient from field measurement

Rainfall event	Runoff (mm)	Rainfall (mm)	(K) Runoff/Rainfall
26/06/09	5.0	7.0	0.71
4/07/09	25.0	20.0	1.25
7/07/09	544.0	51.0	9.0
9/07/09	540.0	60.0	1.42
11/07/09	580.0	50.0	3.63
13/07/09	420.0	160.0	3.62
16/07/09	10:0	116.0	0.5
20/07/09	596.0	20.0	3.51
18/08/09	385.0	170.0	4.28
24/08/09	550.0	90.0	3.79
Total			42.38
Mean			3.85

Table 5: Guidelines for Interpretations of water Quality for Irrigation

Potential Irrigation Problem		Units	Degree of Restriction on Use None	Slight to moderate	Severe
Salinity (affects crop water availability)					
	EC_w	dS/m	<0.7	0.7-3.0	>3.0
	(or)				
	TDS	mg/l	<450	450-2000	>2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)					
SAR	= 0-3 and EC_w =		>0.7	0.7-0.2	<0.2
	= 3-6 =		>1.2	1.2-0.3	<0.3
	= 6-12 =		>1.9	1.9-0.5	<0.5
	= 12-20 =		>2.9	2.9-1.3	<1.3
	= 20-40 =		>5.0	5.0-2.9	<2.9
Specific Ion Toxicity (affects sensitive crops)					
	Sodium (Na)				
	Surface irrigation	SAR	<3	3-9	>9
	Sprinkler irrigation	me/l	<3	>3	
	Chloride (Cl)				
	Surface irrigation	me/l	<4	4-10	>10
	Sprinkler irrigation	me/l	<3	>3	
	Boron (B)	mg/l	<0.7	0.7-3.0	>3.0
	Trace Elements				
Miscellaneous Effects (affects susceptible crops)					
	Nitrogen (NO_3-N)	mg/l	<5	5-30	>30
	Bicarbonate (HCO_3)				
	(overhead sprinkling only)	me/l	<1.5	1.5-8.5	>8.5
	pH		Normal Range 6.5-8.4		

Source: FAO (1985): Water Quality for Agriculture

Table 6:Cost Analysis of the project

COST ANALYSIS OF THE PROJECT

S/N	DESCRIPTION OF ITEMS	QUANTITY	UNIT PRICE (₦)	AMOUNT (₦)
1.	Design diagram	-	-	5, 000:00
2.	Soil sampling and analyses	-	-	10, 000:00
3.	Land clearing and preparation	-	-	5, 000:00
4.	Planks	15	1,000	15, 000:00
5.	Loading and transport of planks	-	-	5, 000:00
6.	Field layout and construction	-	-	7, 000:00
7.	Collection tank	1	-	6, 000:00
8.	Seedlings (citrus)	18	500	9, 000:00
9.	Labour/man-hour	5	1,000	5, 000:00
10.	Field measurement/data collection	-	-	5, 000:00
		SUM TOTAL		**72, 000:00**
	Contingency	10% of Total Cost		7, 200:00
		GRAND TOTAL		**79, 200:00**

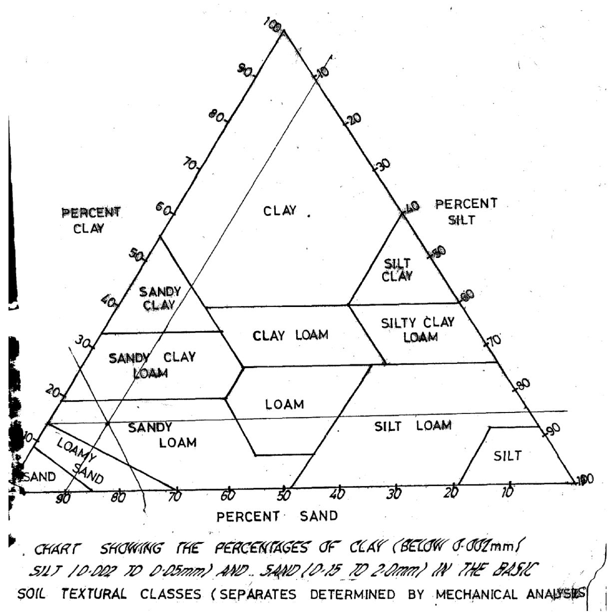

Fig. 1. Guide for textural classification (U.S.D.A)
Source: USDA (1986)

SOIL ANALYSIS LABORATRY REPORT SHEET

SAMPLE COLLECTOR   LOCATION: DATE: SENDER'S SERIAL NO.

Soil Acct. No./Lab. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Field No.		A								A									
STANDARD DIAGNOSTIC CHARACTERISTICS																			
Depth of horizon or soil layer in (cm.)		0-55								0-55									
Gravel or concretions %		NONE								NONE									
Caco3 (Calcium Carbonate) %		NONE								NONE									
Coarse Sand (200–2000mu)																			
Sand %		74.00								74.00									
Silt (2–50mu)%		11.00								11.00									
Clay(< 2mu)%		15.00								15.00									
Textural classes (U. S. D .A Textural triangle		SL								SL									
Organic cabon% (Walkley & Black)		0.49								0.49									
Organic matter %		0.85								0.85									
Total Nitrogen (Kjeldahl) %		0.07								0.07									
Nitrate Nitrogen %		– –								– –									
PH - Water (Suspension 1:2) (P^H)		7.10								7.10									
PH - Kc l (Suspension 1:2) (P^H)		6.50								6.50									
EC - 2 (Extract 1:2½)		0.00								0.00									
Exchangeable cations Ca Cmol/Kg. of Soil		2.10								2.10									
Mg. Cmol/Kg. of Soil		0.90								0.90									
K. Cmol/Kg. of Soil		0.023								0.023									
Na Cmol/Kg. of Soil		0.10								0.10									
Exchangeable acidity Cmol/Kg. of Soil		0.20								0.20									
Cations Exchange Capacity (C.E.C.) Cmol/Kg. of Soil		3.32								3.32									
Base saturation Percent %		94.10								94.10									
Exchangeable sodium Percentage (E.S.P.) %		3.01								3.01									
Available Phosphorus (Bray I) ppm		15.10								15.10									
Lime. Requirement (Kg./ha of Ca Co3		—								—									
Water saturation Percent %		40.00								40.00									

KEY TO TEXTURAL CLASSES:–

(i) S — SAND
(ii) LS — LOAMY SAND
(iii) SL — SANDY LOAM
(iv) L LOAM
(v) SL -- SILTY LOAM
(vi) SI — SILT
(vii) SCL — SANDY CLAY LOAM
(viii) CL — CLAY-LOAM
(ix) SCL — SILTY CLAY LOAM
(x) SIC — SILTY CLAY
(xi) SC — SANDY CLAY
(xii) C — CLAY

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Printed by: Damokun Printers, Ilorin. 01-069

Figure 2: Soil Analysis Laboratory Report Sheet