Universal Journal of Agricultural Research 10(3): 185-192, 2022 http://www.hrpub.org
DOI: 10.13189/ujar.2022.100301

Assessment of Transverse Runoff in the Terraced Area for Adaptation and Mitigation of Climate Change

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Received February 28, 2022; Revised April 29, 2022; Accepted May 23, 2022

Cite This Paper in the following Citation Styles

(a): *[1] Ricson L. Ines, Ronald E. Garcia, Benedicto D. Torres, Zoila M. Duque , "Assessment of Transverse Runoff in the Terraced Area for Adaptation and Mitigation of Climate Change," Universal Journal of Agricultural Research, Vol. 10, No. 3, pp. 185 - 192, 2022. DOI: 10.13189/ujar.2022.100301.*

(b): *Ricson L. Ines, Ronald E. Garcia, Benedicto D. Torres, Zoila M. Duque (2022). Assessment of Transverse Runoff in the Terraced Area for Adaptation and Mitigation of Climate Change. Universal Journal of Agricultural Research, 10(3), 185 - 192. DOI: 10.13189/ujar.2022.100301.*

Abstract The inland water regime is a major problem in crop production due to the irregular formation of the soil surface which includes water as the main factor for crop production. The objectives of the study were to measure and evaluate the performance of intercepted in terms of trapped soil sediments, water storage capacity, and crops produced through economic analysis. The research was carried out at BPSU, Bangkal, Abucay, Bataan, Philippines (North 14°46' East 120°30'). During the study period, the average yearly rainfall depth at BPSU-AWS Station was 2,899.4 mm, whereas the average rainfall depth from January 2019 to May 2020 was 4,059.6 mm. Four benches or terraces were built, along with four runoff interceptors. The runoff interceptor, which retained water during a rainy runoff event, is 131.6 meters long and 0.5 meters wide by 0.4 meters deep. A total of 26.32 m^3 of water was stored. Vertisols were the type of soil (Antipolo Clay). At the peak of the first-year season, 4.11 m^3 of soil was eroded within the runoff interceptor (4,808.7 kg of dry soil). In 284.5 m^2, three rice varieties were sown. Rice was harvested with a total weight of 248.5 kg. Three vegetable crops were planted during the second crop, while Wax Pepper had the highest gross income. The ROI and payback period for the two seasons studied were 0.09 percent and 11.05 years, respectively. Water stored in runoff interceptors can be used to supplement irrigation water for the production of rice, high-value crops, and crops with low water requirements.

Keywords Runoff Interceptor, Soil Sediments, Irrigation, Terraced, High-Value Crops, Bataan Philippines

1. Introduction

Climate change can be defined as a major shift in climate within a region as a result of reckless human actions as measured by common indicators such as rainfall, temperature, and air quality.

The Philippines had excessive rainfall but was not uniformly distributed within the country. The unexpected distribution consequences to runoff, flooding, erosion, and water deficit during the dry season. Therefore, part of heavy rainfall water is for supplemental purposes during water scarcity [1].

The water system within the upland is one major problem in crop production due to irregular soil surface configuration. Soil surface layout is one component to consider while deciding on a production area that includes water, which is the most important factor in crop productivity. Due to this soil aspect, few areas are non-productive.

Although the rainfed upland crops, permanent and seasonal, are established in sloping agricultural land technology (SALT) when long season drought comes, without a source of irrigation water, still sustainability in yield won't meet [2][3].

To mitigate and adapt to global climate change within the hilly areas, rainwater harvesting will solve the problem of the water system within the highlands [4][5]. In rainfed areas, water storage is used to provide supplemental irrigation water during the dry season and for the production of seasonal crops. Aside from irrigation, the water in the interceptor could be utilized for small-scale livestock watering and basic soil sediment study [6].

During the season, water in the mountains usually goes to rivers right down to lakes and oceans, which is the chance for farmers to store free water from rainfall in anyways, to use when the dry season's crops produce.

The stored water from the established runoff interceptor within the upland area was utilized in rice production (July to November) and thus the area was planted with vegetables (November to June) just after rice production.

The main objective of the study was to assess and evaluate the performance of the runoff interceptor as influenced by hydrological and economic factors, and to assess and evaluate the established permanent and seasonal crop yield: assess the performances of runoff interceptor in the terraced area and trapping sediment; evaluate water management and irrigation strategies using the stored water, particularly high-value crop production; to assess and evaluate the economic advantage of the system in crop production.

The study for crop production, water management strategies using runoff interceptors as a water container, and utilization of stored water for crop production.

1.1. Importance

The establishment of water storage within the upper reaches of the watershed might be a defense against floods at the same time for irrigation and erosion control [7]. The establishment of water storage uses the surface runoff water to conserve soil, and water for productive use. Apart from uses, stored water in the container eradicates evaporation, seepage, and percolation losses during storage compared to an open-pit small farm reservoir. The study specializes in the physical performance of the water storage within the upland and its economic impact [8].

Sediment trapped within the runoff interceptor will return to the production area by desilting. Trapped can store more water for incoming rainfall as a source of water. Sediment that flows along with surface runoff freely may cause nutrient losses from original soil and pollution to bodies of water downstream resulting in the reduction of aqua-marine life if the soil sediments are not trapped.

Change in the environment makes people search for adaptation and mitigation strategies to survive the changing world condition. Mountains and soil fertility will degrade for a certain area. The production of crops, fish, and livestock will decrease because the volume of water we extracted will decrease. Groundwater conditions will also change, the aquifer will pollute, and salt intrusion will experience.

The technology that stores water within the upland area will ensure the availability of irrigation water even if there's global climate change, specifically the unpredictable occurrence of rain during crop growth development, still we've enough water for irrigation.

2. Methodology

Includes and present the materials used, the crop used in the study, the site identified, the preparation of the experimental area, data gathered and monitored during the experimental design, and data analysis.

2.1. Conceptual Framework

The framework and its discussion illustrated the input, process, and output of the study. The area identified was cleared, terraces or benches, and a runoff interceptor was installed while farm inputs were procured (INPUTS). Rice will be raised on terraces formed during the rainy season while collecting rainfall depth, growth parameters, and crop yield. The use of the accumulated water in the runoff interceptor was followed by vegetable development. Growth and yield (PROCESS) are also obtained. At the end of two seasons, the volume of soil sediments, evaluated irrigation method, yield, and cost-benefit, were recorded and analyzed (OUTPUT) (Figure 1).

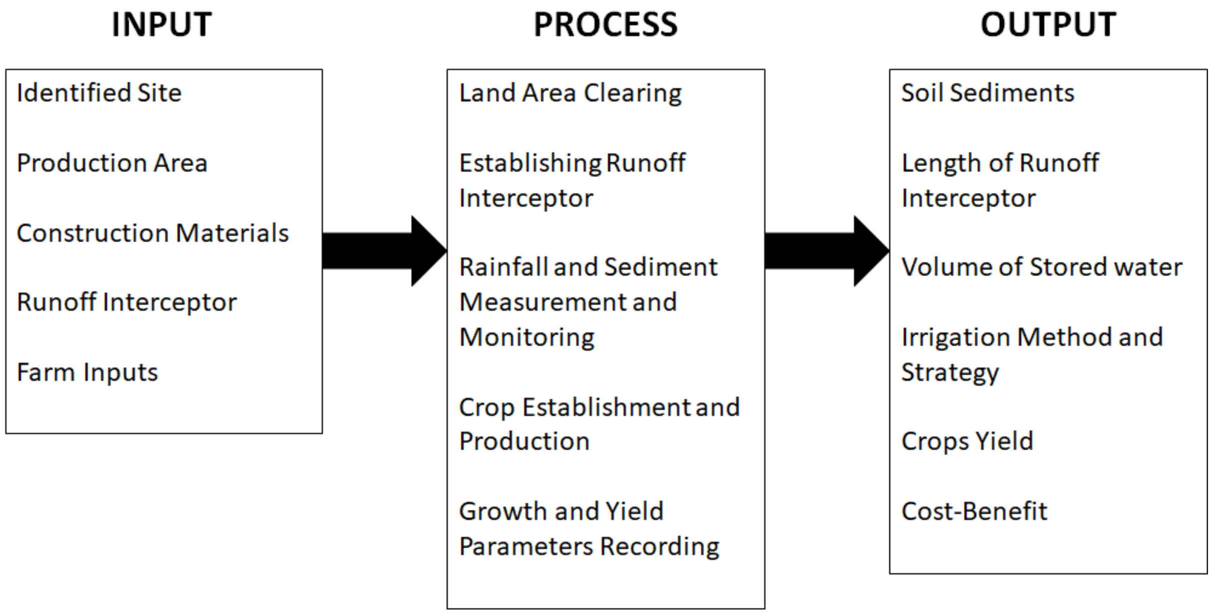

Figure 1. Conceptual Framework

2.2. Materials

Seasonal crops are to be raised and produced within the benches established.

(a) Rainy season crop. Rice will be raised in the rainy season as the main crop
(b) Second crop. High-value crops will be raised, such as eggplant, tomato, and wax pepper.
(c) PE pipes. Used as drainpipes and for manual irrigation.

2.3. Identified Site

The study area was located in the BPSU Abucay Campus, Bangkal, Abucay, Bataan. The area has grasses of different species at 2 – 2.5 meters in height. The identified site was sloping (17% - 30%) with an area of 1,000 square meters (25 x 40 m) including the catchment area, however, the production area was 284.5 square meters. The soil was vertisols (Antipolo Clay). The length was from east to west and the width was from south to the north. The sloping area was formed into benches through manual digging and earth movement using hoes and spades.

2.4. Runoff Interceptor

For each of the four benches [9] created by manual digging and constructed lined canal interceptors, Runoff interceptors were built (Figure 2). The runoff interceptor will be evaluated by calculating the catchment area, rainfall depth over the volume of water held in the interceptor (capacity), and the volume of water used for agricultural production.

2.5. Crop Production Establishment

The area defined (Figure 2) will be used for tillage and crop management using the machinery available. Seasonal crops of high value will be included in the analysis. Three rice varieties were initially soaked for pre-emergence during the rainy season and developed by manual seeding at the benches. It was cleared after rice, while seedlings of high-value crops were prepared. Twenty-four (24) eggplants, 20 tomato plants, and 32 wax peppers were planted in terraced shaped manually at the recommended distance.

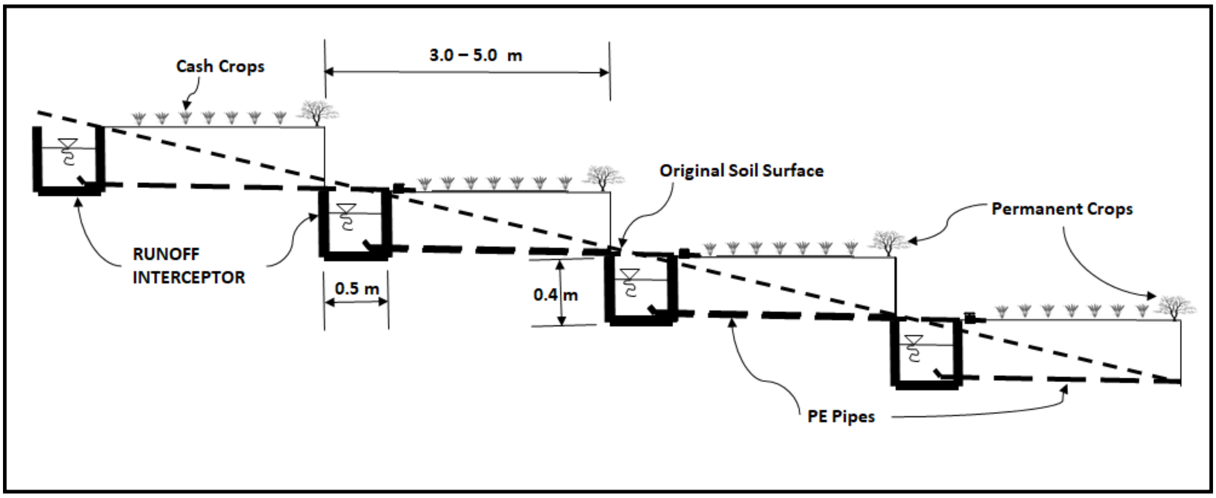

Figure 2. Experimental setup

2.6. Crop Management and Conservation

Weeding. Regular monitoring of the weed emergence and removal eradication.

Fertilization. Fertilizer will be split application for rice, also with the vegetable production using both organic and inorganic fertilizers.

Irrigation. Stored water in the runoff interceptor will be used as irrigation water in crop production considering the water requirement of crops established. A manual overhead irrigation method was used.

2.7. Data Gathering and Collection

Rainfall depth, amount of stored water, volume and weight of soil silted in the runoff interceptor, growth and yield parameters in crop production, irrigation strategies, and water use efficiency were the data collected and gathered. The result was analyzed after the analysis, considering products and total revenue.

2.8. Experimental Design and Data Analysis

Using regression analysis, experimental design, and using F-Test for the significance of the data obtained, the compiled data from the study were analyzed.

Table 1. Rainfall depth (mm) during the study period

Month (January 2019 – May 2020)	Rainfall Depth (mm)
January	33.4
February	10.6
March	15.0
April	70.8
May	82.6
June	789.0
July	569.8
August	965.2
September	877.2
October	57.4
November	150.2
December	98.6
January	15.2
February	19.6
March	44.6
April	46.2
May	214.2
TOTAL	4,059.6

3. Result and Discussion

3.1. Rainfall

The area has two distinct seasons, the dry season from November to May, and the rainy season from June to October of the year. The depth of rainfall in the BPSU-AWS Station from January 2019 to May 2020 was 4,059.6 mm (Table 1).

3.2. Volume of Stored Water

Four (4) benches or terraces with four (4) runoff interceptors (Figure 3) were constructed and created. The water storage interceptor during the rainfall-runoff event [9] has a total length of 131.6 meters with a dimension of 0.5 m in width and 0.4 m in depth, respectively (Table 2).

Table 2. Dimension of runoff interceptor

	Length (m)	Depth (m)	Width (m)	The volume of Runoff (m^3)
Upper Up	35.5	0.4	0.5	7.10
Upper Middle	36.8	0.4	0.5	7.36
Lower Middle	45.7	0.4	0.5	9.14
Lower Low	13.6	0.4	0.5	2.72
TOTAL	**131.6**			**26.32**

Figure 3. Runoff interceptor with rice production

3.3. Soil Erosion

The bulk density of the soil was 1.17 g/cc, considering the properties of the soil at the study site. At the end of the rainy season, the observed soil eroded in the lined canal at 6.25 centimeters deep, and the width of 0.5m was 4.11 m^3 (4,808.7 kg of dry soil at 131.6 m) [10]. On the other hand, the soil erosion was severe when the field was not terraced and planted with pineapple across the contour line. As recommended [11][12][13], reducing the hillslope gradient and length of the terrace and increasing the width of the terraced bench are beneficial to an increase in infiltration rates, reduction of runoff production, and surface flow velocity at the local scale.

3.4. Irrigation Water

Production (1st crop e.i. rice) during the rainy season (July-October), does not require more irrigation due to rainfall. But during this development period, precipitation was adequate to conserve irrigation water. Diversified crop production began immediately after the main crop when the dry season began. For each kind of diversified crop, the amount of irrigation water used was 25.5 liters (24 eggplants, 20 tomatoes, and 36 wax peppers) (Figure 4). Based on soil characteristics, irrigation was performed six times. Manual overhead irrigation was the irrigation method used.

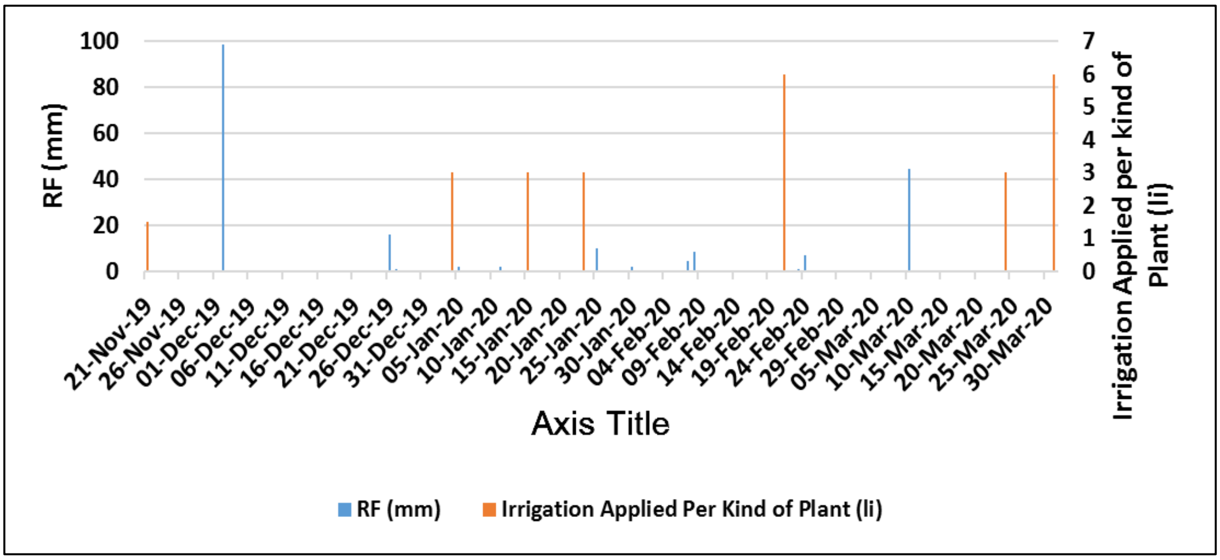

Figure 4. Rainfall and irrigation applied during crop production

Table 3. Growth and yield of three rice varieties

Parameters	APO	LG 27	NSIC 27
Height, cm	112.2	100.6	108.2
Length of Panicle, cm	18.5	17.9	15.7
Seeds per panicle	90.2	77.2	88.0
No. of Tillers	8.3	3.1	4.9
No. of Productive Tillers	7.7	2.8	4.5
No. of Unproductive Tillers	0.7	0	0.4
Seeds per hill	697.0	239.3	431.2
No. of hill (10 X 10 cm)	28,450.0	28,450.0	28,451.0
TOTAL Seeds	13,076,650.5	6,808,654.0	12,268,071.2

Table 4. Crop production after the main crop

Crop	Eggplant	Tomato	Wax Pepper
No. of Plants	24	20	36
Planting distance, m	0.75 x 0.75	0.75 x 0.75	0.75 x 0.75
Average height, cm	52	84.1	31.7
No. of Harvest, pcs	451	523	2487
Weight, kg	20.5	11.97	10.2
Average weight per piece	45.46 g/pc	22.9 g/pc	4.1 g/pc
Price as of March 1, 2020	P 40 / kg	P 30 / kg	P 150 / kg
Gross (Php)	820.10	359.30	1529.51

3.5. Growth and Yield of Crops

The area (248.5 m^2) is planted with rice in different varieties. After crop care and management, including that it was supplemented with irrigation water through manual overhead irrigation from the Runoff Interceptor, the APO upland rice variety was assessed (Table 3). It has 7.7 productive tillers, the length of the panicle was 18.5 cm, seeds per panicle was 90.2, and was 112.2 cm in height. The yield was 8.73 tons/ha (248.5 kg for 284.5 m^2 at 10 cm x 10 cm planting distance).

The diversified crop (Table 4) used eggplant, tomato, and wax pepper (siling panigang). They were planted at a 0.75 x 0.75 m distance. Fertilization was done in four split applications for each kind of plant based on soil chemical analysis by the Bureau of Soil (Department of Agriculture Regional Field Office III).

The average height of Wax Pepper was 31.7 cm. The yield was 5.04 tons/ha (143.4 kg for 284.5 m^2). Fertilization was done in four split applications with a total of 15 kg for each kind of plant. Wax Pepper has the highest gross production (Php 1529.51).

3.6. Cost and Benefit

Initial expenses include runoff establishment supplies and labor. Fixed costs include depreciation, interest on investment, repair, and maintenance, while the variable costs were farm inputs and labor costs for crop production. Table 5 is derived from the first crop (rice) and the second crop (wax pepper, eggplant, and tomato). For the benefit and cost analysis, wax pepper was used because it had the highest gross production.

Table 5. Cost and Benefit Analysis

BASIC COMPUTATION	Amount (Php)
I. Initial	121,778.25
II. Fixed cost	
a. Depreciation cost (5 % of the initial cost)	6,088.91
b. Interest on Investment (5 % of the initial cost)	6,088.91
c. Repair and Maintenance (2 % of the initial cost)	2,435.57
Useful Life, years	20
Total Annual fixed cost	14,613.39
III. Variable Cost	
a. Mulching Film, seeds, fertilizers, insecticide, etc.	2,210.00
b. Labor Cost	5,250.00
Total Variable Cost	7,460.00
Total Annual Cost	22,073.39
IV. Gross Income	33,098.60
a) First Crop (Rice), Diversification (wax pepper)	
V. Net Income	11,025.21
VI. ROI (%)	0.09
VII. Payback Period (years)	11.05

4. Conclusions

The runoff interceptor is formed along contour lines. A terrace was constructed between runoff interceptors. For the first harvest, 248.5 kg of rice was produced with an area of 284.5 m^2. Soil extirpation was also observed. For supplementary irrigation, the amount of water intercepted was 26.32 m^3.

In the production area formed in the form of terraces with runoff interceptors along contour lines that stored water for irrigation purposes during the rainy season, three different high-value crops (eggplant, tomato, and wax pepper) were grown. There were twenty-four (24) eggplants, 20 tomatoes, and 36 wax peppers raised. Four split fertilizations were done. During this management period, rainfall occurred, but in plant water requirements manual overhead irrigation was performed. There were 588.6 mm of rainfall (November 2019 – May 2020) and 25.5 liters of irrigation water applied for every kind of plant. The average height was 52 cm, 84.1 cm, and 31.7cm for eggplant, tomato, and wax pepper, respectively. The harvested crop was 25.5 kg for eggplant, almost 12.0 kg for tomato, and 10.2 kg for wax pepper, but the highest gross value was for wax pepper. The cost-benefit analysis illustrated that return of investment (ROI) was 0.09% and the payback period was more than 11 years for recovery of investment.

In farm development in upland or rolling areas, especially during the first year, there will be almost no or zero net income, but if the area were used and maximized it would increase hypotenuse in subsequent years. Left topsoil undisturbed perimeters and catchment area should be planted with high-value crops that have been tolerant to drought and do not require adequate irrigation water. The use of low-cost substitute materials to minimize initial costs may be used to create runoff interceptors. Runoff interceptor maintenance should be followed periodically. Select high-value, off-season, and minimum water requirement crops to grow in crop production in terraced areas.

Conflict of Interest

All authors declare no conflicts of interest in this paper.

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