Evaluation of terrace design as soil and water conservation technique in Karangkobar catchment, Banjarnegara, Indonesia

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Abstract. Karangkobar catchment is upland of Serayu watershed, characterized as rough topography, thick soil, high rainfall, and the land use dominated by agriculture. Unfortunately, the agricultural system ignores the principles of soil and water conservation. The purpose of this study was to describe and to evaluate the terrace design as soil and water conservation. The tools used were GPS, roll meter, and abney level. The study was conducted using qualitative descriptive. The purposive sampling method was adopted to determine the terrace point. The indicator to evaluate terrace design were slope, solum, soil texture, and land management. Terrace suitability evaluation used arithmetic matching methods based on technical requirements and observations of soil terracing. This study revealed that the percentage of bench terrace in study area was 43.75%, 25% ridge terrace, 12.5% water drainage channel, and without conservation 18.75%. The suitability of design: 25% was the fit design, moderate 18.75%, and bad design 56.25%. Making and repairing terraces to fit design was costly.

1. Introduction

The increasing number of population gains the demand for land and food. It leads conversion from non-agricultural into agricultural land. The agriculture in sloping areas has been a challenge for farmers. However, it vulnerable to natural disasters such as landslides and erosion [1,2]. Soil conservation is an effort to maintain or improve land include soil fertility by making civil engineering building beside plants (vegetative), to avoid damage and deterioration of land use and productivity [3]. The forms of soil conservation can be divided into 3 methods: mechanical, vegetative, and chemistry [4].

In 2018, one of the hamlets in Karangkobar catchment suffered a landslide disaster. This is not the first case, there had been several similar incidents. One reason is that the traditional farming system practiced does not guarantee the sustainability of land and water resources. There needs an improvement effort that
leads to erosion control and sustainability based on soil and water conservation principles such as terraces. A terrace is a land embankment that is adjusted to soil properties and slopes to control runoff [4]. The terrace can be classified as a bench terrace and broad-base terrace [5].

The terrace types in Karangkobar catchment are not based on land conditions, but based on hereditary knowledge. Terraces built by cutting contours to make it easier for the drainage system. However, the terrace is also not equipped with a drainage system, because it requires a lot of costs and reduced planting areas. However, the design does not comply with the technical requirements of the conservation building. This condition can cause the function of conserved buildings to decrease even to the detriment. Improvement efforts are needed in Karangkobar catchment which leads to erosion control and sustainability based on the principles of soil and water conservation.

2. Methodology
The study was conducted at Karangkobar catchment, from March until November 2018. A land unit map was made by overlaying land use and slope maps. Soil sampling was done by purposive sampling. The data include the morphometry of each land unit (coordinates, land area, slope), terrace identification, terrace morphometry, and technical requirements for land suitability at the sample points. The data were analyzed by qualitative descriptive statistical methods.

The identification of conservation buildings was carried out by describing the buildings that have been applied in each unit of land. Evaluation of land suitability using the arithmetic matching method. The indicator to evaluate terrace design were slope, soil thickness, soil texture, and land management. All indicators were considered to have the same opportunity to be used as a limiting factor.

The terrace design was analyzed by grouping to the type recommended. Here are the formulas used for designs from bench, channels, and individuals terraces [6-7]:

Table 1. Terrace design formula

| Channel | Bench       | Individual   |
|---------|-------------|-------------|
| $VI = \frac{s + 4}{100}$ | $VI = \frac{(S \times Wb)}{100 - (S \times U)}$ | $VI = 0.3 \times \left(\frac{s}{3} + 2\right)$ |
| $HI = \frac{VI \times 100}{s}$ | $RH = Wb \times 0.05$ | $HI = \frac{V1 \times 100}{s}$ |
| $Cd = \frac{h + sW}{2}$ | $HR = VI + RH$ | $SR = 0.75$ |
| $Sf = \frac{W}{h}$ | $Wr = Hr \times U$ | $RS = 10$ |
| $Sb = \frac{Wt}{Cd + sW}$ | $Wt = Wb + wr$ | $H = 0.15$ |
| $L = \frac{10000}{Wt}$ | $A = L \times Wb$ | $d = 1.5 \text{ dan } 2.1$ |
| $Pb = 10000 \times 100$ | $c = \frac{(Wb \times Hr)}{8}$ | $V = L \times C$ |
3. Results and Discussion

Based on field investigation, the application of soil and water conservation in Karangkobar catchment presented in Table 2.

**Table 2. Karangkobar catchment conservation technique**

| No | Land Unit | Conservation Technique          | Description                                      |
|----|-----------|---------------------------------|-------------------------------------------------|
|    |           | Vegetative                      | Mechanic                                        |
| 1  | P-1       | Intercropping                   | Ridge Terrace and Waterways                      |
| 2  | P-2-A     | Grass Planting                  | –                                               |
| 3  | P-2-B     | Grass Planting and Wood Plants  | Bench Terrace, Waterways, Steep Buildings       |
| 4  | P-2-C     | Intercropping                   | Ridge Terrace and Waterways                      |
| 5  | P-3       | Grass Planting                  | Bench Terrace, Waterways, Steep Buildings       |
| 6  | TL-1      | Grass Planting and Intercropping| Bench Terrace, Waterways, Steep Buildings       |
| 7  | TL-2-A    | Grass Planting and Intercropping| Ridge Terrace and Waterways                     |
| 8  | TL-2-B    | Grass Planting and Wood Plants  | –                                               |
| 9  | TL-2-C    | Grass Planting                  | Bench Terrace and Waterways                     |
| 10 | TL-3      | Grass Planting and Intercropping| Waterways                                       |
| 11 | K-1       | Grass Planting and Intercropping| Waterways                                       |
| 12 | K-2-A     | Intercropping                   | Ridge Terrace and Waterways                     |
| 13 | K-2-B     | Grass Planting and Intercropping| –                                               |
| 14 | K-2-C     | Grass Planting and Intercropping| Bench Terrace, Ridge Terrace, and Waterways     |
| 15 | K-3       | Grass Planting, Planting on the Path, and Intercropping| Bench Terrace, Waterways, Steep Buildings     |
| 16 | S-1       | Overlapping Turn, and Strengthening the terrace | Following the contour                           |
In general, soil and water conservation in Karangkobar catchment are mechanical and vegetative methods. The application of vegetation conservation is carried out by almost all land units. The most common practice is grass planting and intercropping. Grass as cover crop, used to protect soil from erosion, to gain organic matter, and to increase soil productivity [8]. Unfortunately, intercropping is not doing well because of some requirements not applied.

Mechanical methods of soil and water conservation applied in the Karangkobar catchment are Bench Terrace (TB), Ridge Terrace (TG), and waterways (S). However, several land units did not apply to mechanical conservation (N). Overall, almost all land units use waterways. The use of waterways in Karangkobar aims to divert excess water flow to other places, so as not to cause landslides. Meanwhile, erosion control is carried out using a terrace to increase water absorption. The use of bench terraces (43.75%) is the most commonly found, then ridge terrace (25%), waterways (12.5%), and the last without conserving (18.75%).

Even though the terrace used in Karangkobar catchment is more than without terracing, several terrace manufacturing requirements are not implemented. This can cause the terrace not suitable. Evaluation of terrace types in the Karangkobar catchment is presented in Table 3.

**Table 3. Terrace evaluation**

| No | Land Unit | Slope (%) | Solum (cm) | Textur | Land Management | Obstacle Factor | Suitability |
|----|-----------|-----------|------------|--------|-----------------|----------------|-------------|
| 1  | P-1       | 3         | 185        | Medium | Corn            | SI             | AS          |
| 2  | P-2-A     | 4         | 50         | Medium | Field           | P              | AS          |
| 3  | P-2-C     | 5         | 70         | Rather smooth | Galangal | SI, T         | TS          |
| 4  | K-1       | 5.5       | 120        | Rather Rough | Cassava | P            | AS          |
| 5  | TL-2-B    | 8.5       | 115        | Rather smooth | Fishpond | P, T         | TS          |
| 6  | K-2-A     | 9         | 55         | Medium | Mustard Cutting contours | SI, P | TS          |
| 7  | S-1       | 17        | 140        | Medium | Rice            | -              | S           |
| 8  | TL-2-A    | 19        | 70         | Medium | Chili           | SI, P          | TS          |
| 9  | K-2-C     | 19        | 120        | Medium | Galangal and Chili | -     | S           |
| 10 | K-3       | 22        | 165        | Medium | Corn            | -              | S           |
| 11 | TL-1      | 23        | 100        | Medium | Coffee          | -              | S           |
| 12 | TL-3      | 35        | 110        | Medium | Moorings not maintained | SI, P | TS          |
| 13 | TL-2-C    | 40        | 215        | Medium | Not maintained garden | SI, P | TS          |
| 14 | P-3       | 47        | 90         | Rather smooth | Corn | SL, P, T                  | TS          |
| 15 | K-2-B     | 50        | 160        | Medium | Cassava and Galangal Settlement | SI, P | TS          |
| 16 | P-2-B     | 73        | 42         | Medium |                | SI, P          | TS          |

Based on Table 3, Karangkobar catchment is represented in 3 suitability classes of a terrace. The land unit that applied suitable has been 4 units (25%), moderate 3 units (18.75%), and not suitable as many as 9
units (56.25%). The slope of the land is the main factor that must be considered because conservation techniques are chosen according to the slope of the land and carried out in the direction of the contour line [9]. The land unit which has a slope inhibiting factor uses a terrace that does not match the slope. In this study, there were no obstacles from the soil solum. Because of several researchers, the thick soil solum is suitable for all types of terraces. However, it should be noted that thick soils have higher erosion potential. The soil soluble in receiving and storing water is greater [10]. In sandy soil, the infiltration capacity and permeability have a deep depth of impermeable layer, so that even if heavy rainfall is possible, there will be a small surface flow. Likewise, on the contrary, fine-textured soil in the Karangkobar catchment absorbs water very slowly, so that only low rainfall can cause surface flow. Processing land that is not suitable in terms of the type of terrace that is applied, the direction of planting, land use, and plants planted. The use of land that is not under the ability and carrying capacity will result in the high potential of landslides [11]. Judging from the results of the terrace morphometric evaluation in the field and the results of the analysis, terrace improvements are presented in Table 4.

Table 4. Terrace for each unit of land

| No | Slope (%) | Land Unit | Conservation Applied | Conservation Recommended |
|----|-----------|-----------|----------------------|--------------------------|
| 1  | 3         | P-1       | Ridge Terrace        | Chanel Terrace           |
| 2  | 4         | P-2-A     | –                    | Individual Terrace       |
| 3  | 5         | P-2-C     | Ridge Terrace        | Chanel Terrace           |
| 4  | 5.5       | K-1       | Waterways            | Chanel Terrace           |
| 5  | 8.5       | TL-2-B    | –                    | Individual Terrace       |
| 6  | 9         | K-2-A     | Ridge Terrace        | Chanel Terrace           |
| 7  | 17        | S-1       | Bench Terrace        | Bench Terrace            |
| 8  | 19        | TL-2-A    | Ridge Terrace        | Bench Terrace            |
| 9  | 19        | K-2-C     | Bench Terrace dan Gulud | Bench Terrace            |
| 10 | 22        | K-3       | Bench Terrace        | Bench Terrace            |
| 11 | 23        | TL-1      | Bench Terrace        | Bench Terrace            |
| 12 | 35        | TL-3      | Waterways            | Bench Terrace            |
| 13 | 40        | TL-2-C    | Bench Terrace        | Bench Terrace            |
| 14 | 47        | P-3       | Bench Terrace        | Individual Terrace       |
| 15 | 50        | K-2-B     | –                    | Individual Terrace       |
| 16 | 73        | P-2-B     | Bench Terrace        | Individual Terrace       |

The recommended terrace was analyzed for its morphometric design so that it can reach its destination optimally. Analysis of the terrace design is presented in Table 5, Table 6, and Table 7.

Table 5. Analysis of channel terrace designs

| No | S (%) | Land Unit | VI (m) | HI (m) | h (m) | W (m) | Cd (cm) | Sf | Sc | Sb |
|----|------|-----------|--------|--------|-------|-------|---------|----|----|----|
| 1  | 3    | P-1       | 0.40   | 13.43  | 0.35  | 1     | 17.52   | 0.03| 0.03| 0.06|
| 2  | 5    | P-2-C     | 0.41   | 8.10   | 0.35  | 1     | 17.53   | 0.03| 0.03| 0.06|
### Table 6. Analysis of bench terrace designs

| No | S (%) | Land Unit | wb (m) | VI (m) | Cd (m) | RH (m) | HR (m) | Wr (m) | Wt (m) | L (m) | A (m²) | Ca (m²) | V (m³) |
|----|-------|-----------|--------|--------|--------|--------|--------|--------|--------|-------|--------|---------|--------|
| 1  | 17    | S-1       | 13.3   | 2.6    | 23.3   | 0.67   | 3.27   | 2.45   | 15.8   | 633   | 8449   | 5.44    | 3449   |
| 2  | 19    | TL-2-A    | 8.2    | 1.81   | 0.62   | 0.41   | 2.22   | 1.66   | 9.8    | 102   | 8308   | 2.26    | 2300   |
| 3  | 19    | K-2-C     | 11.5   | 2.56   | 0.88   | 0.58   | 3.14   | 2.35   | 13.9   | 719   | 8308   | 4.53    | 3257   |
| 4  | 22    | K-3       | 14     | 3.68   | 0.06   | 0.7    | 4.37   | 3.28   | 17.2   | 580   | 8096   | 7.63    | 4426   |
| 5  | 23    | TL-1      | 9.3    | 2.59   | 7.41   | 0.47   | 3.06   | 2.29   | 11.6   | 861   | 8026   | 3.57    | 3069   |
| 6  | 35    | TL-3      | 7.4    | 3.52   | 1.76   | 0.37   | 3.89   | 2.92   | 10.3   | 968   | 7177   | 3.60    | 3487   |
| 7  | 40    | TL-2-C    | 4      | 7.69   | 15.5   | 0.2    | 2.17   | 1.63   | 5.6    | 177   | 7105   | 1.09    | 1930   |

### Table 7. Analysis of individual terrace designs

| No | S (%) | Land Unit | HI (m) | VI (m) | SR (%) | RS (%) | H (m) | d (m) |
|----|-------|-----------|--------|--------|--------|--------|-------|-------|
| 1  | 4     | P-2-A     | 22.5   | 0.9    | 0.75   | 10     | 0.15  | 2.1   |
| 2  | 8.5   | TL-2-B    | 14.6   | 1.2    | 0.75   | 10     | 0.15  | 2.1   |
| 3  | 47    | P-3       | 11.3   | 5.3    | 0.75   | 10     | 0.15  | 1.5   |
| 4  | 50    | K-2-B     | 11.2   | 5.6    | 0.75   | 10     | 0.15  | 1.5   |
| 5  | 73    | P-2-B     | 10.8   | 7.9    | 0.75   | 10     | 0.15  | 1.5   |

From the terrace design results, the land area that can be utilized tends to be less. Comparison of planting area is presented in Table 8.

### Table 8. Terrace design in Karangkobar catchment

| No | Slope (%) | Recommended Terrace | Land Unit | Planting Area (%) |
|----|-----------|---------------------|-----------|-------------------|
|    |           |                     |           | Applied | Recommended |
| 1  | 3         | Channel             | P-1       | 90     | 85           |
| 2  | 5         |                     | P-2-C     | 96     | 75           |
| 3  | 5.5       |                     | K-1*      | 99     | 73           |
| 4  | 9         |                     | K-2-A     | 84     | 56           |
| 5  | 17        |                     | S-1       | 90     | 84           |
| 6  | 19        |                     | K-2-C     | 88     | 83           |
| 7  | 19        |                     | TL-2-A    | 91     | 83           |
| 8  | 22        |                     | K-3       | 93     | 81           |
| 9  | 23        |                     | TL-1      | 89     | 80           |
| 10 | 35        |                     | TL-3*     | 94     | 72           |
| 11 | 40        |                     | TL-2-C    | 95     | 68           |
| 12 | 4         |                     | P-2-A*    | 97     | 88           |
| 13 | 8.5       |                     | TL-2-B*   | 99     | 74           |
A significant difference between the recommended and applied terrace design is one of the reasons Karangkobar catchment people do not use the appropriate terrace. The wider use of planting areas is carried out by the community to increase agricultural yields. In Table 9, an estimate of the creation of a terrace is based on the experience of making a terrace in the Karangkobar catchment area.

**Table 9. Labor and cost of making a terrace**

| No | Slope (%) | Terrace | Land Unit | Labor | Cost (IDR) |
|----|-----------|---------|-----------|-------|------------|
|    |           |         |           | Applied| Recommened | Applied| Recommend ed|
| 1  | 3         | P-1     | 2.5       | 3.7   | 187,500    | 281,250|
| 2  | 5         | P-2-C   | 6.7       | 9     | 506,250    | 675,000|
| 3  | 5.5       | K-1*    | 1         | 10    | 75,000     | 750,000|
| 4  | 9         | K-2-A   | 7.5       | 9     | 562,500    | 675,000|
| 5  | 17        | S-1     | 42        | 49    | 3,150,000  | 3,675,000|
| 6  | 19        | K-2-C   | 15        | 22.5  | 1,125,000  | 1,687,500|
| 7  | 19        | TL-2-A  | 12.5      | 31.5  | 937,500    | 2,362,500|
| 8  | 22        | K-3     | 21.9      | 36.7  | 1,640,625  | 2,756,250|
| 9  | 23        | TL-1    | 17.5      | 26.2  | 1,312,500  | 1,968,750|
| 10 | 35        | TL-3*   | 0.6       | 9     | 46,875     | 675,000|
| 11 | 40        | TL-2-C  | 3.7       | 9.4   | 281,250    | 703,125|
| 12 | 4         | P-2-A*  | 3.1       | 16.9  | 984.375    | 1,265,625|
| 13 | 8.5       | TL-2-B* | 4         | 17.5  | 300,000    | 1,312,500|
| 14 | 47        | P-3*    | 3.7       | 6.7   | 281,250    | 506,250|
| 15 | 50        | K-2-B   | 1.5       | 4.5   | 112,500    | 337,500|
| 16 | 73        | P-2-B*  | 7.9       | 10.5  | 590,625    | 787,500|

4. Conclusion

The mechanical method of soil and water conservation applied to Karangkobar catchment were bench terraces (43.75%), ridge terraces (25%), waterways (12.5%), and without conserving (18.75%). The land unit that applied suitable terrace has been 4 units (25%), moderate 3 units (18.75%), and not suitable 9 units (56.25%). Making and repairing terraces based on evaluation of slope, the thickness of soil, texture, and processing of land requires more costs and produces a narrower planting area.

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