Effect of Surface Runoff on Nigerian Rural Roads (A Case Study of Offa Local Government Area)

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Abstract

Runoff occurs only when the rate of precipitation exceeds the rate at which water infiltrates into the soil. As watershed is urbanized, much of the vegetation is replaced by impervious surface, thus reducing the area where infiltration to ground water can occur. The Investigation Survey Research Approach (ISRA) method was used, which includes questionnaire, oral interview and the information obtained from books, pamphlets and journals. It was observed for parameters from β_0 to β_{10} that 60% of β values where less than 0.05 while the remaining 40% had values greater than 0.05.

Keywords: *Drainage, farm produce, rural roads, ergonomics, maintenance, regression analysis.*

Introduction

When snow or rain falls onto the earth surface, it moves according to the law of gravity, a portion of the precipitation seeps into the ground to replenish earth's ground water, but most of it flows downhill as runoff (Schertz *et al*. 1989). Runoff occurs only when rate of precipitation exceeds the rate at which water infiltrates into the soil. After the infiltration rate is exceeded, the water begins to fill various depressions, either small or large. Once the depressions are filled, overland flow of water begins (Schwab *et al*. 1992).

Runoff is extremely important. It not only does serve rivers and streams, but also changes the landscape by an action of erosion. Water erosion is the removal of soil from earth's surface by running water. Water transportation involves the kinetic energy which removes and transports the soil particles, and the resisting forces which retard erosion (Schwab *et al*. 1992).

Flowing water has tremendous power, it can move boulders and carve out canyons (Aneke 1985). There are two main types of erosion, these are water and wind erosion. Water erosion needs to be controlled to maintain motor-able rural roads, crop productivity, sedimentation and stream pollution. Erosion problems are principally caused by human exploitation of natural resources and the removal of the protective cover of natural vegetation (Schwab *et al*. 1992). Runoff can be explained further as the part of precipitation or snow melt on uncontrolled surfaces, streams, rivers, drains, sewers or roads, which may further be classified according to the speed of appearance after rainfall or melting snow as direct or base runoff (Boardman *et al*. 1990).

Runoff that occurs on surfaces before reaching a channel is called non-point source. If a non-point source contains man-made contaminants, the runoff is called non-point source pollution. A land area which produces runoff due to a common point is called watershed. When runoff flows along the ground, it picks up soil contaminants in particular herbicides and insecticides that are discharged into streams to become non-point source pollution. Water is absorbed into soil by infiltration, stored as ground water and slowly

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discharged into streams through seeps and springs (Horn and Schwab 1963).

As watershed is urbanized, much of the vegetation is replaced by impervious surface, thus reducing the area where infiltration to ground water can occur. The more the storm water runoff occurs, the more the water that will be collected by the drainage systems and ditches which carry storm water runoff to streams. On the other hand, in a developed watershed, more water arrives into a stream faster, resulting in an increased likelihood of more frequent and more severe flooding (Chow 1962).

Drainage ditches to carry storm water runoff to a storage pond are often built to hold runoff and collect excess sediments in order to keep the runoff off rural roads. Runoff from agriculture land, even our own yard, can carry excess nutrients such as nitrogen and phosphorus into surrounding streams, lakes and ground water supplies. These excess nutrients have the potential to degrade water supply quality, roads and farm lands (Horn and Schwab 1963).

As more development and urbanization occur, more of the natural landscape is replaced by impervious surfaces such as roads, parking lots and buildings, hence reducing the rate of infiltration of water into the ground and thus accelerating runoff to ditches, streams or drainages. In addition to increasing imperviousness, removal of vegetation and soil, grading the land surface and constructing drainage networks increase runoff volume and shorten runoff time into streams from rainfall and snow melt. This results in a peak discharge, and volume and frequency of floods increase in nearby streams (Schwab *et al*. 1992).

The aim of this study is to analyze the effect of runoff on rural roads, the causes of the runoff and its contribution to the economy. The objectives of this study are to determine: the effect of surface runoff on rural roads and agricultural lands; the effects of runoff on the farmers economy and revenue; the effects of runoff on agricultural produce transported on the rural roads; and to suggest possible ways to keep surface runoff minimal on the rural roads in the area considered for the study (Offa).

Methodology

The Investigation Survey Research Approach (ISRA) (Morenikeji 2006) was used to conduct the study which includes questionnaire and oral interview and the information obtained from books, pamphlets and journals. This study was based on the following rural roads and farm lands in Offa Local Government Area, Nigeria. The roads considered are the Erin-Offa road, Oyun-Offa road, Maikka-Offa road, Ojoku-Offa, Wara-Ilorin, and Ogbomosho-Ilorin road and the farm lands in the area. The simple random selection method was used in administering the questionnaires to the farmers and the transporters. This method eliminates discrimination and favoritism of some farmers in the communities visited.

Two sets of questionnaires were designed for this study, the first questionnaire was administered to the farmers, while the second questionnaire was administered to the drivers, with each questionnaire consisting of two sections, A and B. In each of the locations, a minimum of about twenty farmers and fifteen drivers were chosen and questioned, respectively. Table 1 shows the distribution of the questionnaires among the farmers, while Table 2 shows the distribution of questionnaires among the drivers.

The questionnaires were necessary to collect information such as type of problem encountered on the roads, damages caused by the roads, ergonomic factor of the drivers and the vehicles used on the road, maintenance level, method of maintenance, type of the drainage available, blocked drainages, type of farm produce, location of the farm, name of the roads and farmer’s biodata.

One hundred and twenty questionnaires were distributed among the farmers, while ninety questionnaires were administered to the drivers. The questionnaires were collected from the field, the data and information gathered from the six different locations was analyzed using regression analysis and analysis of variance (ANOVA).

Table 1. Distribution pattern of questionnaires to farmers along some major roads in Offa Local Government Area of Kwara State.

S/No	No of questionnaires administered	Roads
1	20	Oyun-Offa
2	20	Erinle-Offa
3	20	Ojoku-Offa
4	20	Maika-Offa
5	20	Wara-Ilorin
6	20	Ogbomosho-Ilorin

Table 2. Distribution of questionnaires among the drivers.

S/No	No of questionnaires administered	Roads
1	15	Oyun-Offa
2	15	Erinle-Offa
3	15	Ojoku-Offa
4	15	Maika-Offa
5	15	Wara-Ilorin
6	15	Ogbomosho-Ilorin

Regression Analysis

The multiple regression analysis was used to analyze the questionnaires (Morenikeji 2006). This method estimates the value of dependent variable (location) from the knowledge of the value of one or more independent variables.

The variable Y is obtained from regression formulae

$$Y = \beta_o + \beta_n X_n, \qquad (1)$$

where Y is the location, β_o is the y intercept of the line or coefficient of regression, β_n is the constant known as the slope of the line, X_n is the independent variable, while n are numbers ranging from 1 to 10. The coefficient of determination (R-square) was obtained by calculating the total variation which equals the total sum of squares (SS) while the error variation is the sum of square errors ($SSR = SS_{total} - SSE$). Therefore:

$$R^2 = SSR / SS. \qquad (2)$$

The standard error was calculated from

$$SE = \sqrt{\frac{\sum (Y_i - Y)^2}{n-k-1}}\,, \qquad (3)$$

where n is the number of observations, k is the number of independent variables and Y is the mean value.

Mean square error

The mean square for error which measures the sampling variability within the treatment is calculated from

$$MSE = SSE / (n - p), \qquad (4)$$

where MSE is the mean square error and p is the number of treatments. T is a statistic which is used to test the significant or R-square:

$$T = SSR / k. \qquad (5)$$

F is derived from the following equation:

$$F = SSE / [n - (k - 1)]. \qquad (6)$$

T is used to either accept or reject the hypothesis. If $T \leq 0.05$, the result is significant, but if $T \geq 0.05$, the result is insignificant. The analysis of variance provides a basis for determining whether two or more samples means differ significantly. ANOVA is used to conduct a formal statistical test of hypothesis. The sum of squares of treatment (SST) measures the variation between each treatment mean and it is calculated by squaring the independent variable between each treatment mean and the overall treatment. This formula expresses the sum of square treatments (SST):

$$SST = \sum_{i=1}^{p} n_i (Y_i - Y)^2\,, \qquad (7)$$

where p is number of treatments, Y is the overall mean and n_i is the sample size, while error variation will be calculated from the sum of square errors (SSE):

$$SSE = (Y - Y_i)^2, \qquad (8)$$

where Y_1 represents the measurement in sample 1 and Y_2 is the measurement in sample 2, etc. The mean square for treatments (MST) was obtained from

$$MST = SST / (p - 1), \qquad (9)$$

where $p - 1 = DF$, the degree of freedom.

Results and Discussion

The data obtained for the research study were subjected to statistical analysis to ascertain the effect of surface runoff on rural roads. The results obtained using regression analysis and analysis of variance (ANOVA) are shown in Tables 3, 4 and 5, respectively.

Table 3. Results of regression analysis on the independent variable parameters.

Predictor	**Coef. of regression**	***SE* coef.**	***T***	***P***
Constant	-0.2387	0.6364	-0.38	0.709
Type of farm produce	-0.01625	0.03113	-0.92	0.604
Problem encountered during rainy season	2.08611	0.04519	1.91	0.062
Maintenance level	0.7707	0.639	4.90	0.00
Method of maintenance	-0.0697	0.1183	-0.59	0.559
Type of drainage system	0.6349	0.4771	1.53	0.89
Blocked drainage	0.8782	0.2980	2.95	0.005
Effort put into repairing of the road	-0.1436	0.1960	-0.73	0.005
Damages caused by surface runoff	-0.01761	0.05055	-0.35	0.1769
Quantity of farm produce damaged during transportation.	-0.00716	0.09993	-0.07	0.729
Ergonomics of the driver and vehicle	-0.0970	0.2451	-0.40	0.943
Total	1.77989	2.3616		0.694

Table 4. Results of analysis of variance (ANOVA).

Source	***DF***	***SS***	***MS***	***P***
Regression	10	150.973	20.00	0.000
Residual error	55	41.527		
Total	65	192.500		

Table 5. ANOVA results for the independent parameters considered.

Source	**Degree**	**Seq *SS***
Type of farm produce	1	8.979
Problem encountered during rainy season	1	0.449
Maintenance level	1	101.180
Method of maintenance	1	0.433
Type of drainage system	1	16.498
Blocked drainage	1	22.887
Effort (comm../farmer)	1	0.369
Damages caused by surface runoff	1	0.061
Ergonomics of driver and vehicle	1	0.114
Quantity of farm produce transported	1	0.004

where *DF* is the degree of freedom, *F* is the sum of the degrees of freedom, *SS* is the sum of squares, *MS* is the mean square, and *P* is the significance probability level (significance).

The results show that surface runoff has greater effects on rural roads and farm lands as there is a great significant level between the surface runoff and rural roads, farm lands, farm produce as well as farmers income or revenue. The regression equation is given as:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10}, \quad (10)$$

where Y is the location, β_o to β_{10} are the regression coefficients, X_1 is the farm produce, X_2 is the problem encountered during the rainy season, X_2 is the maintenance level, X_4 is the method of maintenance, X_5 is the drainage system, X_6 is the blocked drainage system, X_7 is the effort put into repairing of the road, X_8 is the damaged coursed by the road to the farm produce, X_9 is the quantity of farm produce transported and X_{10} is the ergonomics involved during the transportation of the farm produce. Replacing β_0 to β_{10} with their coefficients, we have:

$$Y = - 0.239 - 0.0163X_1 + 0.0861X_2 + 0.771X_3 + 0.0697X_4 + 0.6349X_5 + 0.8782X_6 - 0.1436X_7 - 0.01761X_8 - 0.097X_9 - 0.0072X_{10}. \quad (11)$$

Significant Level

The standard statistical significant level is given as 0.05, if any parameter or variable has probability or significant level greater than 0.05, it implies that the parameter or the variable is unimportant, in other words, the effect of the parameter is insignificant. If the parameter or variable has probability or significant value less than or equal to 0.05, it means that the effect of the parameter is significant and viable, therefore, the parameter must be considered important. This can be observed from parameters β_0 to β_{10}, 60% of β values where less than 0.05 while the remaining 40% had values greater than 0.05.

R - square

From the data obtained from the questionnaire, the *R*-square value is 78.40% which implies that surface runoff/erosion strongly affects rural roads and farm lands, which also implies that this percentage of variation is a dependent variable of *Y* (location) while 22.6% does not affects farm lands and rural roads, which accounts for the independent variables of *X* (such as farm produce, quantity transported, ergonomics, etc.). It is observed that the residual value of *X* is small enough to say that we have better prediction of effects of surface runoff on the rural lands and farm lands.

Correlation Coefficient R

The degree to which two or more predictors (independent or *X* variables) are related to the dependent (*Y*) variable is expressed in the correlation coefficient of *R*, which is the square root of *R*. In multiple regression, *R* can assume values between 0 and 1. Thus, the correlation coefficient *R* is obtained to be 0.8854.

The relationship between variables also depends on the sign before the regression coefficient which could either be negative or positive. If a regression coefficient (β_n) is negative, the relationship is negative, and vice versa. When a regression coefficient is zero then there is no relationship between the dependent variables and the independent variable. The negative or positive signs of regression coefficients show the strength of the relationship between both dependent and independent variables.

Discussions relating to independent variable

The newest concern of farmers is not about the weather or about the farm labour shortage, or whether the market price is good for the farm produce or not. Instead, it is about the impact of moving farm produce from one location to another. The results in Table 3 show that the probability of farm produce is greater than the significant value of 0.05, which implies that surface runoff has no direct effect on the farm produce. The sign (minus) in front of the regression coefficients means that the relationship between independent variable X_1 (farm produce) and dependent variable *Y* (location) is negative.

The major problem encountered during the raining season from June to October in Kwara State is the erosion activity created by the surface runoff of water flowing across farm lands and rural roads as these roads are vulnerable to the erosive effect of water, causing a number of potholes. Table 3 shows that rainfall contributes immensely to surface runoff consequently damaging the rural roads and farm land. The probability value of the problem encountered during the rainy season is 0.062 while the significant level is 0.05 indicating that rainfall affects surface runoff. Due to this effect, surface runoff is creating potholes on the rural roads.

Man-made infrastructure needs to be maintained periodically and roads are not an exception. Maintenance is imperative for all roads in use as it also improves the economy and the agricultural production of the area. The results of regression analysis in Table 3 show that the maintenance level is significant in controlling the bad effect of surface runoff on the rural roads and farm lands. The probability of maintenance level (0.00…) is much smaller than that of the significant value of 0.05; since the significant level is less than or equals to 0.05, this shows that the maintenance level and surface runoff are correlated. The positive sign before the regression coefficient (β_3) also justifies the relationship between maintenance level and roads.

The method of maintenance in restoring rural roads to proper conditions was also considered. There are different methods of road maintenance such as filing the potholes, grading, and tarring among others. According to the regression analysis results in Table 3, the probability of method of maintenance is 0.559 and the significant level is 0.05. As stated earlier, any parameter with its significant value greater than the standard statistical significant value of 0.05 is considered insignificant. Therefore the method of maintenance is rather insignificant to damages caused on the road.

The negative sign before its coefficient of regression (-0.0697) shows that there is negative relationship between the method of maintenance and the location, therefore, there is no correlation between the maintenance method and the surface runoff in the study area.

The drainage system is used in carrying surface runoff and loosened soil particles. Particles most often settle out where there are obstructions in the drainage system, thus diminishing the carrying capacity of the ditch and in turn causing roadway flooding which leads to surface runoff, and consequently to roadway erosion. Most of the eroded soil, however, ultimately ends up in streams and rivers where it diminishes the channel capacity, causing more frequent and severe flooding which in turn has adverse effects on the rural roads and farm lands. There is no drainage system in Wara-Oja-Ilorin road and where provided the drainages are blocked with manmade materials or non-source materials disallowing the water flowing to find its way to rivers, streams or dams, consequently causing flood in the adjacent road. If adequate measures are taken and intensive maintenance of the drainage and regular cleaning of the drainage system are put in place, the problems of drainage blockage may not be encountered. The results of this study consider the drainage system as insignificant, showing that the type of drainage system does not affect surface runoff. The regression analysis results in Table 4 show that the probability of drainage system is 0.01189 while the standard significant level is 0.05, therefore, the hypothesis is null. This deduction made it clear that the type of drainage system does not contribute to road degradation but blocked drainage systems have impact in the bad effect of surface runoff on the roads.

The results obtained for regression analysis show the effect of the blocked drainage system, the probability of blocked drainage system is 0.005 and the standard statistical significant level is 0.05 meaning that the blocked drainage system is significant in surface runoff control measures.

From Table 3 it can be seen that the efforts of the farmers to repair the roads are quite low and hence insignificant, therefore, causing more potential for surface runoff to cause further deterioration of the roads. The probability of the efforts to repair the roads is 0.457 which is higher than the significant level meaning that the road users lack maintenance culture and the effort put in place is insignificant. Surface runoff does not have any direct impact on the farm produce carried but on the vehicles that pass through the road. The damages caused by erosion on the road that affect the farm produce are due to the vibration experienced on the roads by the plying vehicles. Damages caused on the road may also result in the rapid wearing of the engine, weakening of the vehicle body, unnecessary loosening of bolts and nuts, hazard to the driver health, peeling and breaking of tuber crops, etc. For instance, in the Maika area, where farmers produce tuber crop such as sweet potatoes, yam and cassava in large quantities, damage of tubers by the road is experienced. The results in Table 3 show that damage caused by the road has a probability value of 0.729 which is above the significant level of 0.05. The damage caused by the road on the crops would not occur if adequate maintenance services are carried out on the rural roads. Working methods can be improved by reducing the fatigue and improving the control through a better interaction between humans, machines and the environment. The results obtained show that the ergonomics is not significant as its probability is 0.694, while the significant level is 0.05. The ergonomics probability is higher than the significant level which renders ergonomics insignificant.

The transportation of a large quantity of farm produce increases the income and at the same time gives the farmer opportunity to expand or cultivate more land, consequently providing more dishes for consumers and more access for agro-allied industries to access sufficient raw materials for their productions. The problems the farmers face in transporting enough quantity of farm produce from their farms to the marketplace hinder the expansion of the farming, thus reducing the revenue generation. A very bad road like that of Ojoku - Offa road, that deters the ability of the farmers to move enough farm produce from their farms to the market, tends to make the quantity of produce transported irrelevant. The results obtained from statistical analysis show that the probability value of quantity of farm produce is 0.943 which is higher than the significant level, hence, it is considered insignificant.

Conclusion

The effect of surface runoff on rural roads and farm lands in Offa local government area, Nigeria, cannot be overemphasized as most farmers loose their farm produce during the course of both transportation and reduction in farm land size. Farmers and drivers encounter much more problems on the roads during the peak rainy season because of the increased number of potholes on the road created by surface runoff. This does not have a direct impact on the farm produce being transported along these roads but on the vehicles which carry these produce. During the course of movement, the vehicles experience vibrations because of the various sizes of potholes which affect the farm produce carried in them, hence reducing their market value. This in turn affects the local farmers who are expecting so much from the sales of these farm produce. The reduced size of farm lands also affects the farmers' activity and further decreases their productivity.

In conclusion, it is important for all the concerned parties, namely, farmers, drivers, district heads, local government chairmen, the state government through the State Ministries of Works, Environment and that of Agriculture and Natural Resources that they should come together to resolve these problems of surface runoff by constructing good drainage systems and also coming up with good and practicable maintenance programme for the roads and farm lands.

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