Classification of anthropogenic landforms in the rural area: study case Bompon catchment, Central Java.

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Abstract. Geomorphologists have considered the anthropogenic process as one of important factors in landforms studies. Numbers of anthropogenic classification are recently introduced without clearly monitoring the relationship between the classes and map scale. This study was designed to classify the anthropogenic landforms in Bompon catchment at a detailed scale. We employed a descriptive and observational survey using the traverse method at 1:10,000 and 1:2,000 map scale. The former created a path of travel with a width of 100 m and 20 m along the stretch of the catchment area. The observation points were selected based on the human activities encountered along the path and in the representative areas, namely type of intervention, formation process, and area. The anthropogenic landforms were grouped according to the modified classification of Szabó & Dávid. The results indicated that human intervention or land transformation occurring in Bompon catchment fell into the categories of Agrogenic, Urbanogenic, Traffic, and Water Management. Each of the four landforms was visible in 1:2,000 map scale, but only the Agrogenic and Urbanogenic ones were classified on a scale of 1:10,000. Denudation, construction, and association are the dominant process in the formation of anthropogenic landforms in the study area.

1. Introduction

Anthropogenic landforms are landforms arising from the transformation induced by human activities that can affect the environment or shape the earth’s surface either directly or indirectly (Szabó et al., 2010; 2Tsermegas, 2015). Land modification occurs worldwide and is concentrated in urban areas (3Burghardt et al., 2015). Current estimation shows that 50% of the area on the earth’s surface and 83% of its habitable parts have been disrupted by human activities (4Hooke et al., 2012).

Anthropogenic landforms differ from natural geomorphology in features and, particularly, constituent materials (5Mu and Tan, 1990). It reflects that apart from the geomorphological units that are naturally formed by internal and external forces, there is an increase in ones shaped by anthropogenic activities on the earth’s surface (1Szabó et al., 2010).

Based on the process, the formation of anthropogenic landforms can be divided into two, namely direct and indirect (6Zhang, 1990; 1Szabó et al., 2010). The former refers to the process in which human directly reshapes the surface environment and results in various landscapes of new landforms (6Zhang, 1990). Relative to this process, the latter often produce landforms that are more difficult to
recognize because it mostly occurs at a rate that exceeds the natural process. In this case, human actions unintentionally bring about environmental changes that precede indirect formations. For example, the removal or modification of land cover by cutting, clearing, burning, and grazing has accelerated the rate of erosion and sedimentation (Li et al., 2017).

Anthropogenic landform classification systems are currently more developed in urban areas, but in reality, human intervention has taken place in rural areas, including Bompon catchment. Bompon catchment is part of the Kodil Watershed system that stretches between two subdistricts in Magelang Regency-Central Java Province, namely Salaman and Kajoran, with an area of 294.7 ha. In general, Bompon Catchment is a system that has transformed into anthropogenic landforms. Humans have contributed to the modification of existing natural forms in an attempt to create spaces for built-up land and agricultural practices. Human interventions both directly and indirectly leave different characteristics to the appearance of the earth’s surface and, if improperly planned, can negatively impact the environment.

2. Methods

This study was conducted in Bompon catchment using descriptive and observational survey methods. The research materials included the 1:10,000 land use map obtained by delineating aerial photo imagery and landform data at the same scale, which was acquired from DEM interpretation and material survey.

2.1. Survey of Human Activities in Utilizing Land Resources

The land use map resulted from delineating aerial photo imagery was surveyed to determine the actual border of the land use. Meanwhile, the field survey aimed to acquire the distribution of points where human activities involved the use of land resources. The observation site was determined by the traverse method on 1:10,000 and 1:2,000 map scale. The traverse method created a path of observation with the widths of 100 m and 20 m and the length as far as the stretch of the catchment area (Figure 1). The observation points were selected based on human activities encountered along the path and in representative areas by considering the type of intervention, the formation process, and the horizontal extent of land resources utilization. The land transformation process was later divided into two, namely direct (denudation and construction, association) and indirect.
2.2. Classification of Anthropogenic Landforms

The anthropogenic landforms were classified based on the survey of human activities in land resource utilization. Based on the type of intervention and process, the identified anthropogenic landforms in each observation point were grouped according to the modified Szabó & Dávid classification [8]. Afterward, these points were overlaid with the Landform Map (Figure 2) to determine the distribution of human intervention in natural landforms (Order 3).

3. Results and Discussion

3.1. Classification of Anthropogenic Landforms

Based on the results of the field survey, several forms of human intervention and artificial modification on land morphology were identified. The types of modifications were parts of Agrogenic, Urbanogenic, Traffic, and Water Management. The denudation, construction, and association are direct processes, and their outcomes have a secondary impact on the formation of anthropogenic landforms in Bompon Catchment (Table 1).

| Interventions /Landforms | Processes | Denudation | Construction | Association | Indirect |
|--------------------------|-----------|------------|--------------|-------------|----------|
| Agrogenic                | Pseudoterraces | -          | -            | -           |          |
| -                        | Intensive Irrigation and Plowing | -          | -            | -           |          |
| -                        | Double-bedding Mounds | -          | -            | -           |          |
| Urbanogenic              | -         | Planation for Construction | -          | -           | -        |
| -                        | Cuts and House Constructions | -          | -            | -           |          |
| Traffic                  | -         | Roads      | -            | -           | -        |
3.1.1 Agrogenic Landforms

Agrogenic intervention is an agricultural activity capable of changing the shape of the surface (Szabó et al., 2010). Agrogenic is found in agricultural practices that mostly take place in multi-species tree plantations, rice fields, and farms with alternating bed system. Based on Table 1, the morphological appearances of agrogenic interventions are shaped by direct (denudation and association) and indirect processes (deposition). The denudation process includes the making of terraces, while the association process involves the building of canal ridges and intensive irrigation and plowing. As for the indirect process, it forms pseudo-terraces.

Terrace formation by cutting the soils in slope sequences was identified in nearly all of the catchment area. The initially sloping morphology had turned into graduated terrace steps (Figure 3a). Terracing is a type of modification that is principally a conservation technique on a sloped plane, but this technique does not apply to all soil conditions. Poorly planned land modification can instead accelerate two geomorphological processes, namely erosion and landslides. The field survey found that the terrace morphology was widely varied.

When exposed to geomorphological processes, human-made terraces indirectly transform into pseudo-terraces (Figure 3b). In the study area, some of the pseudo-terraces had been reconstructed to terraces (Figure 3c). Therefore, this landform does not cover a large area. The morphology developing due to intensive irrigation and plowing is generally centered on alluvial plain and colluvial foot slope. Irrigation involves wetting or flooding soil surface with water, while plowing is the process of turning over the soil. These interventions are carried out cumulatively every year during the rainy season, changing the soil surface into a pool (Figure 3d).

| Water Management | Waterholes | Artificial Channels | Natural Channels |
|------------------|------------|---------------------|------------------|
| Roads            | -          | -                   | -                |

Source: Field survey (2019), and Szabó J & Dávid L (2006) with modification.
Figure 3c. Reconstruction of Pseudo-terraces into Terraces

Figure 3d. Rice fields resulting from irrigation and intensive plowing.

The double-bedding mound is a morphological appearance resulting from a combination of rice fields and dry farmland for CGPRT crops (i.e., coarse grains, pulses, roots, and tubers). These microfeatures are the results of association by excavating (denudation) and mounding soils (construction) to create higher surface than before the intervention. Also, flowing water to each side of the mounds allows a prolonged aquatic condition. This situation is possible because the double-bedding mounds spread on alluvial plain and abut rice fields (intensive irrigation and plowing) and rivers (Figure 3e).

Figure 3e. Double-bedding mounds in rice fields

3.1.2 Urbanogenic Landforms

Urbanogenic interventions were typically found in residential areas, e.g., the construction of building’s foundation, the import of outside materials, and the cutting and leveling of ground surface for home construction. Based on Table 1, the morphological appearance of urbanogenic landforms is shaped by direct processes, namely, construction and association. The former process includes planation for construction, while the latter is cutting and construction.

In planation for construction, buildings and houses are made without slope leveling. Planation takes place in a flat morphology where the making of building’s foundation and the transport of outside materials can be performed (Figure 4a)
3.1.3 Traffic Landforms

Traffic landforms were found in almost all of the research area. They are human interventions in the form of road construction, meaning that any features describing road construction with concrete, asphalt, and soils (unpaved) are included. Table 1 shows that direct process, i.e., construction and association, and indirect ones shape the morphological appearance of these landforms. The construction process is road construction, while the association process is the cutting and construction of road and road segments. As for the indirect process, it includes natural roads.
In road construction, it does not involve slope cutting and leveling. In general, it was mostly found on Interflues because of their flat-to-sloping morphology (Figure 5a). In the upper, middle, and lower hill slopes, many association processes were involved, namely road construction by cutting (denudation), leveling or planation, and soil hardening with and without concrete or asphalt (construction). Also, any road segments that were constructed directly or formed due to natural geomorphological processes fell into the categories of association and indirect process (Figure 5b).

Figure 5. (a) Road cutting and construction with artificially and directly formed road segments and (b) road cutting and construction with naturally formed road segments.

3.1.4 Water Management Landforms
In Bompon Catchment, the identified water management was affiliated with landforms shaped by agrogenic, urbanogenic, and traffic interventions. It consisted of water network modifications. Based on Table 1, the morphological appearance of this intervention is shaped both directly (denudation and association) and indirectly. The denudation process is the digging of waterholes (springs), and the association process is the construction of artificial water channels. Meanwhile, the indirect process includes natural water channels.

In the study area, denudation incorporated soil extraction up to a certain depth to build water reservoirs, for instance, large wells or ponds (Figure 6a). Water channels for agricultural purposes and road drainage are the anthropogenic microfeatures resulting from the combination of denudation and construction. Soil digging or displacement (denudation) and the installation of rocky foundations (construction) for embankments are human’s engineering efforts to drain water and, at the same time, control surface flow (Figure 6b). In the roads constructed by slope cutting and leveling, the absence of drainage system has caused surface runoff to erode soil surface and form rills and gullies (Figure 6c).

Figure 6a. Waterholes Figure 6b. Artificial water channels
3.2. Classification of Anthropogenic Landforms on 1:10,000 Map scale

The delineation of the observation points revealed that the forms of intervention classified at a scale of 1:10,000 were only Agrogenic and Urbanogenic, whereas alterations in the form of Traffic and Water Management did not meet the minimum area for classified. In other words, the morphological appearances resulting from the last two alterations are visible at a more detailed scale. Agrogenic and Urbanogenic interventions were apparent in most of the catchment area, whereas land modification due to Traffic and Water Management were detected only in certain regions. This finding demonstrates that landform transformation in Bompon Catchment focuses on agricultural and residential areas.

Table 2. Agrogenic Interventions in Natural Landforms on a Scale of 1:10,000

| Processes                              | Locations | Area (Ha) | %  |
|----------------------------------------|-----------|-----------|----|
| Denudation                             | Association |          |    |
| Terraces                               | If        | 53.37     | 19.85 |
| Terraces                               | Lap       | 32.72     | 12.17 |
| Terraces                               | Ltp       | 129.58    | 48.20 |
| Terraces                               | Lbp       | 15.44     | 5.74  |
| Intensive Irrigation and Plowing       | Ltp       | 1.58      | 0.59  |
| Intensive Irrigation and Plowing       | Lbp       | 1.42      | 0.53  |
| Intensive Irrigation and Plowing       | Lkk       | 12.86     | 4.78  |
| Intensive Irrigation and Plowing       | Da        | 20.21     | 7.52  |
| Double-bedding Mounds                  | Da        | 0.69      | 0.26  |
| **Total**                              |           | **268.83**| **100.00** |

Notes: If= Interfluve, Lap= Upper hillslope, Ltp = Middle hillslope, Lbp= Lower hillslope, Lkk= Colluvial foot slope, and Da= Alluvial plain.

Based on Table 2, agrogenic terraces were distributed on middle hillslope (Ltp) with an area of 129.58 ha or 48.20% of the total catchment area, as well as at the Interfluve (If; 53.37 ha; 19.85%), upper hillslope (Lap; 32.72 ha; 12.17%), and lower hillslope (Lbp; 15.44 ha; 5.74%). Principally, every slope sequence in a catchment has the same opportunity to be modified into graduated terrace steps because, in farming systems, terraces are part of conservation strategies. However, practically, not every slope segment can be transformed into terraces. If developed in the wrong segment and soil characteristics, terraces can lead to slope failure and accelerate landslide occurrences instead.

Other agrogenic interventions were intensive irrigation and plowing and double-bedding mounds. Intensive irrigation and plowing were identified on alluvial plain (Da; 20.21 ha; 7.52%) and colluvial foot slope (Lkk; 12.86 ha; 4.78%). Meanwhile, the double-bedding mounds covered only a small part of the alluvial plain (0.69 ha; 0.26%). These two agrogenic modifications are distributed only on alluvial and colluvial foot slope because the land is suitable for rice paddies and alternating bed system for CGPRT crops (i.e., coarse grains, pulses, roots, and tubers). Besides, these landforms have a flat topography with large water capacity during rainy seasons.

Based on Table 3, two urbanogenic interventions were detected in the study. First, planation for construction was concentrated on the Interfluve (If; 4.32 ha; 17.31%) and lower hillslope (Lbp; 3.43...
ha; 13.74%). Second, cutting and construction were found on middle hillslope (Ltp; 14.77 ha; 59.17%) and upper hillslope (Lap; 2.44 ha; 9.78%). Overall, the association process covered a more extensive area of intervention than construction, meaning that house construction with slope cutting is the most widespread morphological modification in the catchment. However, slope cutting and construction (association) can perturb slope stability and accelerate runoff or surface flow, increasing the potential for soil loss.

Table 3. Urbanogenic Interventions in Natural Landforms on a Scale of 1:10,000

| Processes             | Locations | Area (Ha) | %  |
|-----------------------|-----------|-----------|----|
| Planation for Construction | If        | 4.32      | 17.31 |
| - Cutting and Construction | Ltp     | 14.77    | 59.17 |
| Planation for Construction | Lbp     | 3.43      | 13.74 |
| - Cutting and Construction | Lap     | 2.44      | 9.78  |
| **Total**             |           | **24.96** | **100.00** |

Notes: If= Interfluve, Lap= Upper hillslope, Ltp= Middle hillslope, Lbp= Lower hillslope, Lkk= Colluvial foot slope, and Da= Alluvial plain.

3.3. Classification of Anthropogenic Landforms on 1:2,000 Map scale

The results showed that the classification of anthropogenic landforms on 1:2,000 map scale consisted of four types of interventions, namely agrogenic, urbanogenic, traffic, and water management. On this scale, two additional types of intervention were classifiable. Contrary to the 1:10,000 landform Classification, the information at 1:2,000 scale also includes traffic and water management. The morphological appearances of these two types of interventions did not meet the area requirements for 1:10,000 scale but they were classified at 1:2,000. Table 4 summarizes the agrogenic, urbanogenic, traffic, and water management interventions in natural landforms at a scale of 1:2,000.

Table 4. Anthropogenic interventions on natural landforms on a Scale of 1:2,000

| I | Processes                     | Landforms | Area (a) | %  |
|---|-------------------------------|-----------|-----------|----|
|   | Denudation | Association | Indirect | If  | 138.22 | 9.05 |
|   | Terraces                     | -         | -         | Lap | 93.28  | 6.11 |
|   | Terraces                     | -         | -         | Ltp | 405.84 | 26.58 |
|   | Terraces                     | -         | -         | Lbp | 71.56  | 4.69 |
|   | Terraces                     | -         | -         | Lkk | 25.03  | 1.64 |
|   | - Intensive Irrigation and Plowing | - | Ltp | 12.47 | 0.82 |
|   | - Intensive Irrigation and Plowing | - | Lkk | 16.32 | 1.07 |
|   | - Intensive Irrigation and Plowing | - | Da  | 376.91 | 24.69 |
|   | - Double-bedding Mounds      | -         | -         | Lkk | 11.59  | 0.76 |
|   | - Double-bedding Mounds      | -         | -         | Da  | 7.46   | 0.54 |
|   | -                            | -         | Pseudo-terraces | Lap | 5.52  | 0.36 |
|   | -                            | -         | Pseudo-terraces | Ltp | 104.52 | 6.85 |
|   | -                            | -         | Pseudo-terraces | Lbp | 24.59  | 1.61 |
|   | Urbanogenic                  |           |           |     |        |      |
|   | - Cuts and House Constructions | -        | -         | If  | 10.02  | 0.67 |
|   | - Cuts and House Constructions | -        | -         | Lap | 18.33  | 1.20 |
|   | - Cuts and House Constructions | -        | -         | Ltp | 103.84 | 6.80 |
|   | - Cuts and House Constructions | -        | -         | Lbp | 70.18  | 4.60 |
|   | Traffic                      |           |           |     |        |      |
|   | - Road Cuts and Constructions | -        | -         | If  | 4.62   | 0.30 |
|   | - Road Cuts and Constructions | -        | -         | Lap | 0.95   | 0.06 |
|   | - Road Cuts and Constructions | -        | -         | Ltp | 15.94  | 1.04 |
|   | - Road Cuts and Constructions | -        | -         | Lbp | 5.96   | 0.39 |
|   | Water Management             |           |           |     |        |      |
|   | Waterholes                   | -         | -         | Da  | 0.19   | 0.01 |
|   | Artificial Channels          | -         | -         | Da  | 3.46   | 0.23 |
|   | **Total**                    |           |           |     | **1526.85** | **100.00** |
Notes: If = Interfluve, Lap = Upper hillslope, Ltp = Middle hillslope, Lbp = Lower hillslope, Lkk = Colluvial foot slope, and Da = Alluvial plain.

4. Conclusions

Human activities in Bompon Catchment have a significant influence on natural landforms. Agrogenic, urbanogenic, traffic, and water management are forms of intervention that have become an influencing factor of land transformation into anthropogenic landforms. The anthropogenic macro- and microfeatures give distinctive impacts on the surface and the environment of the catchment. Land modifications without proper planning cause compaction, erosion, and high threats of landslide and sedimentation.

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