AN INTEGRATED SOIL CONSERVATION PROGRAM AND ITS IMPACT ON THE ANNUAL SOIL LOSS OF THE DUMPUL (INDONESIA) SUBWATERSHED

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF SOILS, WATER AND ENGINEERING

In Partial Fulfillment of the Requirement
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN SOIL CONSERVATION

In the Graduate College

THE UNIVERSITY OF ARIZONA

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STATEMENT BY AUTHOR

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ACKNOWLEDGMENT

The author wishes to express his gratitude to Dr. David M. Hendricks, his major professor, and the other members of his committee, Dr. Arthur W. Warrick, Dr. Donald F. Post, and Dr. Kenneth G. Renard, whose guidance and assistance made this work possible.

Special thanks must be addressed to Dr. McComb who read and gave a valuable critique on the draft of this thesis.

Financial support of the Food and Agriculture Organization of the United Nations through its Project of TA INS 72/006 is acknowledged.

I owe special recognition to the most important people in my life--my wife Srigati, my mother, and my children, Agung, Gendon, Ririn, and Effi.

Finally, the author expresses appreciation to Joan P. Farmer for her finishing touch on this thesis.

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ABSTRACT

In some areas an increasing population causes an increasing population density and, hence, increases demand for food of the particular areas. To produce more food people usually expand their cultivation area onto steep, unsuitable for annual crops, areas. In many cases this expansion results in a deterioration of natural resources due to rapid runoff and erosion. An integrated soil conservation program, therefore, is necessary to be implemented on these areas to minimize soil erosion and maintain the productivity. The impact of the program on the annual soil loss can be measured or escalated by some methods: iron pins, sediment tank, sediment sampling from a gauge station, and Universal Soil Loss Equation (USLE). In this case, the USLE is superior and useful not only for evaluating the impact of a program but also for designing a plan of a soil conservation program and evaluation of criticalness of the area.

INTRODUCTION

"Increasing population and decreasing production from watershed resources are on a collision course" (Soedarma, 1976, p. 3). Therefore, without an intensive soil conservation program, soil erosion will exceed permissible rates resulting in a manmade wasteland. The problem is particularly acute in areas of Indonesia. To counter this problem an integrated soil conservation program is being established.

The primary objective of this study was to measure the impact of an integrated soil conservation program on the annual soil loss of the Dumpul (Indonesia) subwatershed. The soil loss was calculated by using the Universal Soil Loss Equation (USLE) which was developed by Wischmeier and Smith in 1958.

A secondary objective was to assess the suitability of the USLE for determining the seriousness of erosion hazard in different parts of Indonesia.

DETERIORATION OF NATURAL RESOURCES

The Growing World Population and Its Effects

The world population 2,000 years ago was stabilized at 1 billion people. As cures and prevention of diseases and improved nutrition were developed, the growth rate increased to a point well over 2.0% per annum. In 1981 the rate of population growth was reported as 1.7% (Hill and Rosen, 1981). In some countries the population growth exceeds 3.0% per year. The increase in world population is shown in Table 1.

Table 1. World population growth. -- From Encyclopaedia Britannica, (1974b, p. 816).

Year	Population (person)	Percent Growth
1000	340,000,000	-
1650	545,000,000	0.092
1800	907,000,000	0.443
1900	1,610,000,000	0.775
1950	2,509,000,000	1.117
1970	3,650,000,000	2.274
1985*	5,000,000,000	2.466

*Estimated by Hill and Rosen (1981).

The world's population first reached 1 billion people in 1830. This figure doubled between 1830 and 1930. After that, the period needed to double the population decreased. By 1965 the world population reached the 3 billion mark and by 1980 it reached 4 billion. Brink (1977) stated that as developing countries Asia, Africa, and Latin America would account for 90% of the next billion of growth by 1995. This is supported by Table 2 which shows the growth rate of the world's continents. Asia, Africa, and Latin America have an annual growth rate of 1.9%, 2.9%, and 2.3%, respectively, while the United States, Europe, and the U.S.S.R. have less than 1%. At these rates the present world population will double in 40 years or by 2022.

Increasing Demand for Food

The growing world population leads to an increasing demand for food. Consequently, to feed the growing population the food production should grow at least proportionally with the population growth to ensure that each person gets adequate food for normal life. The Food and Agriculture Organization (FAO) of the United Nations in its Proportional Indicative World Plan for Agriculture Development reported that 64 developing countries will need to import $43 billion worth of food by 1985 as compared to $3 billion in 1962 (*Enclyclopaedia Britannica*, 1974a). At this level the developing countries are still under minimum standard nutritional requirements. At the same time the food demand of the developing countries will increase 3.7% a year with 2.7% due to population growth and the remainder due to an increase in purchasing capacity. It is clear that food supply in developing

Table 2. Population and the growth rates of selected continents and countries. -- From Hill and Rosen (1981).

Continent/Country	Population (million)	Growth (%)
Africa	484.8	2.9
Nigeria	79.5	3.2
Egypt	43.4	2.7
Asia	2,682.4	1.9
People's Republic of China	1,044.8	1.6
India	692.9	1.9
Latin America	369.5	2.3
Brazil	124.7	2.3
Mexico	69.4	2.7
North America	353.5	0.7
United States of America	229.3	0.7
Canada	24.1	0.9
Europe	486.1	0.4
Union of Soviet Socialist Republics	268.2	0.9
Federal Republic of Germany	61.3	-0.1
United Kingdom of Great Britain	55.9	0.0

countries always lags behind the food demand. In cases of abnormal weather conditions such as drought, flood, pest and disease infestations, and other disasters, the condition will be even worse. The Foreign Agricultural Economic Report (U.S. Department of Agriculture (USDA), 1981) stated that some developing countries have population growth rates matching the rate of increase in food production. In other cases, the demand for food surpasses the supply, and often there is little gain in per capita food production and significant drops when harvests are poor. In fact, the average food intake level in the developing countries is still below the levels considered nutritionally adequate by FAO and the World Health Organization (WHO) of the United Nations.

To increase the per capita food intake, therefore, these developing countries must increase their food production to avoid dependence upon imported food. Table 3 shows that Africa, Asia, and Latin America greatly increased their cereal imports between 1974 and 1979.

Increasing Demand for Land for Other than Agricultural Purposes

The growing population not only needs additional food supplies but also needs additional public services such as parks, roads, shopping centers, airports, all of which use large areas of land. Certainly these facilities reduce food plantation areas and, hence, reduce the food supply.

Table 3. World population, grain exports, and per capita energy consumption. -- Taken from Hill and Rosen (1981).

Region	Population (million)	Net Grain Export (1,000 t) 1974	Net Grain Export (1,000 t) 1979	Per Capita Energy Consumption (kg coal equivalent)
North America	253.5	76,374	118,851	11,304
Oceania	23.1	6,947	9,507	5,158
Africa	484.8	- 6,936	- 13,945	324
Asia	2,682.4	-47,078	- 58,849	642
Latin America	369.5	- 443	- 3,682	1,126
Europe	486.1	- 28,470	- 29,728	4,518
World	4,567.6	6,947	9,507	2,019

Increasing per Capita Energy Consumption

The developing countries also have very low per capita energy consumption, lagging behind the developed countries. Table 3 shows per capita energy consumption in North America was 11,304 kg of coal equivalent, while Africa and Asia consumed only 324 and 642, respectively. The industrialization of developing countries will increase the demand for energy. Because these countries often lack oil, gas, and coal resources, increased energy demand is usually met by cutting forests. Clear cutting of forests on mountains and hilly land often leads to erosion and destructive floods.

In many developing countries, fuelwood is the main source of energy. Table 4 shows that fuelwood demand in the developing countries is increasing while for the developed countries it is decreasing. Consequently, deforestation with its deleterious effects will continue.

Natural Resources Deterioration

The growing world population results in growing world demand for food. The increasing demand for food can be met by increasing the acreage of land in cultivation, improving crop species, fertilization, and irrigation. In the developing countries where technology in agriculture is not well developed, additional food is gained through expanding the arable lands. In some cases, the expansion is done by the shifting cultivation system. People clear-cut forests for crop plantations by burning the trees and then cultivating the new land, often practicing a mono-cropping system. Lal (1977) observed that the mono-cropping system causes greater erosion and runoff than the mixed-cropping system. Observations in Ibadan, Nigeria, showed that the soil loss from a mono-cropping area increased from 2.7 t/ha/yr on the 1% slope field to 221.1 t/ha/yr on the 15% slope, while on the mixed-cropped area the losses ranged from 2.5 t/ha/yr to 137.3 t/ha/yr. On the other hand, runoff as a percentage of rainfall ranged from 18% to 43% on the mono-cropped area, and 14% to 33% on the mixed-cropped area (Table 5). Clearly, practicing shifting cultivation with the mono-cropping system deteriorates land resources rapidly. As the yields on these lands decrease year after year, the land is abandoned and becomes a wasteland where "Alang-alang" grass, *Imperata cylindrica*,

Table 4. World fuelwood consumption. -- From Earl (1975).

Region	1960	1970	1975	1985*
	(million m^3)			
Europe	91	62	74	58
U.S.S.R.	98	87	80	82
North America	48	19	24	14
Latin America	188	223	230	244
Africa	208	225	246	312
Asia Pacific	397	475	545	626
World	1,030	1,120	1,199	1,335

*Estimated.

Table 5. Comparison of soil loss and runoff under mono-cropping (cassava) and mixed cropping (cassava with maize) on alfisol near Ibadan, Nigeria. -- Lal (1977).

Slope (%)	Soil Loss (t/ha/yr)		Runoff (% rainfall)	
	Mono-crop	Mixed-crop	Mono-crop	Mixed-crop
1	2.6	2.5	18	14
5	87.4	49.9	43	33
10	125.1	85.5	20	18
15	221.1	137.3	30	19

is the only plant that will grow on it. Because the people always move to new forest areas after leaving the former shift-crop areas, the resulting wasted areas occupy large portions of land in some countries. Shifting cultivation seriously reduces food production in these countries. People in densely populated areas are especially prone to expand their tilled land on mountains by clear cutting the natural forests which exposes the surface soil and accelerates the erosion (Figure 1). Once the land is eroded, its recovery is difficult. Because erosion on the sloping land is greater than the rate of soil formation, productivity on the steep land areas decreases, resulting in food production decreases.

Soil erosion of the upper watershed land also has negative effects on the downstream areas due to siltation of lakes, dams,

Figure 1. Expansion agriculture land onto steep area by cutting forest

canals, and other irrigation facilities, thereby covering the fertile arable lands with rocks and infertile materials. All of these processes reduce or destroy the production capabilities of the areas. Although food production can be increased by irrigation of previously unproductive dry land, land reclamation, and draining of swamps, in densely populated countries the tendency is to expand the tilled land onto forested mountains. Therefore, runoff, erosion, and flooding are serious problems, urgently in need of being solved.

Runoff and erosion affect plant, animal, and human lives in many ways such as:

1. Breaking the soil aggregates into small particles.
2. Destroying soil-binding agents such as organic matter.
3. Removing the most nutritious soil needed for plant growth.
4. Causing soil loss to exceed the rate of natural soil formation (Figure 2).
5. Plugging soil pores by dispersing soil particles, thus decreasing the soil infiltration rate and increasing the runoff capacity.
6. Lowering the ground-water table and decreasing the groundwater supply.
7. Decreasing the soil-water retention capacity through loss of organic matter.
8. Upsetting the water balance and lowering water quality.
9. Silting reservoirs and lakes decreasing their storage capacity.

Figure 2. Abandoned land; deterioration of the natural resources

10. Causing floods which threaten human life, property, livestock, and crops.
11. Covering fertile soil downstream with infertile materials.

People in these developing countries face difficult tasks. On one hand the people have to increase their food production; on the other hand, the natural resources, water, and soil as main resources for growing food crops deteriorate due to soil erosion and runoff.

In order to increase food production in the future, the people in the developing countries have to conserve their soil resources against erosion and runoff through an intensive soil conservation program. As defined by Kohnke and Bertrans (1959, p. 3), soil conservation is "the integration of all actions preventing the deterioration of soil, and more than just gully plugging, and using more grass in crop management."

INTEGRATED SOIL CONSERVATION ON DUMPUL (INDONESIA) SUBWATERSHED

History

The Government of Indonesia and the Food and Agriculture Organization (FAO) of the United Nations in 1972 set up a joint project known as the Upper Solo Watershed Management and Upland Development. This project was proposed by Dr. Andrew L. McComb, the third FAO expert working on the Upper Solo River basin. McComb (1970) made a general study of the Upper Solo River basin and a project proposal was made to the Government. This finally became the Upper Solo Watershed Management and Upland Development Project known as TA INS 72/006.

McComb (1971) conducted a study of the sediment load of the Solo River to estimate the erosion rate. He found that 8.5 million tons of soil had been carried past Solo city during the rainy season, which is equivalent to a 2.5-cm depth of soil on that part of the watershed that has undergone serious erosion within a 6.5-yr period. This is equivalent to an erosion rate of 4 mm/yr. On some watersheds, where physical conditions are very critical relative to erosion susceptibilities, this rate seems too small. Moreover, McComb (1971) estimated that there is crop value loss of approximately $20 million in the Upper Solo every year due to erosion.

Based on the characteristics of the whole watershed, the project selected four of the seven subwatersheds of the Solo River basin as pilot project areas for further planning and development.

In each of the four subwatersheds, except Padas, two smaller subwatersheds were selected for intensive soil conservation treatments. The four watersheds with their two smaller subwatersheds are:

1. Samin watershed with Dumpul and Tapan subwatersheds.
2. Wiroko watershed with Wader and Wungu subwatersheds.
3. Temon watershed with Plawatan and Duren subwatersheds.
4. Padas with Poleng subwatershed.

An integrated soil conservation treatment was applied to each subwatershed for demonstration and trial in controlling erosion. As stated by Constantinesco (1976, p. 33), "the broad objectives of a national soil conservation program should be to increase food production and the standard of living of the people by applying soil and water conservation measures to the best advantage." The final goal of the Upper Solo Project is to increase the human land carrying capacity to adequate nutritional levels through increasing land productivity. The Master Plan of Development for the four watersheds was prepared from the seven pilot projects.

The Dumpul subwatershed of the Samin watershed was selected for demonstration and trial. The selection was based on information obtained from aerial photo and from ground checking. Administratively the Dumpul subwatershed is in the regency of Karanganyar, residency of Surakarta, and province of Central Java, Indonesia. Further descriptive data are as follows (Figure 3):

1. Latitude: 110° 52' 48"-110" 54' 28" East
   7° 38' 35"-7° 39' 22" South.

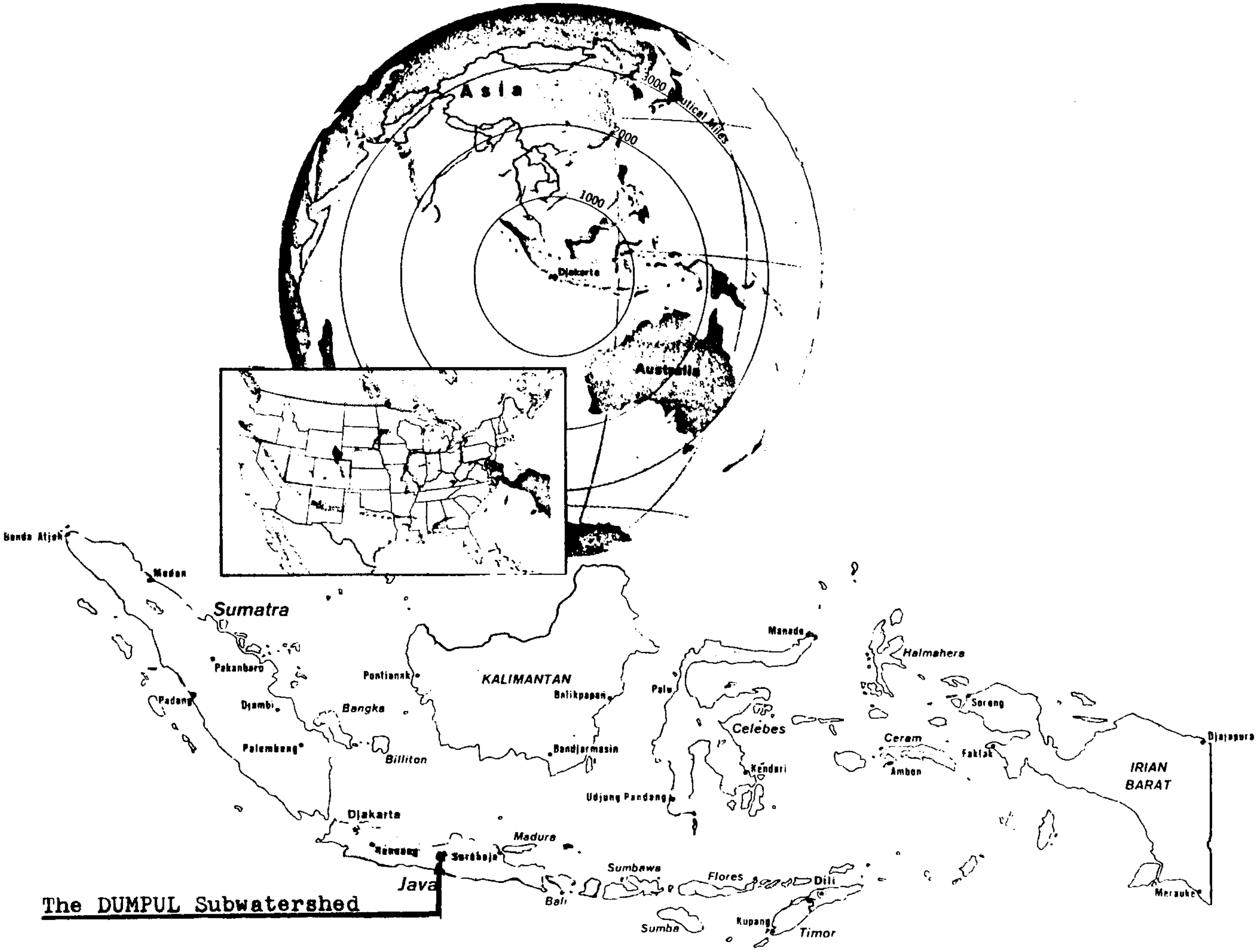

Figure 3. Location map of the Dumpul subwatershed

2. Altitude: + 190 m-293 m.
3. Slope: gentle to steep.
4. Soil type: oxisol or latosol.
5. Rainfall: 2,300 mm/yr.
6. Population density: 870 person/km^2.
7. Size of farm ownership: 0.5-1.0 ha/family of five.
8. Area: 184.2 ha.
9. Land use: 53.66 ha village, 22.00 ha irrigaged rice field, 106.01 ha dry land, and 1.53 ha other.

The watershed has serious soil erosion problems including both sheet and gully erosion. Some of the farms have been abandoned by their owners as they were no longer productive. An attempt was made to grow Citonenella grass (Andropogon nardus) on the abandoned areas previously under extensive cultivation. The farmers would cut the Citoenella leaves and sell them to the factory without returning any to the soil with any fertilizer management or other soil-conservation measures. Therefore, the soil was unprotected against raindrop impact and splash, and sheet, rill, and gully erosion occurred rapidly until the area was abandoned.

On some other areas, soil erosion was accelerated by farmers themselves when they marked their ownership boundaries by water-carrying channels. Those boundaries that extended up and down slope soon became deeply gullied.

For demonstration purposes, the Dumpul area has some advantages such as its proximity to the city, its closeness to the main road, and all erosion stages exist on the area. Adjacent to it are other areas that have similar conditions which left untreated can be used readily as comparison.

Organization

Six sections active in the field and one for office administration were established to manage the project. The six sections are Soil Conservation, Forestry, Hydrology, Agronomy, Extension Education, and Watershed Economy. Referring to the soil erosion factors, each section works on one factor. The Soil Conservation section works on topographic factors, Forestry on vegetation, Hydrology on climatic, and Agronomy on soil factors, and Extension Education on the human factor, while the Watershed Economy is concerned with all sections.

Project Activities

Erosion Rate Measurements

McComb (1971) estimated the erosion rate on the Solo basin as a whole to be about 4 mm/yr. To obtain measurements of the erosion rate on particular watershed and subwatersheds, additional experiments are underway utilizing several methods: iron pins, sediment tanks, gully plugs, and sediment sampling analyses.

The Iron-pin Measurement. Iron pins 75 cm in length are driven into the ground, leaving 10 cm exposed above the ground surface. The pin should be at least 75 cm in length to stabilize the pin and make it difficult to be removed. The length of each pin above the ground is measured after a certain period or after one rainy season.

To get correct measurements, each pin above the ground is referenced to a concrete bench mark. The heights of the pins above ground surface show the depth of soil erosion or deposition. John (1976) showed that during one rainy season after the pins were placed the soil erosion removed 2 to 3 cm, indicating a soil loss on gentle slopes of 370 t/ha. On more sloping land, the soil loss was 600 t/ha. Table 6 shows the pin readings on the Dumpul subwatershed.

Sediment Tank. The Hydrology Section build several types of sediment tanks, depending on the different conditions of the small catchment areas, to collect sediment from the particular catchment following a single storm. One measurement showed that 3.5 m^3 of sediment was collected from a single storm from a 1,660 m^2 catchment area. This meant that the erosion rate of that storm was 2 mm (John, 1976). The annual soil loss of the terraced dry land was 9.3 t/ha; the control unterraced was 87.0 t/ha (Ditsi, 1979a).

Gully Plug. The gully plugs were built on two 14,000 m^2 catchments representing (1) traditional dry land use and (2) treated or bench terraced land use. During the first rainy season, the gully plug under the control catchment collected 230 m^3 of sediment which is equivalent to a 16-mm soil depth eroded from the entire plot while the other gully plug in the same period collected only 58 m^3 of sediment equal to 4 mm of soil eroded from the terraced land. On newly established terrace areas, the sediment noticeably comes from the risers. In the second year after the terrace had been stabilized with appropriate grass cover on the riser and lip, the erosion

Table 6. Rate of erosion and sedimentation; measurements using iron pins. -- All measurements 1/10 mm. From John (1976).

Date of Observation	Bare Land Not Cultivated						Land With Sparse Grass Cover		Land With Light Forest Cover		Rainfall (mm)	
	Slope 15 to 20%		Slope 5 to 15%		Slope < 5%		Slope 5 to 15%		Slope 5 to 15%			
	Running Total	Incre-ment	Running Total	Incre-ment	Running Total	Incre-ment	Running Total	Incre-ment	Running Total	Incre-ment	Total	Incre-ment
9-25-74	00	0 0	0	0	0	0	0	0	---	---	0	0
10-07-74	+ 50	+ 50	+ 109	+ 109	+ 126	+ 126	+ 14	+ 14	0	0	142	142
11-05-74	- 82	- 132	+ 42	- 67	+ 217	+ 91	- 8	- 22	- 29	- 29	299	157
11-11-74	- 39	+ 43	+ 57	+ 15	+ 224	+ 7	- 6	- 2	---	---	376	77
11-26-74	- 115	- 76	- 26	- 83	+ 162	- 62	- 28	- 22	- 31	- 2	593	217
12-19-74	- 223	- 108	- 43	- 19	+ 135	- 27	- 44	- 16	- 43	- 12	781	188
01-13-75	- 241	- 18	- 47	- 02	+ 153	- 18	+ 34	- 10	- 43	0	1,010	228
02-19-75	- 378	- 138	- 381	- 334	- 162	- 315	- 53	- 19	- 8	35	1,708	699
04-18-75	- 402	- 23	- 353	+ 28	- 98	+ 64	- 46	+ 7	---	---	2,345	637
Total for Wet Season (05-02-75)	- 449	- 47	- 360	- 7	- 59	39	- 34	+ 12	+ 21	+ 29	2,486	141

Note: Each reading is the average of observations on approximately 15 iron pins.

decreased to 2 mm. The erosion rate of the second year on the untreated area increased to 18.4 mm.

Sediment Sampling Analyses at Stream-flow Measuring Stations.

At the end of the stream on the Dumpul subwatershed the Hydrology Section built a stream-gauging station. The sediment samples collected were then analyzed in the laboratory. By using the stream-flow data and the concentration of sediment in the flow, the total sediment yield or erosion from the watershed is calculated.

All observations but the last were conducted during the first year. The observation from the stream gauge will be continued for at least 15 years to monitor the effects of the treatments by comparing the data from this watershed with the other adjacent subwatersheds under traditional cultivation.

Physical Treatment

The conservation treatments applied to the Dumpul subwatershed were based on the slope classes of the land. The slope classification is made with the use of aerial photographs with a scale of 1:10,000. The construction of certain treatments is based on topography maps with a scale of 1:1,000 or 1:500. The conservation treatments include:

1. Reforestation of areas with slope greater than 50% is being done by the Forestry Section.
2. Bench terracing of areas with slopes less than 50%, gully plugs, check dams, gully drops, and road construction are done by the Soil Conservation Section.
3. Agriculture intensification is done by the Agronomy Section.

4. Stream gauge station and water development for small irrigation schemes are done by the Hydrology Section.

Reforestation

Reforestation on the Dumpul subwatershed was intended as a trial. Eucalyptus alba, a quick-growing species, was the only species planted on very shallow soils on slopes less than 50% and for stream bank protection. On the other, subwatersheds where the slope is more than 50%, the reforestation program used Pinus mercusii, Albizia falcata, and Eucalyptus alba as the main species. All trees were planted on a meter grid with Elephant grass (Pennisetum purpureum) underneath the main trees (Figure 4). Thinning is done 2 years after planting to spacing of 2 x 2 m, which yields firewood for the owner. The grass gives additional income to the farmer by providing cattle feed. The grass is fertilized with urea at a rate of 2 quintals/ha[1] to increase forage production. Thus the animal-carrying capacity of the forested areas can be increased from one animal unit to five animal units per hectare. The applied fertilizer also improves the growth of the trees. For the farmer who has no other land than reforested land, cattle manure is used for fertilizing the forest. For the farmer who has other fields, the manure is used to increase the crop production of those fields.

During the first 4 yr of the project, the farmer gets food compensation from the Project. This food, provided by the United Nations Development Program (UNDP), World Food Program (WFP), consists

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1. 1 quintal equals 100 kg.

Figure 4. Sylvopasture, a combination of forest and grass

of bulgur wheat, butter oil, canned fish, and dried milk in order that the farmer does not need to cut the forest before maturity to support his family. The amount of the food compensation is based upon the daily calorie requirement recommended by the FAO of 1,920 calories/person/day. This amount is gradually reduced in accordance with the additional income the farmer gets from the forest.

Four years after establishment, the farmer can live on the income from his forest, including firewood, resin, and grass. A successful reforestation program will improve the farmer's income. This income comes from firewood (7 m^3/ha/yr), timber (3 m^3/ha/yr), and meat (475 kg/ha/yr) (van Dillewyn, 1976). Moreover, reforestation requires 308 mandays of labor/ha/yr and costs $457.6/ha.

Bench Terraces, Gully Control, Check Dams, and Other Accessory Construction

Bench Terraces. All Dumpul areas with less than 50% slopes are put into the bench terrace system if the soil depth is still more than 50 cm. On other watersheds, if the soil depth is less than 30 cm, it is put under a permanent vegetation (reforestation) even though the slope is less than 50%.

The reversed slope bench terrace was chosen for the Dumpul area because the land is dry farmed. Furthermore, this type of terrace is more effective in controlling erosion than the other type. Because of unemployment in the area, all construction was done manually using local labor as labor intensification. The farmer laborers are paid for their labor with food furnished by the project. Heavy equipment is not appropriate for this situation. Using local farmer labor is also intended to educate the farmer in controlling erosion and farming and also to build a "sense of belonging" among the farmers. Farmers build the structures themselves on their fields; thus, if there is any damage such as broken terrace or drop structures, they will repair the damage. They have the responsibility of maintaining and preventing the structures from being damaged.

The construction is started by the Project's field supervisor who lays out a bench-mark contour line. At 10-m intervals along the contour line, the supervisor makes a mark with a bamboo stick. Then the farmers, in groups of 10, build the terraces. Waterways were located at 100-m intervals along the contour by the supervisor and were built across the contour line. The cross section of a bench terrace is shown in Figure 5.

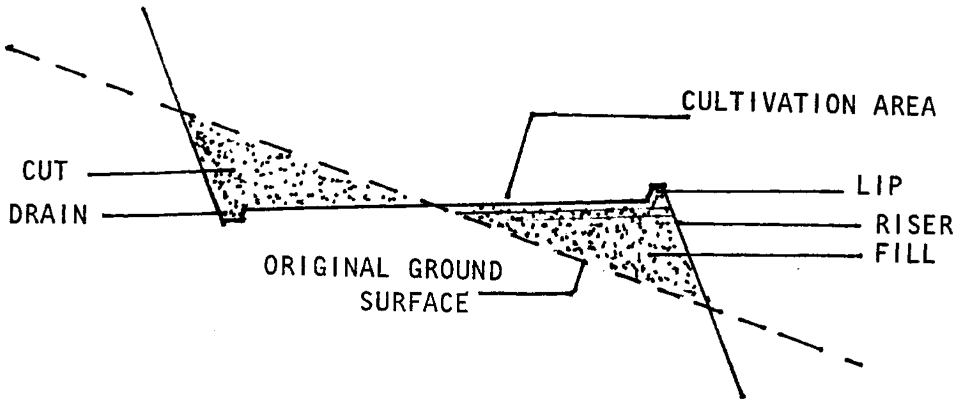


Figure 5. Cross section of bench terrace

Figure 6. Waterway built across the contour line

The vertical interval of the terrace is dependent on the slope and the soil depth. If the soil is shallow, the cut area should not expose the rock material, so the entire bench terrace contains good soil. However, due to lack of soil homogeneity it is not uncommon for the terrace to hit the rock material. The slope of the cultivated area is about 0.1% to allow the water to flow into the drain below the riser. The width of this area is also dependent on soil slope, soil depth, and type of crop to be grown on the area (John, 1976).

Any excess water in the drain flows into the waterway which is built across the contour lines (Figure 6). The maximum distance between two adjacent waterways is 100 m with the object to maintain a flow velocity of 0.6 m/s and a time concentration of 10 min (John, 1976). John (1976) calculated this velocity based on the characteristics of a bench terrace as shown in Figure 7. The volume of the drain, which has a trapezoidal shape, is 0.75 m^3. Using the Manning equation, $V = 1/n\ S^{1/2}R^{2/3}$ with $n = 0.025$, V calculated is 0.16 m/s. The velocity of flow in the waterway is controlled by drop structures (Figures 8 and 9) and the velocity is maintained below 1.25 m/s so that erosion will not occur in the canal. However, the size of the waterway is dependent on the catchment area. Therefore, the waterway is narrow at the upstream and broader at the lower end. For guidance to the farmer in the building runoff waterways, the project developed a guide (Table 7) so that the field worker or the farmer can easily build the waterways in correct shape (John, 1976).

Suitable grass species are planted to prevent erosion in the waterways as well as to avoid erosion on the lips and the risers which

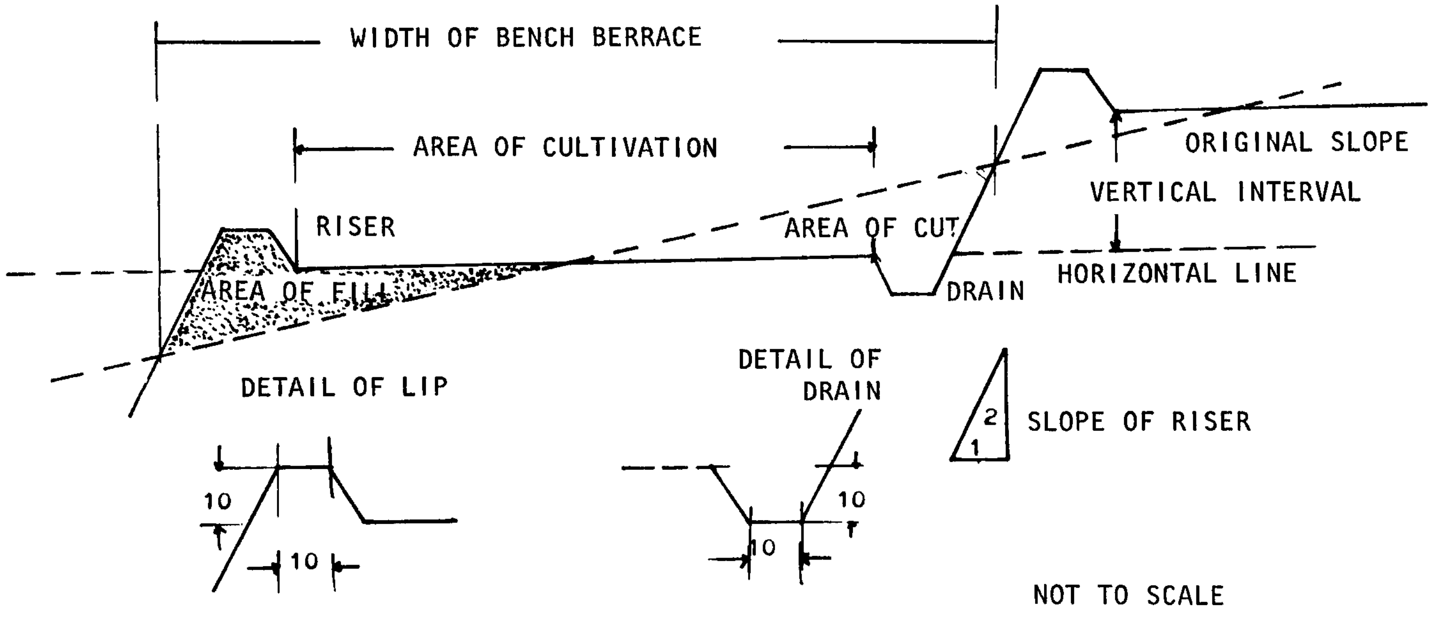


Figure 7. Detail dimension of bench terrace

Figure 8. Bamboo drop structure

Figure 9. Prefabricated drop structure

Table 7. Volume of runoff and dimension of waterways in small catchment areas for bench terrace. -- Taken from John (1976).

Catchment Area * (ha)	Time of Concentration (min)	Runoff (1/s)	Maximum Depth of Flow (m)	Waterway Dimensions Bed Width (m)	Waterway Dimensions Depth (m)
0.5	10	255	0.29	0.5	0.5
1.0	11	560	0.34	1.0	0.5
2.0	12	1,100	0.45	1.5	0.5
3.0	13	1,620	0.52	2.0	1.0
4.0	13	2,160	0.56	2.5	1.0
5.0	14	2,650	0.59	3.0	1.0

*It is assumed the catchment areas have a fairly regular shape.

have steep slopes. Grass such as Penisetum purpureum (Figure 10) or legumes such as Stillosanthes gracilis is planted on the risers; the lips are planted with other bigger legumes such as Leuceuna glauca, Caliandra thalothirsus, and Sesbania glandiflora (Figure 11). The protective plants for the risers and lips are also intended to provide forage for cattle and firewood for home use.

Mandays of labor required for bench terrace construction range from 367 to 1,294 mandays/ha, depending on the ground slope and vertical interval. Standard labor requirements for bench terracing, waterway construction, and drop structure are listed in Appendix A. One manday is 8 hr with normal working hours from 0700-1100 and 1300-1700.

Figure 10. Grass plantation on risers of new terraces

Figure 11. Leucena glauca (legumes) on lip of terrace

Because the construction of bench terraces and their accessories are to be built by the farmers, they need adequate equipment for making level lines, measuring slopes, and measuring heights and elevations. For these, the Project introduced some simple tools made from local materials such as bamboo, wood, rope, etc. These are "ondol-ondol," "segi-tiga," and "plastic water level." By these instruments, the farmers are able to make contour lines. The tools are sketched in Figure 12.

Gully Control. On areas that cannot be terraced due to extensive gully formation, the gullies must be plugged. Before building the plug, all surface runoff, whether coming from wild areas or from terraced areas, has to be diverted away from the gully to avoid further growth and possible collapse of the plug during the construction. Figure 13 shows a plugged gully and the direction of runoff from it.

The plugged gully has a trapezoidal shape consisting of earthfill excavated from the surrounding area and compacted with a simple manmade soil compactor usually made of wood or stone with a wooden handle. All work is done by hand by men or women rather than by machinery to relieve the high unemployment rate. Gully plugs differ from check dams in that they do not necessarily need an impervious stratum as a core. The maximum height of the plug is usually 6 m. It is better to build a series of gully plugs of small size rather than one large gully plug (Figure 14). Both sides of the gully bank are sodded with local grass to protect it against erosion. An overflow is necessary to discharge excess water from the gully.

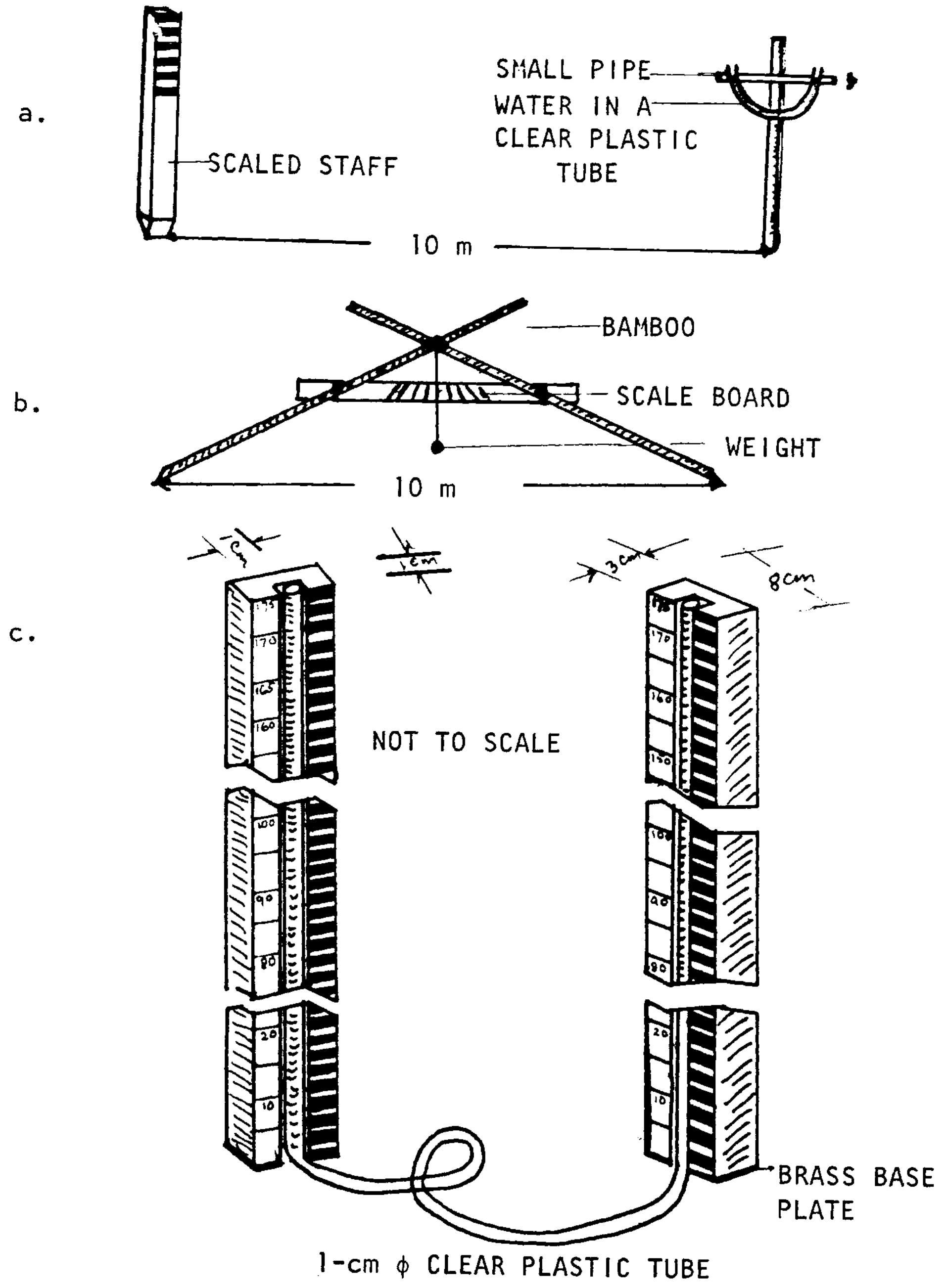


Figure 12. Simple tools used for slope measurement. -- (a) Ondol-ondol, (b) segi-3, (3) water level.

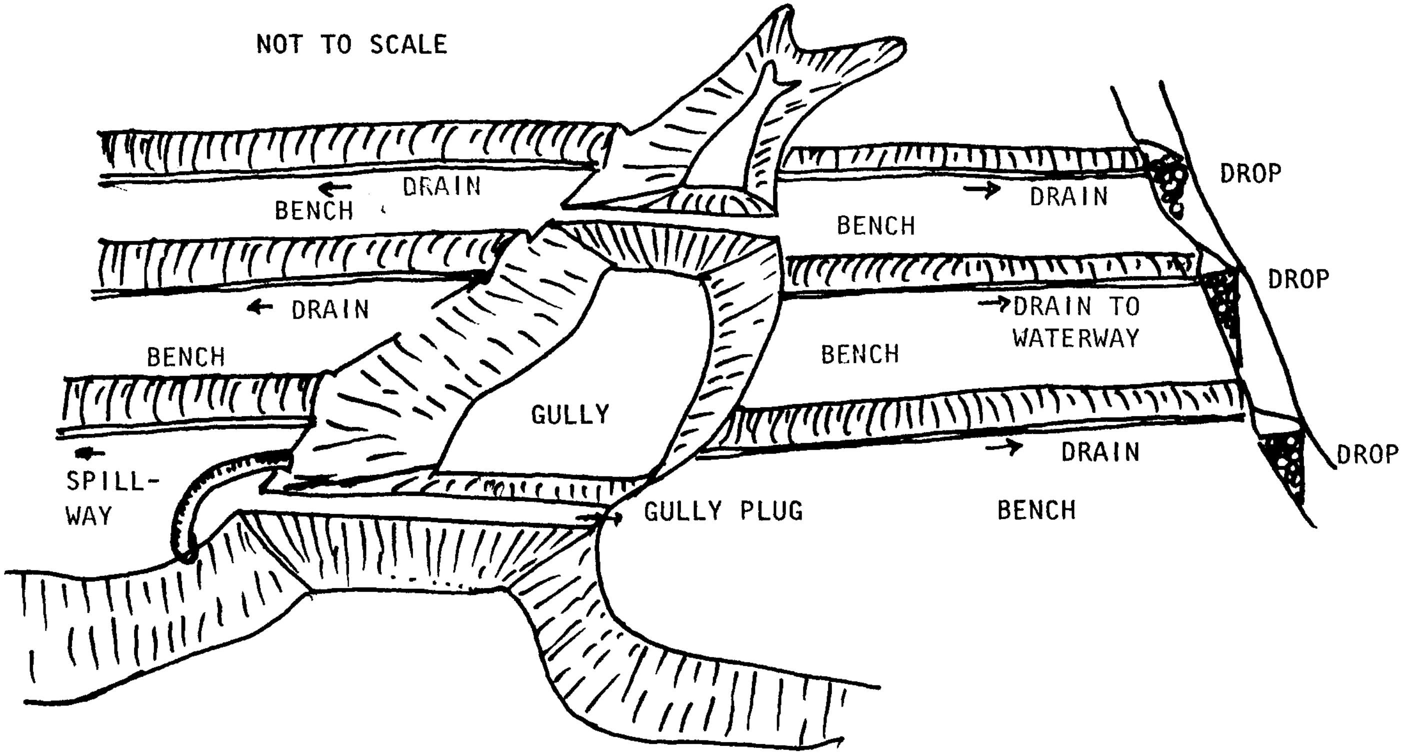


Figure 13. Direction of flow from the gully

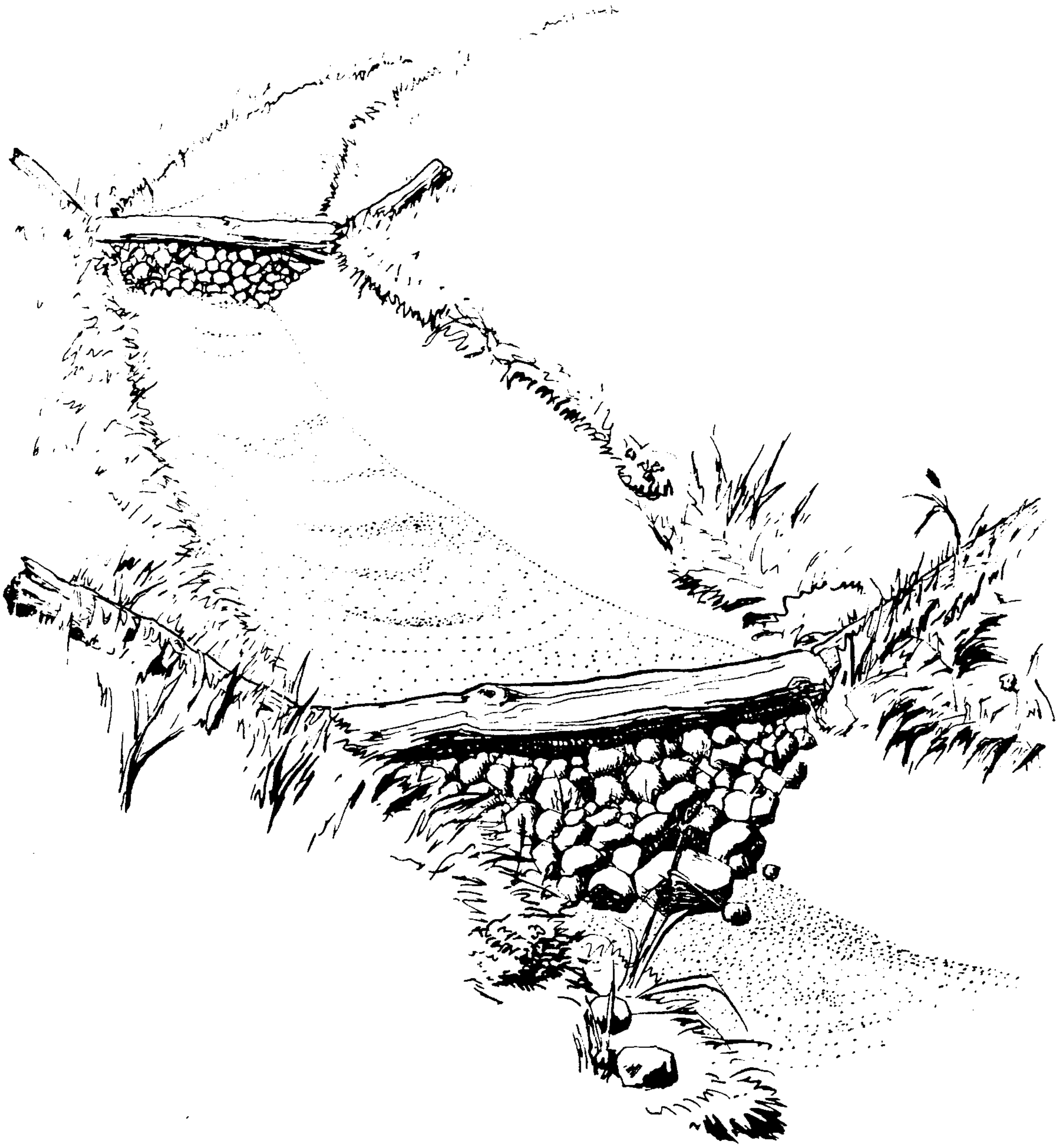


Figure 14. Series of gully plugs. -- From Heede (1960).

Although Gifford, Hancock, and Calthrap (1978) stated that the function of the gully plug is mainly for sediment and runoff control, the Dumpul Project finds that the gully plug does more than that. Not only does it control sediment and runoff, but it also provides water for fish ponds and small irrigated fields, especially in the rainy season. During the dry season this structure also provides clean water for the local people.

On the entire Dumpul subwatershed, the Project built 188 gully plugs, single or in series. In some cases, the Project utilized the existing gullies as waterways but with some improvements and additional gully drops to control the water velocity and improve the gully itself.

Check Dams. Another structure for controlling erosion is the check dam. It works as a sediment and water collector similar to a gully plug but on a larger scale. The main structure consists of the dam, a spillway or overflow canal, an intake pipe with a sluice gate, and an irrigation canal whenever possible.

There are three types of check dams: pervious or porous check dams from loose rock; impervious check dams of earth fill with impervious core; and concrete check dams (Heede, 1976). Siswomartono (1978) classified the check dams as temporary, semi-permanent, and permanent. The temporary dam is made of wood, loose rocks, wire, or bamboo net; the semi-permanent is made from earth fill with impervious core; and the permanent check dam is built with concrete or masonry.

In Indonesia the soil conservation project uses the earth fill with impervious core type of dam. The core is made from a mixture of clay and lime. The ratio of clay to lime is dependent on the quality of the clay and the lime and usually is determined by testing. The shape of the dam has a trapezoidal cross section with a 1:1.5 slope on the front bank and a 1:2 slope for the back bank (the flooded bank) as sketched in Figure 15.

A spillway or an overflow canal is located on one side of the dam to release excess water and maintain the water surface at a certain level, as high as the impervious core. The size of the spillway depends on the catchment area, the runoff coefficient of that particular area and the maximum 25-year rainfall intensity.

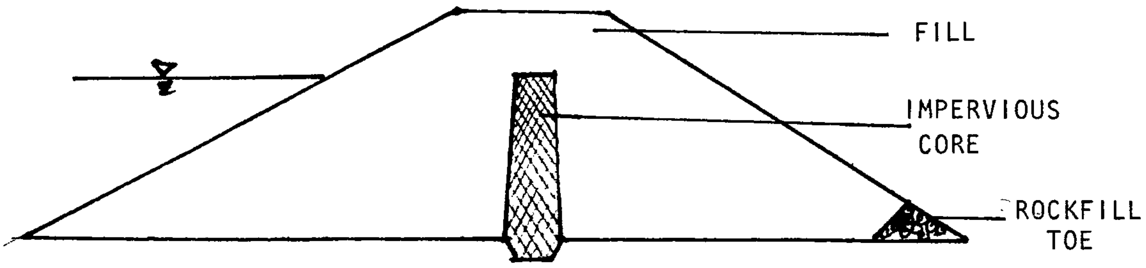


Figure 15. Sketch of the cross section of check dam built in Indonesia

The Government of Indonesia introduces this system to the farmers with the intent that it be built by the farmer himself or by the local people in a group. Thus the construction of the check dam rarely uses engineering calculation and the structures are usually limited to catchment areas of less than 20 ha with a maximum height of the body being 10 m (Siswomartono, 1978). The check dams are not to be built on heavy clay soils.

The advantages of check dams in soil conservation are in controlling soil erosion and runoff, balancing the hydrologic cycle by releasing water from the dam annually, increasing ground-water levels, providing water for cattle and domestic use, making possible fisheries, and providing water for small irrigation schemes.

In some cases construction of check dams tend to stimulate and accelerate other soil conservation activities. People whose lands are on the upper part of the catchment realize what happens to their land; they see the soil sediments deposited behind the dam, that other farmers are able to grow rice on the sediments in the dam, and that the increasing ground-water level will improve the plant growth. They then realize that those fertile soils come from their land and they are willing to start soil conservation programs. Terrace construction and other soil conservation measures follow. Due to water availability people are able to provide nuseries for the reforestation program.

For the Dumpul subwatershed, one check dam was built on the adjacent subwatershed to irrigate the terraced area, but the water is all consumed in that watershed and never flows into the Dumpul subwatershed.

Other Accessory Construction. The Soil Conservation Section had the responsibility for road construction, road crossings, irrigation of canals, and water culverts. The following is a list of work completed by the Soil Conservation Section:

1. Bench terrace construction, 86.52 ha.
2. Waterways, 18,417 m.
3. Drop structures, 1,866 m.
4. Gully plugs, 118 each.
5. Inspection roads, 4,893 m.
6. Fish ponds, 5 each.
7. Irrigation canals, 150 m.
8. Road crossings, 4 each.
9. Waterway crossings, 4 each.

The average cost for treatment of 1 ha of dry land with bench terrace is $404/yr. After development it is expected that production expressed as calories will increase from 645 to 2,970 (10^3 kcal), an increase of 360% (Ditsi, 1978a).

Agricultural Intensification

Immediately after the terraces have been constructed, the Agronomy Section established a crop rotation for the area including the introduction of new high-yield varieties and the distribution of fertilizers to the farmers. This section also conducts species and variety trials and establishes demonstrations concerned with food crop production, grass trial for covering the risers and lips of the terraces, and the method for managing of fish ponds. Intensification of agriculture on terraced land increased farm production as shown in Table 8. Average cost per hectare for agricultural intensification is $140/yr.

Stream Gauge Stations

To monitor the impact of the development projects, the Hydrology Section built steam gauging stations at the outlet of the subwatersheds. Each station is equipped with an automatic water level recorder and two rain gauge recorders (one at the station site and

Table 8. Crop production with and without bench terraces and agricultural intensification. -- From Ditsi (1978b).

	Treatment			
Crops	With	Without	Addition	Percentage
Cassava (t)	6,130	2,852	3,278	115.0
Paddy (t)	1,170	242	928	383 0
Corn (t)	2,832	517	2,315	448.0
Groundnut (t)	1,884	309	1,575	510.0
Calorie production (10^3 kcal)	2,970	645	2,325	360.0

one upstream). Hydrologically, the impact on the surface flow of the integrated soil conservation of the Dumpul subwatershed is shown by Figure 16. By assuming that the 1974-1975 record (before treatment) is 100%, the curve shows that the peak flow decreased to 81.54% during 1975-1976 and 77% during the 1976-1977 water years, and the flow ratio to rainfall depth decreased from 100% to 81% to 63%. On the other hand, the time of recession increased from 100% to 113% and 112.54%.

Non-physical Treatment

Extension Education

The farmers on the project and the surrounding areas require a knowledge of appropriate ways to cultive the land to receive optimum

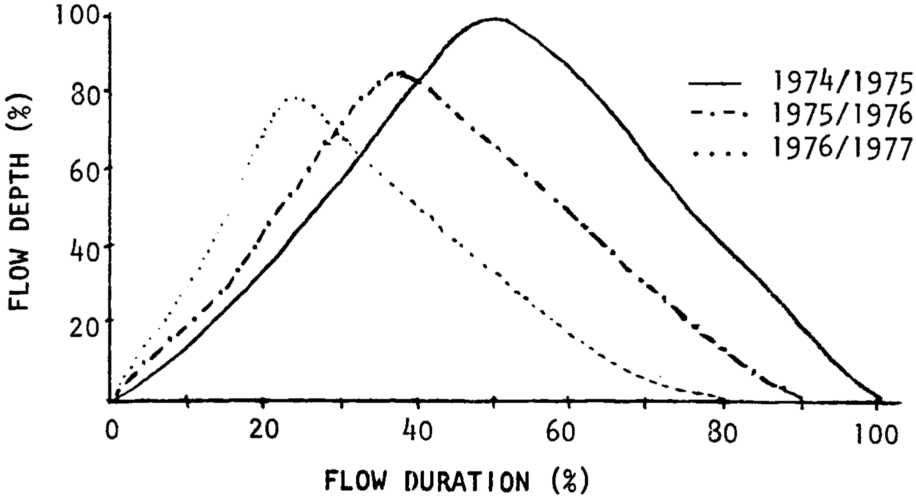


Figure 16. Hydrograph of the Dumpul subwatershed, 1974-1977

yield without deteriorating the soil. Moreover, the farmers must be organized in a water-user association so that the water can be distributed and used wisely. Cooperation is needed to organize product marketing and to obtain fertilizer, pesticides, insecticides, and other requirements at reasonable prices. At harvest time a cooperative can collect the farm product and avoid lower prices such as would be the case if the products are bought by a middle man.

The section of Extension Education periodically conducts job-training sessions for the farmer on several fields. It also educates through meetings, field trips, extension programs, and through radio and television. In every village the project forms a cadre in soil conservation that will later lead other farmers in a soil conservation program. Furthermore, family planning is a key factor in maintaining the population at a level the land can sustain.

Watershed Economy

Every investment in development must be economically as well as technically sound. When technical development through an integrated soil conservation program has a desirable impact, soil erosion and surface runoff are nearly eliminated and the crop yield is increased significantly. However, it is necessary to evaluate the work from an economic point of view. The Watershed Economy Section of the Project works on this problem. This economic section collects data on input and output and calculates the benefits in terms of cost. Two criteria are used to make this evaluation: (1) the Benefit and Cost Ratio (BCR) and (2) the Internal Rate of Return (IRR). The results of economic evaluation are listed in Table 9. Table 9 shows that from the economic viewpoint the program is a sound investment. The overall BCR is 2.8 , and the IRR is 22.4% at a 12% per annum rate of interest.

Gauchon (1976) commented that these figures represent a striking find of the project because from the beginning it was thought that the program would be too costly.

Table 9. Benefit and Cost Ratio and Internal Rate of Return of the development at 12% per annum interest rate. -- From Gauchon (1976).

Treatment	Benefit and Cost Ratio	Internal Rate of Return (%)
Reforestation	2.0	17.4
Bench terracing	1.8	18.8
Water development	3.1	26.3
Home garden improvement	---	21.1
Overall	2.8	22.4

THE IMPACT OF AN INTEGRATED SOIL CONSERVATION PLAN ON THE ANNUAL SOIL LOSS OF THE DUMPUL SUBWATERSHED

There are many different ways to measure the annual soil loss from an area. As discussed in an earlier chapter, they include iron pin, sediment collection tank, gully plug, and sediment sampling of a stream. These systems were already in use for evaluating the erosion rate of the Dumpul subwatershed and six other subwatersheds of the Upper Solo River Project.

There is still another method of computing (original word is "predicting") soil loss from an area, a method established by Wischmeier and Smith in 1958 in the United States of America. This method employs the Universal Soil Loss Equation (USLE) which is now widely used by many workers throughout the world such as Lal (1977) and Roose (1977) in Africa, El-Swaify and Dangler (1977) in the tropical soils of Hawaii, and Bols (1978) in Indonesia.

This thesis applies the USLE to evaluate the impact on erosion of the development of the Dumpul subwatershed. This has not been previously used on the Upper Solo Project. The advantage of using this equation is that the amount of soil loss of an area can be computed simultaneously under both treated and untreated conditions. However, the prediction of soil loss on the subwatershed is not as simple as the soil loss prediction of an area in the United States where all factors have been established and are available and ready for use. Some adjustments are thus needed in the application of the USLE to the Dumpul subwatershed.

The USLE is written mathematically as a functional relationship, where its factors are expressed numerically. The equation is:

$$A = R \times K \times L \times S \times C \times P,$$

where

A = the amount of soil loss in unit weight per unit area per unit time. In the metric system, it is expressed in t/ha/yr.

R = the rainfall erosivity, which depends on the rainfall intensity and the kinetic energy of the rainfall, is expressed in MJ•mm/ha•h•yr.

K = the soil erodibility, which is a parameter for estimating the ease of the soil being eroded by an erosive agent expressed in t•ha•h/ha•MJ•mm.

L = the slope length, which is the ratio of soil loss from a field with a certain slope length to that of identical field of 22 m or 72.7 ft in length.

S = the slope steepness, which is a ratio of soil loss from a field with that slope to that of identical field with 9% slope gradient.

C = the cover management, which is a ratio of soil loss from an area under specified cover and management to that from an identical area under tilled continuous fallow.

P = the support practice, which is a ratio of soil loss with support practice to that with straight row farming up and down the slope.

Because the equation was empirically established for the western United States, transferring the equation needs careful consideration. However, the idea of "erosion prediction and control is accepted" worldwide (Foster, Moldenhouer, and Wischmeier, 1980, p. i). Foster and Wischmeier (1974), Athesian (1974), Lal (1977), and Bols (1978) tried to determine what adjustments were necessary to apply the equation to different places in order to universalize it.

Application of the Universal Soil Loss Equation to Predict the Annual Soil Loss from the Dumpul Subwatershed

The Dumpul subwatershed, which is in the tropics, has many characteristics which are different than those of watersheds in the United States, where the USLE was developed. Therefore, some factors of the USLE may not be directly transferable to the Dumpul area, although some others may be. Vegetation cover and rainfall intensity need special consideration (Foster et al., 1980).

Computation of the Universal Soil Loss Equation Factors for the Dumpul Area

Whether adjustments are needed or not, each factor of the USLE will be discussed in this section.

Rainfall Erosivity (R). Wischmeier and Smith (1958) stated that the rainfall erosivity factor (R) is a function of rainfall

intensity (I), and kinetic energy (E). The R factor is the product of the maximum 30-min intensity (I30) and the total kinetic energy (E) divided by 100; R = E X I30 M.J. mm/ha.,
depending upon the system of measurement being used. The 30-min maximum rainfall intensity (I30) is computed from a recorded chart of an automatic rainfall recordeer. The kinetic energy (E) is computed from an equation derived by Wischmeier and Smith (1978).

In metric, $E = 120 + 89 \log I$ (I is in cm/h).

In British, $E = 916 + 331 \log I$ (I is in in/h).

Because the I30 is not available in some countries, particularly in the developing countries, the R value is difficult to assess. Those countries often do have rainfall records for more than 25 yr.

Soil erosion has a linear relationship with the EI30, but not with the precipitation (P). Therefore, EI30 cannot be directly substituted with the amount of rainfall to estimate the erosion. Athesian (1974), Bols (1978), and Richardson and Foster (1980) sought another relationship between erosion and rainfall where recorded rainfall data are not available at a particular place in question. Athesian (1974) developed an equation on $R = 27\ (P6)^{2.2}$ and $R = 16.55\ (P6)^{2.2}$ for the East and West Rocky Mountain regions, respectively, where P6 is 2-yr 6-hr rainfall depth in inches. Richardson and Foster (1980) developed another model where $\log EI30 = \log a + b \log P + E'$, where a and b are equation parameters. Bols (1978), who worked in Java, Indonesia, came up with a different relationship,

$$(R)_m = (EI30)_m = 6.119\ (RAIN)^{1.21} \cdot (DAYS)^{-0.47} \cdot (MAX.P)_m^{0.53}$$

where

$(EI30)_m$ = an average monthly erosivity,

RAIN = monthly precipitation in cm,

DAYS = number of rainfall days per month, and

$(MAX.P)_m$ = maximum precipitation in 24 hr of the month.

All the parameters, rain, days, and maximum precipitation, are available at many stations throughout the country.

On the Dumpul subwatershed rainfall records are available for 7 years, from 1974 to 1980. Therefore, the R factor used in this area is derived from Bols' equation. Table 10 shows the computation of the R factor for the Dumpul subwatershed using Rain, Days, and Max.P data. The value is computed from the average 7-yr rainfall data and it was found that R = EI30 = 2,039 MJ•mm/ha•h•y.

The Soil Erodibility Factor (K). According to Foster et al. (1980), this USLE factor is the most difficult to apply in the tropics. There are many variations of soil characteristics in the world affecting erosion. Soil with similar appearances often will differ widely in its erodibility. Wischmeier and Smith (1978) and Wischmeier, Johnson, and Cross (1971) stated that the soil erodibility nomograph gives accurate K values by using five soil parameters. These are the percentage of silt and fine sand, percentage of sand greater than 0.10 mm, organic matter content, structure, and soil permeability.

Table 10. Annual precipitation, maximum precipitation, days, and EI30 of Dumpul subwatershed

	Month												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
						1974							
Rain (mm)	-----	-----	168.9	273.1	187.6	-----	0.4	54.1	132.4	355.1	284.1	286.8	1,742.5
Max.P	-----	-----	38.5	84.2	90.5	-----	0.4	20.4	36.5	71.4	58.6	66.2	
Days	-----	-----	9	17	12	-----	1	14	17	25	18	19	132
EI130*	-----	-----	136.1	273.3	212.4	-----	0.0	19.9	73.1	287.1	230.4	242.3	1,474.6
						1975							
Rain (mm)	532.4	358.0	404.2	299.2	189.4	42.0	15.0	50.0	216.0	503.4	313.4	290.6	3,213.6
Max.P	129.8	80.4	37.8	88.0	61.8	28.2	8.5	49.5	56.4	53.8	62.2	53.6	
Days	30	24	30	21	22	4	4	2	13	25	24	24	223
EI130*	590.5	314.7	220.0	283.0	131.7	31.7	4.8	72.3	188.8	377.0	233.8	197.2	2,645.9
						1976							
Rain (mm)	397.6	324.4	209.8	92.8	7.0	0.2	3.4	73.7	27.2	197.2	309.5	284.0	1,926.8
Max.P	50.4	56.2	43.8	32.0	4.0	0.2	3.2	43.1	17.5	50.2	57.5	86.5	
Days	27	21	18	14	4	1	2	4	3	13	15	10	132
EI30*	264.0	246.1	136.8	48.6	1.3	0.0	0.6	77.6	16.5	159.5	275.5	373.0	1,599.5
						1977							
Rain (mm)	271.5	375.5	417.5	225.0	36.0	189.1	0.6	-----	1.2	23.5	130.7	327.0	1,997.6
Max.P	58.0	59.5	55.5	50.0	14.5	55.0	0.6	-----	1.2	23.5	32.5	71.5	
Days	17	20	23	17	4	11	1	-----	1	1	9	18	124
EI30*	222.8	309.8	317.8	164.1	18.3	171.6	0.0	----	0.2	27.1	91.2	303.5	1,626.3
						1978							
Rain (mm)	418.9	423.7	408.7	159.5	321.0	318.3	125.2	131.9	69.2	172.2	162.7	342.8	3,054.1
Max.P	59.0	61.0	85.0	79.0	89.5	84.0	29.5	88.0	25.0	63.5	46.0	54.0	
Days	19	15	17	10	18	18	10	11	9	14	12	22	175
EI130*	360.5	415.7	447.5	176.9	334.3	319.9	78.3	142.2	37.4	147.6	124.9	251.9	2,837.4
						1979							
Rain (mm)	228.8	350.8	275.0	319.3	380.8	51.2	7.6	0.4	28.6	77.2	289.5	353.0	2,362.2
Max.P	59.9	48.4	53.6	59.4	65.0	20.8	4.0	0.4	23.5	23.5	89.5	81.0	
Days	16	21	19	22	16	6	4	1	6	6	13	23	153
EI130*	189.5	249.9	205.9	243.2	366.6	28.0	1.4	0.0	14.8	49.2	343.7	316.9	2,009.1
						1980							
Rain (mm)	387.0	247.7	468.0	512.8	22.4	0.6	21.5	19.8	36.6	80.0	241.0	249.3	2,286.7
Max.P	76.5	53.0	65.0	131.0	14.0	0.4	6.5	11.0	27.4	22.6	45.2	62.5	
Days	20	23	21	22	5	2	6	5	3	9	21	14	151
EI130*	367.5	164.8	413.9	656.3	9.0	0.0	5.3	6.9	29.9	41.5	153.0	229.0	2,077.5

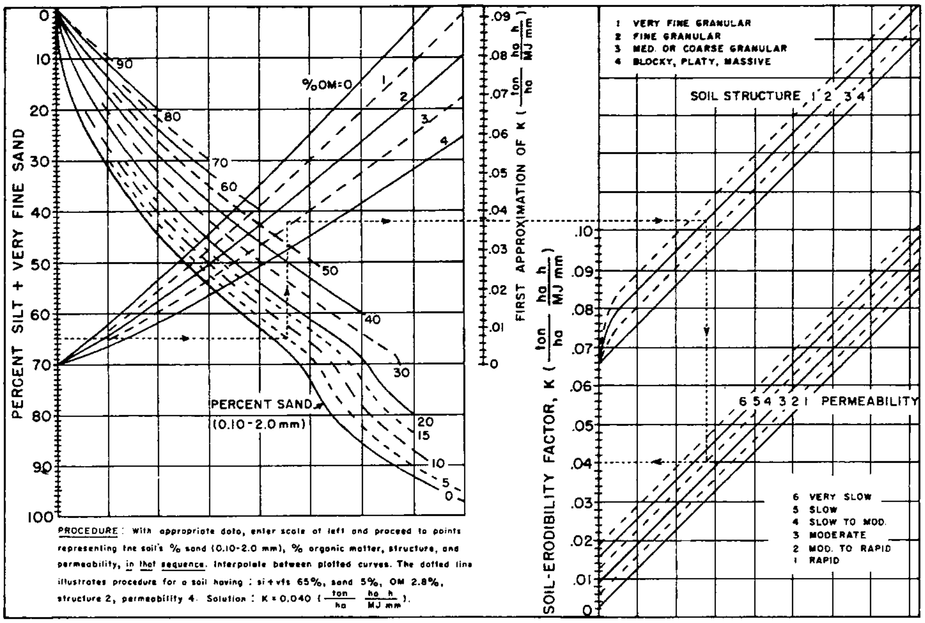
Not all workers agree with Wischmeier and his associates. El-Swaify and Dangler (1977) disagreed that the K factor is dependent of soil texture. They showed that the percentage of clay, silt, and silt plus very fine sand did not strongly influence the K value for Hawaiian tropical soils. Holzhey and Mausbach (1977), on the other hand, supported Wischmeier and associates' idea and found that usually the range of the K values for sandy and loamy particle sizes is wider than that of a silty soil.

Roose (1977) found that the K values of some soils in West Africa range from 0.05-0.10 for Tertiary sands, 0.10-0.15 for granite, and 0.15-0.18 for schist. For other soils it ranges from 0.20-0.30. All investigators suggested that more experiments on many types of soil are needed to obtain a better value for K. It appears that soil erodibility is "a function of complex interactions" of not only physical but also soil chemical properties (Wischmeier and Mannering, 1969). Foster et al. (1980), however, state that errors in selecting K are less than the range of effect of cover and management.

The chief soil of the Dumpul area is classified in the Latosol soil order (Ditsi, 1979b). According to the U.S. taxonomy, this soil is an Oxisol (Donahue, Miller, and Shickluna (1977). Its properties related with the K factor are presented in Table 11. Using these properties and the nomograph in Figure 17 (Foster et al., 1981), the average K value of the Dumpul subwatershed is 0.14.

Table 11. Properties of soil of the Dumpul subwatershed. -- From Ditsi (1979b).

Depth	Structure	Permeability	Texture			Organic Matter
			Clay	Silt	Sand	
		Horizon I				
0- 20 cm	granular	slow	77.5	17.2	7.3	4.95
		Horizon II				
20- 50 cm	granular	slow	62.7	18.5	18.8	4.87
		Horizon III				
50-100 cm	granular	slow	76.6	13.7	9.5	4.10



PROCEDURE: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0 mm), % organic matter, structure, and permeability, in that sequence. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: si+vfs 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.040 ($\frac{ton}{ha}$ $\frac{ha\ h}{MJ\ mm}$).

Figure 17. Soil erodibility (K) factor nomograph in SI units. -- From Foster et al. (1981, Figure 2).

The Slope Length (L) and the Slope Steepness (S). These two factors are usually combined as the slope-length (LS) factor rather than as an individual factor. Its value is a function of slope length (λ) and angle of the slope (θ) (Wischmeier and Smith, 1958). Wischmeier and Smith found the relationship of the LS to its factors as:

$$LS = (\lambda/72.6)^m \ (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065)$$

where, for a slope less than 1%, m = 0.2; 1-3%, m = 0.3; 3.5-4.5%, m = 0.4; and for 5% or greater, m = 0.5.

Because the LS value is dimensionless, the numerical values are the same whether computed in the British or metric systems.

The Universal Soil Loss Equation is applicable for predicting soil erosion under uniform land conditions; i.e., uniformity in slope steepness, crop management, and soil type. For these reasons, then, the area of the Dumpul subwatershed is classified, based on the slope steepness as shown in Figure 18 (in pocket).

Capital letters (A, B, C, . . .) are used for naming sawah or irrigated rice fields. Small letters (a, b, c, . . .) are used for village areas. Arabic nunbers (1, 2, 3, . . .) are used for dry field areas. After that, the slope steepness and the slope length (m) are computed or measured and listed in Appendix B, Columns 6 and 7. The slope length of the untreated or control subwatershed is directly measured from the map. The slope length of the treated area is adapted from Table 12. The LS value is then computed using Wischmeier and Smith's (1958) equation where,

$$LS = (\lambda/72.6)^m (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065.$$

The results of the entire LS computation for the Dumpul subwatershed are listed in Appendix B.

For an irregular slope the computation is more complex (Foster and Wischmeier, 1974). The slope length is divided into segments, then Table 13 is used to find a coefficient for the LS values which are then multiplied by the computed LS value to get the LS value for irregular slopes. The segmentation of the Dumpul area is done by interpretation from the Dumpul aerial photographs.

Table 12. Width of bench terrace (m) in relation to slope gradient and vertical interval where the riser slope is 2:1. -- From John (1976).

Vertical Interval (m)	Slope Gradient (%)					
	5	10	15	20	25	30
0.25	4.48	2.50	1.67	1.25	---	---
0.50	---	4.35	2.68	1.85	1.35	---
0.75	---	6.72	4.22	2.97	2.22	1.72
1.00	---	---	5.77	4.10	3.10	2.43

Table 13. Estimated relative soil loss from successive equal length segments of uniform slope. -- From Wischmeier and Smith (1978).

Number of Sequence	Sequence Number of Segment	Fraction of Soil Loss		
		m = 0.5	m = 0.4	m = 0.3
2	1	0.35	0.38	0.41
	2	0.65	0.82	0.59
3	1	0.19	0.22	0.24
	2	0.35	0.35	0.35
	3	0.46	0.43	0.41
4	1	0.12	0.14	0.17
	2	0.23	0.24	0.24
	3	0.30	0.29	0.28
	4	0.35	0.33	0.31
5	1	0.09	0.11	0.12
	2	0.16	0.17	0.18
	3	0.21	0.21	0.21
	4	0.25	0.24	0.25
	5	0.28	0.27	0.25

Detailed segmentation is carried out only on slope lengths of more than 300 m because the area of Dumpul has been classified into uniform slope classes.

The example of segmentation computation given below was taken from the area under code "h" of the Dumpul subwatershed (Appendix B). From the topographic map (Figure 18, in pocket), the horizontal length is 325 m, the height is 12 m, and the slope length is 325.22 m. From the aerial photo it can be segmented into 225 m with slope of 3.11% and 100 m with 5% slope (Figure 19).

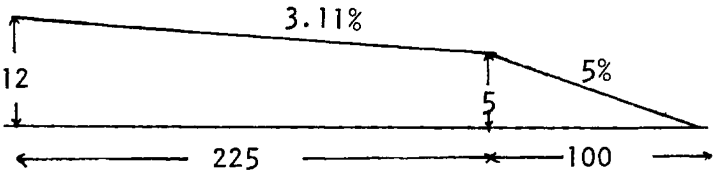


Figure 19. Segmentation of an irregular slope

The computation of the LS value is as follows:

Segment	Percent Slope	LS Value from Equation	Factor from Table 13	Product
I	3.11	0.6079	0.41	0.2492
II	5.00	0.9090	0.59	0.5717
				LS = 0.8209

If the slope without segmentation is computed as being 325.22 m in length with an average slope of 3.6%, the slope length (LS) value is then 0.97.

Crop Management Factor (C). The main function of the vegetation cover in the soil erosion process is in intercepting raindrops. Thus, in soil erosion control, the effect of the vegetation cover is dependent upon how completely it covers the soil surface.

There are great differences in vegetation types over the world, so that the influence of vegetation cover on soil erosion process varies greatly among areas. Transferring C values of the USLE from one area to another needs special consideration. The computation of C value is a complex process because it involves cropping patterns, management, vegetation type, and the residual effects (Foster et al., 1980).

The cropping pattern on the Dumpul subwatershed is constant. On the irrigated rice field there are two seasons of paddy plantations. There is essentially no erosion on these fields because the cultivated areas are flat, the soil is well covered during the heavy storms in the rainy season, and the water itself is well managed. The waterway and the irrigation canal are always maintained with full grass.

On the dry land, farmers usually grow corn, sweet potatoes, and soybeans in multiple cropping. A multiple cropped field is always well protected because the farmer plants soybean, corn, and cassava at the same time and harvests them over a period of time; soybeans after 3 mo., corn after 4 mo., and cassava at 12 mo. The terraced and unterraced dry land have similar cropping patterns. The differences are in the growth quality of the crop, the capability of the canopy to cover the soil surface, and the amount of litter produced by the crops. The canopy coverage is only 25% on the untreated control areas, due to low plant nutrients in the soil; the treated area canopy reaches 60% to 80%. The percentage of litter coverage on the untreated areas is about 25% and 40% on the treated. The Wishmeier and Smith (1978) charts (Figures 20 and 21) with the above conditions gives an average value 0.3 for C for an untreated dry land area and 0.25 for a treated area. On the irrigated rice fields the C value is 0.07 due to 80% canopy and 80% mulches. The C value of the village area is 0.06 both on treated and untreated fields.

The Supporting Practice Factor (P). The supporting practice factor (P) covers manmade structures to control soil erosion such as contouring, strip cropping, terraces, and contour furrows. The standard USLE (P) values, except for vegetation strips, are directly transferable to the tropics (Foster et al., 1980). The main differences between the treated and untreated area of the Integrated Soil Conservation project areas are changed in the slope length and the slope gradient. The difference of the supporting practice value for the treated and untreated areas is usually small. The P values for the Dumpul subwatershed are shown in Table 14 for the untreated area and Table 15 for the terraced area (Wischmeier and Smith, 1978).

For areas where the slope length exceeds the limit for each slope class, the effectiveness in reducing erosion will decrease. Therefore, the P value must increase to allow for the greater slope length. Because the lands on the Dumpul subwatershed are private lands which have clear boundaries between ownerships, the slope length never exceeds 100 m. Thus, Table 14 is valid for finding the

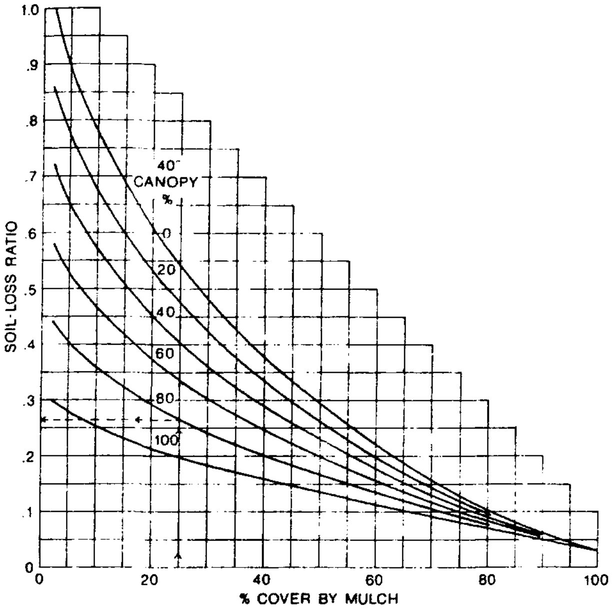


Figure 20. Combined mulch and canopy effects when average fall distance of drops from canopy to the ground is about 40 in. (1 m). -- From Wischmeier and Smith (1978).

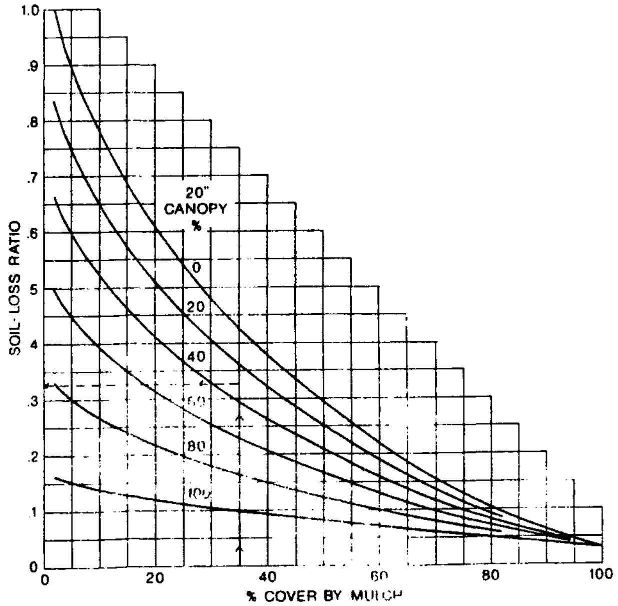


Figure 21. Combined mulch and canopy effects when average fall distance of drops from canopy to the ground is about 20 in. (0.5 m). -- From Wischmeier and Smith (1978).

Table 14. P values, maximum strip widths, and slope length limits for contour strip cropping. -- Wischmeier and Smith (1978).

Land Slope (%)	P Values[2] A	B	C	Strip Width[2] (ft)	Maximum Length (ft)
1 to 2	0.30	0.45	0.60	130	800
3 to 5	.25	.38	.50	100	600
6 to 8	.25	.38	.50	100	400
9 to 12	.30	.45	.60	80	240
13 to 16	.35	.52	.70	80	160
17 to 20	.40	.60	.80	60	120
21 to 25	.45	.68	.90	50	100

1. P values:
   A. For 4-yr rotation of raw crop, small grain with meadow seeding, and 2 yr of meadow. A second row crop can replace the small grain if meadow is established in it.
   B. For 4-yr rotation of 2 yr row crop, winter grain with meadow seeding, and 1-yr meadow.
   C. For alternate strips of row crop and small grain.
2. Adjust strip-width limit, generally downward, to accommodate widths of farm equipment.

Table 15. P values for contour-farmed terraced fields.[1] Wischmeier and Smith (1978).

Land Slope (%)	Farm Planning: Contour Factor[2]	Farm Planning: Stripcrop Factor	Computer Sediment Yield[3]: Graded Channels Sod Outlets	Computer Sediment Yield[3]: Steep Backslope Underground Outlets
1 to 2	0.60	0.30	0.12	0.05
3 to 8	.50	.25	.10	.05
9 to 12	.60	.30	.12	.05
13 to 16	.70	.35	.14	.05
17 to 20	.80	.40	.16	.06
21 to 25	.90	.45	.18	.06

1. Slope length is the horizontal terrace interval. The listed values are for contour farming. No additional factor is used in the computation.
2. Use these values for control of interterrace erosion within specified soil loss tolerances.
3. These values include entrapment efficiency and are used for control of offsite sediment within limits and for estimating the field's contribution to watershed sediment yield.

P values. It found that the P value for the Dumpul subwatershed ranges from 0.5 to 0.7.

Annual Soil Loss of the Dumpul Subwatershed

The results of the predicted soil losses of the Dumpul subwatershed are given in Table 16. The soil loss from the irrigated field is 98.6% less than the untreated area, and the treated village area is able to reduce the soil loss by 93.3%. The treated dry land reduces its soil loss by 98.0%.

All the areas are treated in such a way that all excess water can be drained directly to a waterway without overflowing onto other areas and the total soil loss of the entire subwatershed can be predicted. The total soil loss on the treated subwatershed is 97.7% less than the soil loss from that in untreated subwatershed.

The entire annual soil loss computations are listed in Appendix C.

Table 16. Annual soil loss on Dumpul subwatershed, treated and untreated

Area (ha)	Untreated t/ha	Untreated total t	Treated t/ha	Treated total t	Reduction (%)
		<u>Irrigated Land</u>			
37.44	33.01	1,235.72	0.60	21.22	98.2
		<u>Village Land</u>			
53.66	7.55	405.03	0.51	27.24	93.3
		<u>Dry Land</u>			
90.01	99.10	8,919.74	2.12	190.94	97.9
		<u>Entire Dumpul</u>			
181.11	58.31	10,560.49	1.32	239.40	97.4

DISCUSSION AND CONCLUSIONS

Discussion

Because population growth seems to be difficult to control, especially in the developing countries, the only way to feed an increasing population is by increasing food production. Ironically, soil and water as the main resources in food production are in critical condition due to soil erosion and runoff. Thus, the application of methods to increase food production should be accompanied by an intensive soil conservation program.

The Food and Agriculture Organization (FAO) of the United Nations and the Government of Indonesia in 1972 established a joint project of integrated soil conservation. This was called the Upper Solo Watershed Management and Upland Development Project, but generally is known as the Upper Solo Project. The Project began with the Dumpul subwatershed as a pilot project for demonstration and trial.

Physically, the impact of the program on soil loss has been evaluated by the use of sediment tank, iron pins, gully plugs, and sediment sampling at gauging stations. These methods yield estimates of erosion rates reflecting the overall soil erosion process. By "overall" is meant the total effect of all the soil erosion factors without separating the effects of the individual factors in the soil erosion process.

The Universal Soil Loss Equation (USLE), on the other hand, predicts the amount of soil loss of an area, and gives an estimate of what each factor contributes to soil loss. The predicted soil loss is the product of multiplication of the USLE factors:

$$A = R \times K \times LS \times C \times P,$$

where A is the soil loss and R, K, LS, C, and P are the USLE factors.

A soil conservation planner can investigate the effects of each factor on soil erosion, except the R factor. Using the USLE, the soil conservationist can fix a threshold of soil loss tolerance or permissible erosion. Erosion beyond this point means threatening food production, sedimentation of reservoir, and possible water pollution.

Some of the USLE factors, however, annot be used without modification in every place in the world. Some factors vary greatly fome one place to another and using the USLE worldwide without modification may cause serious errors. More research is necessary to establish the required adjustment of the USLE factors so that the equation is applicable universally.

The annual soil loss on the Dumpul subwatershed as predicted by using the USLE shows that the proposed soil conservation program satisfactorily reduces, if not eliminates, soil erosion. The reduction in soil loss is due to the effect the land treatment has on the USLE factors. The range of values of the USLE factors are shown in Table 17 which compares land given soil conservation treatment with untreated land.

The annual soil loss on the Dumpul subwatershed from which the values in Table 17 were derived are shown in Table 16 (p. 61).

Table 17. Range of values for the Universal Soil Loss Equation (USLE) factors of the Dumpul subwatershed

USLE Factors	Untreated Land	Treated Land
Rainfall erosivity (R)	2,039	No change
Soil erodibility (K)	0.14	No change
Slope length (LS)	0.30-4.28	0.05-0.4
Vegetation (C)	0.07-0.30	0.06-0.25
Management practice (P)	0.50-0.60	0.06

The program of integrated soil conservation on the Dumpul subwatershed reduced the annual soil loss on irrigated land from 33.01 t/ha to only 0.60 t/ha or 98.2%; on the village land from 7.55 t/ha to 0.51 t/ha or 93.3%; on the dry land from 99.10 t/ha to 2.12 t/ha or 97.9%; and for the entire Dumpul subwatershed the reduction was from 58.31 t/ha to 1.32 t/ha or 97.4%.

Studies by the Project personnel using sediment tanks show a reduction of soil loss of 89.3%. However, the average soil loss measured from the tanks on treated dry land is higher than the annual soil loss predicted by the USLE; 9.3 t/ha compared with 2.12 t/ha. On the untreated dry land the erosion rate was relatively the same: 87.0 t/ha calculated from the sediment tanks compared with 99.1 t/ha predicted using the USLE.

If the soil loss that can be tolerated on the Dumpul area is decided, then acceptability of the present annual soil loss can be evaluated. In case the present soil loss is beyond the permissible soil loss limit, the soil conservation planner must design a program which will work successfully on the most critical USLE factors. The highest value for a USLE factor is the one which contributes most to erosion and that shows the promise for treatment. For example, consider a terraced area which still has a soil loss above the permissible limit and assume that the values for the USLE factors are as shown below:

R	K	LS	C	P
2309	1.0	0.12	0.10	0.6

The annual soil loss will then be 16.62 t/ha. The R factor is not susceptible to treatment, while the P factor has low value which it seems cannot be lowered more. Thus, the only factors that can be reduced are the K, LS, and C because they are 1.0, 0.12, and 0.10, respectively; well above the lowest possible value of 0.14, 0.07, and 0.05, respectively, for the Dumpul subwatershed. Because the LS value is relatively low, the treatment should be aimed at reducing the K value.

The K value might be reduced to 0.5 by adding organic matter or chemical soil conditioners to the soil for example. This will cause the soil to become more permeable and develop better structure. The soil loss then will be only 2.31 t/ha.

Technically, this is easily done, but may not be economically feasible. By analyzing the output and input of various factors and combinations, the planner then can select the one which is most economic and which gives the lowest soil loss.

The economic analysis shows that the Dumpul Integrated Soil Conservation Program is economically beneficial (Gauchon, 1976). The Dumpul project increases food production and, hence, human land carrying capacity (Ditsi, 1978b). Moreover, the improved agriculture production results in more opportunities for labor, reduction in unemployment, and it further reducsed the flow of farmers to urban areas.

Furthermore, the Dumpul project benefits not only the Dumpul area itself, but also other areas downstream due to:

1. Reduced siltation in irrigation canals and reservoirs.

2. Elimination of deposition of infertile soil on fertile soil.
3. Reduction of surface runoff and flood losses, increasing water yield.

Conclusions

The Integrated Soil Conservation Program of the Dumpul subwatershed reduces the amount of soil losses to what appears to be permissible rates. This program thus increases food production capability and increases human land carrying capacity and it is economically justified. Implementation of similar programs on a large scale therefore appears promising.

The Universal Soil Loss Equation (USLE) provides a tool for the soil convservation planner to help him design a program for reducing soil erosion and tells him the exact factor that contributes most to soil losses.

The USLE can be used to evaluate the impact of a soil conservation program on the annual soil loss and to measure the criticalness stage of an area qualitatively rather than quantitatively. By this, a kind of program can be allocated effectively.

APPENDIX A

RECOMMENDED LABOR STANDARDS FOR SOIL CONSERVATION WORK*

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* From John (1976).

Bench Terraces

Details of Bench Terraces							Labour Requirements per ha		
Vertical Interval of Benches m	Original Ground Slope % to	%	Width of Benches m to	m	Average Distance of Earth Movement m to	m	Earth Movement Standard 1.4 m^3 per Manday	Sodding 1/4 Slope Area Sodded 8.5 m^2 per Manday	Total Mandays per ha
0.25	5	15	4.5	1.1	3.7	1.3	259	108	367
0.50	10	20	4.4	1.8	3.5	1.7	425	105	530
0.50	15	25	2.7	1.4	2.3	1.4	421	140	561
0.75	20	30	1.7	1.7	2.6	1.7	609	144	753
0.75	25	35	2.2	1.4	2.0	1.4	600	172	772
1.00	25	35	3.1	2.0	2.7	1.9	775	154	929
1.00	30	40	2.4	1.6	2.2	1.6	759	181	940
1.25	35	45	2.4	1.6	2.4	1.8	934	210	1,144
1.25	40	50	2.0	1.4	2.0	1.6	914	239	1,153
1.50	35	45	3.0	2.1	2.8	2.1	1,099	174	1,273
1.50	45	55	2.1	1.5	2.1	1.7	1,046	248	1,294

Waterways

Catchment Area < ha.	Estimates Maximum Runoff (l/s)	Minimum Bed Width of Waterway (m)	Depth of Waterway (m)	Volume of Cut per m length[1] (m^3)	Sodding Area of Bed and Sides (m^2)	Mandays per m length[2] (m/d)	Length of Construction/ Manday (m)
0.5	255	0.50	0.50	0.38	1.91	0.32	3.10
1.0	560	1.00	0.50	0.62	2.41	0.51	1.95
2.0	1,100	2.50	0.75	1.40	3.62	1.09	0.92
3.0	1,620	2.00	1.00	2.50	4.83	1.89	0.53
4.0	2,160	2.50	1.00	3.00	5.34	2.26	0.44
5.0	2,650	3.00	1.00	3.50	5.83	2.62	0.38

1. Side slope of waterway 2 to 1 (2 vertical to 1 horizontal).

2. Based on earth movement at rate of 1.4 m^3 per manday and sodding 8.5 m^2 per manday with one-fourth area sodded.

Stone Drop Structures

Mandays required for collections and transportation of stone, and construction (John, 1976).

Width of Waterway (m)	Height of Drop (m)	Area of Stone Paving (m^2)	Volume of Stone (m^3)
0.5	0.5	0.51	0.13
	1.0	1.25	0.31
	1.5	2.25	0.56
	2.0	3.50	0.88
1.0	0.5	0.88	0.22
	1.0	2.00	0.50
	1.5	3.38	0.85
	2.0	5.00	1.25
1.5	0.5	1.26	0.32
	1.0	2.75	0.69
	1.5	4.50	1.13
	2.0	6.50	1.63
2.0	0.5	1.63	0.41
	1.0	3.50	0.88
	1.5	5.63	1.41
	2.0	8.00	2.00

Labor Standards: Standard rate for colleting and setting stones for construction of drop structures in waterways:

7 mandays/m^3 of stones

Factor to be applied for stone transportation:

Distance up to 30 m 1.00 (standard rate)
Distance up to 100 m 1.11
Distance up to 200 m 1.28
Distance up to 300 m 1.35
Distance up to 400 m 1.42
Distance up to 500 m 1.48
Distance up to 600 m 1.54

APPENDIX B

LS FACTOR OF DUMPUL SUBWATERSHED COMPUTATION

Code	Area (ha)	Horizontal Distance (m)	Height (m)	Slope Length (m)	Slope (%)	LS Control
			<u>Irrigated</u>			
A	0.42	30	4	30.26	13.3	2.11
B	1.56	200	14	200.49	7	2.11
C	1.88	120	11	120.5	9.2	2.22
D	2.94	90	10	90.55	11.11	2.76
E	1.62	160	8	160.21	5	1.23
F	2.24	50	5	50.25	10	1.76
G	1.20	85	7	85.29	8.2	1.72
H	1.76	60	5	60.21	8.3	1.47
I	1.94	75	5	75.17	6.7	1.22
J	1.28	30	3	30.15	10	1.36
K	0.78	30	3	60.30	10	1.93
L	1.78	110	8	110.29	7.3	1.66
M	1.52	60	4	60.13	6.7	1.09
N	0.40	30	3	30.15	10	1.36
O	2.44	135	6	135.10	4.4	0.81
P	3.28	100	10	100.50	10	2.49
Q	1.32	125	5	125.10	4	0.70
R	9.08	375	13	375.30	3.4	0.92
			<u>Village</u>			
a	2.94	75	5	75.17	6.7	1.22
b	4.48	85	5	85.15	5.9	1.10
c	4.12	90	5	90.02	2.2	0.30
d	0.74	200	6	200.09	3	0.50
e	2.90	150	4	150.05	2.7	0.42
f	1.50	250	5	250.05	2	0.38
g	6.06	75	3	75.06	4	0.57

Code	Area (ha)	Horizontal Distance (m)	Height (m)	Slope Length (m)	Slope (%)	LS Control
Village						
h	5.06	325	12	325.22	3.7	0.95
i	1.70	60	10	60.83	16.7	4.30
j	5.42	100	6	100.18	6	1.22
k	6.94	300	9	300.13	3	0.57
l	5.92	475	10	475.11	2.1	0.48
m	1.26	250	5	250.05	2	0.38
n	3.30	2--	5	200.06	2.5	0.43
o	1.32	150	4	150.05	2.7	0.42
Dry land						
1	1.48	100	8	100.32	8	1.80
2	1.24	125	12	125.57	9.6	2.62
3	4.66	140	13	140.60	9.3	2.64
4	2.12	90	10	90.55	11.1	2.76
5	1.64	100	9	100.40	9	2.12
6	0.84	100	5	100.12	5	0.97
7	0.66	50	5	50.25	10	1.76
8	1.66	45	5	45.28	11	1.92
9	1.04	100	7	100.24	11.1	2.90
10	5.34	150	14	150.65	9.3	2.73
11	0.40	35	3	35.13	8.6	1.18
12	1.64	135	10	135.37	7.4	1.87
13	3.22	115	8	115.28	9.4	2.43
14	2.56	110	11	110.55	10	2.61
15	7.46	160	12	160.45	7.5	2.08
16	0.56	35	2	35.06	5.71	0.68
17	1.74	80	4	80.10	5	0.87
18	1.84	125	7	125.20	5.71	1.28
19	3.76	105	6	105.17	5.7	1.17

Code	Area (ha)	Horizontal Distance (m)	Height (m)	Slope Length (m)	Slope (%)	LS Control
			Dry Land			
20	1.00	45	5	45.28	11.1	1.95
21	2.76	95	3	95.95	3.21	0.43
22	1.58	300	20	300.67	6.7	2.44
23	3.34	80	10	8.62	12.5	3.12
24	0.80	60	10	60.83	16.7	4.30
25	0.92	90	8	90.35	3.9	1.99
26	2.32	125	12	125.57	9.6	2.62
27	2.84	150	15	150.75	10	3.04
28	4.18	125	6	125.14	4.8	0.95
29	2.76	90	6	90.20	6.7	1.34
30	1.90	150	8	150.21	5.3	1.28
31	6.59	100	10	100.50	10	2.49
32	2.42	110	8	110.29	7.3	1.66
33	6.50	250	18	250.65	7.2	2.46
34	1.98	95	3	95.05	3.15	0.42
35	2.24	120	12	120.60	10	2.72
36	0.78	40	6	40.45	15	2.95
37	0.64	60	6	60.30	10	1.93
38	1.10	125	10	125.40	8	2.01

APPENDIX C

THE USLE FACTORS AND THE SOIL LOSS OF DUMPUL SUBWATERSHED UNDER CONDITION OF TREATED AND UNTREATED

		Control--Untreated							Treated--Bench Terraced				
Area		USLE Factor					Soil Loss		USLE Factor			Soil Loss	
Code	ha.	R	K	LS	C	P	A	Total	LS	C	P	A	Total
							Irrigated Field						
A	0.42	2039	0.14	0.05	0.07	0.7	0.70	0.29	0.04	0.07	0.60	0.48	0.20
B	1.56			0.05	0.07	0.6	0.60	0.94	0.05			0.60	0.94
C	1.88			0.05	0.07	0.6	0.60	1.08	0.05			0.60	1.13
D	2.94			2.76	0.30	0.6	141.82	416.94	0.04			0.48	1.41
E	1.62			0.05	0.30	0.6	0.60	0.97	0.05			0.60	0.97
F	2.24			0.05	0.30	0.6	0.60	1.34	0.05			0.60	1.34
G	1.20			1.72	0.30	0.5	73.65	88.38	0.05			0.60	0.72
H	1.76			0.05	0.30	0.5	0.60	1.06	0.05			0.60	1.06
I	1.94			0.05	0.30	0.6	0.60	1.16	0.05			0.60	1.16
J	1.28			0.05	0.30	0.6	0.60	0.77	0.05			0.60	0.77
K	0.78			1.93	0.30	0.6	23.14	18.05	0.05			0.60	0.47
L	1.78			1.66	0.30	0.5	71.08	126.52	0.05			0.60	1.07
M	1.52			1.09	0.30	0.5	46.67	70.94	0.05			0.60	0.91
N	0.40			1.36	0.30	0.6	69.88	27.95	0.05			0.60	0.24
O	2.44			0.81	0.30	0.5	34.68	84.62	0.05			0.60	1.46
P	3.28			2.49	0.30	0.5	106.62	349.71	0.05			0.60	1.97
Q	1.32			0.70	0.30	0.5	29.97	39.56	0.05			0.60	0.79
R	9.08			0.05	0.70	0.6	0.60	5.44	0.05			0.60	5.44
Sub Total	37.44						33.01	1,235.72				0.60	21.22

Control Untreated									Treated--Bench Terraced				
Area		USLE Factor					Soil Loss		USLE Factor			Soil Loss	
Code	ha	R	K	LS	C	P	A	Total	LS	C	P	A	Total
							Village						
a	2.94	2039	0.14	1.22	0.06	0.5	10.45	30.72	0.05	0.06	0.6	0.51	1.51
b	4.48			1.10		0.5	9.42	42.20	0.05			0.51	2.30
c	4.12			0.30		0.6	3.08	12.70	0.05			0.51	2.12
d	0.74			0.50		0.05	4.28	3.17	0.05			0.51	0.38
e	2.90			0.42		0.5	3.60	10.44	0.05			0.51	1.49
f	1.50			0.38		0.6	3.91	5.86	0.05			0.51	0.77
g	6.08			0.57		0.5	4.88	29.58	0.05			0.51	3.11
h	5.06			0.95		0.5	8.14	41.19	0.05			0.51	2.60
i	1.70			4.30		0.7	51.55	87.64	0.04			0.41	0.70
j	5.42			1.22		0.5	10.45	54.64	0.05			0.51	2.78
k	6.94			0.57		0.5	4.88	33.88	0.05			0.51	3.57
l	5.92			0.48		0.6	4.93	29.20	0.05			0.51	2.89
m	1.26			0.38		0.6	3.91	4.93	0.05			0.51	0.65
n	3.30			0.43		0.5	3.68	12.15	0.05			0.51	1.70
o	1.32			0.42		0.5	3.60	4.75	0.05			0.51	0.68
Sub Total	53.66						7.55	405.03				0.51	27.24

A		Control--Untreated							Treated--Bench Terraced				
Area		USLE Factor					Soil Loss		USLE Factor			Soil Loss	
Code	ha.	R	K	LS	C	P	A	Total	LS	C	P	A	Total
							Dry Land						
1	1.48	2039	0.14	1.80	0.30	0.5	71.07	114.07	0.05	0.25	0.6	2.14	3.17
2	1.24			2.62	0.3	0.6	134.62	166.93	0.05			2.14	2.65
3	4.66			2.64	0.3	0.6	135.65	632.13	0.05			2.14	9.98
4	2.12			2.76	0.3	0.6	141.82	300.66	0.05			2.14	4.54
5	1.64			2.12	0.3	0.6	90.78	148.87	0.05			2.14	3.51
6	0.84			0.97	0.3	0.5	41.53	34.89	0.05			2.14	1.80
7	0.66			1.76	0.3	0.6	90.43	59.69	0.05			2.14	1.41
8	1.16			1.92	0.3	0.6	98.65	114.43	0.05			2.14	2.48
9	1.04			2.90	0.3	0.5	124.18	129.15	0.05			2.14	2.22
10	5.34			2.73	0.3	0.5	116.90	624.25	0.05			2.14	11.43
11	0.40			1.18	0.5	0.5	84.21	33.68	0.05			2.14	0.86
12	1.64			1.87	0.5	0.5	80.07	131.32	0.05			2.14	3.51
13	3.22			2.43	0.3	0.6	124.86	402.05	0.05			2.14	6.89
14	2.56			2.61	0.3	0.6	134.11	343.32	0.05			2.14	5.48
15	7.46			2.08	0.3	0.5	89.06	664.41	0.05			2.14	15.97
16	0.56			0.68	0.3	0.5	29.12	16.31	0.05			2.14	1.20
17	1.74			0.87	0.3	0.5	37.25	64.82	0.05			2.14	3.73
18	1.84			1.28	0.3	0.5	54.81	100.85	0.05			2.14	3.94
19	3.76			1.17	0.3	0.5	50.10	188.37	0.05			2.14	8.05
20	1.00			1.95	0.3	0.6	100.20	100.20	0.05			2.14	2.14

		Control--Untreated							Treated--Bench Terraced				
Area		USLE Factor					Soil Loss		USLE Factor			Soil Loss	
Code	ha.	R	K	LS	C	P	A	Total	LS	C	P	A	Total
						Dry Land (Continued)							
21	2.76	2039	0.14	0.43	0.3	0.5	18.41	50.81	0.05	0.25	0.6	2.14	5.91
22	1.58			2.44	0.3	0.5	104.48	165.08	0.05			2.14	3.38
23	3.34			3.12	0.3	0.6	160.31	535.45	0.04			1.71	5.72
24	0.80			4.30	0.3	0.7	257.77	206.22	0.04			1.71	1.37
25	0.92			1.99	0.3	0.5	85.21	78.39	0.05			2.14	1.97
26	2.32			2.62	0.3	0.6	134.62	312.33	0.05			2.14	4.97
27	2.84			3.04	0.3	0.6	156.20	443.62	0.05			2.14	6.08
28	4.18			0.95	0.3	0.5	40.68	170.04	0.05			2.14	8.95
29	2.76			1.34	0.3	0.5	57.38	158.37	0.05			2.14	5.91
30	1.90			1.28	0.3	0.5	54.81	104.14	0.05			2.14	4.07
31	6.59			2.49	0.3	0.6	127.94	843.15	0.05			2.14	14.11
32	2.42			1.66	0.3	0.5	71.08	172.01	0.05			2.14	5.18
33	6.50			2.46	0.3	0.5	105.33	684.68	0.05			2.14	13.92
34	1.98			0.42	0.3	0.5	17.98	35.61	0.05			2.14	4.24
35	2.24			2.72	0.3	0.6	139.76	313.07	0.05			2.14	4.80
36	0.78			2.95	0.3	0.6	151.58	118.23	0.05			2.14	1.67
37	0.64			1.93	0.3	0.6	99.17	63.47	0.05			2.14	1.37
38	1.10			2.01	0.3	0.5	88.07	94.67	0.05			2.14	2.36
Sub Total	90.01						99.10	8,919.74				2.12	190.94
TOTAL	181.11						58.31	10,560.49				1.32	239.40

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