Soil destruction level at vegetables cultivation land in upstream Cikapundung Sub Watershed, Indonesia and the alternative sustainable management

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Abstract. The area for cultivating vegetables in the upstream of Cikapundung Sub-Watershed is categorized steeps dryland, which very susceptible on soil erosion. The research objectives were (1) to evaluate the amount of erosion in existing land use, (2) to determine the level of soil damage by erosion and its effect on land productivity, and (3) to formulate alternative management at vegetables cultivation land upstream of the Cikapundung Sub-Watershed to be sustainable. The research was conducted using a survey method in Lembang Subdistrict, West Bandung District, West Java Province, Indonesia. Primary data collection was carried out through interviews, observation, and soil sampling. Data analysis was based on descriptive and literature study. The results of the prediction showed that the largest soil erosion occurred in Mekarwangi Village on intensive cultivated vegetable fields with a slope of > 40%. The amount of erosion that occurred was 141.3 t ha⁻¹ year⁻¹, exceeding limit Tolerable Soil Loss (TSL). The level of soil destruction is quite heavy. There was a decrease in C-organic and soil nutrient content that caused the productivity of cultivated vegetables land had decreased by 26.6%. Management of vegetable cultivation land using soil conservation techniques should be applied appropriately, effectively, and efficiently according to the local agroecosystem conditions.

1. Introduction
The Cikapundung Sub-Watershed is a part of the Citarum Watershed. The upstream position of the Cikapundung Sub-Watershed is located in the north Bandung area. Administratively, the upstream sub-watershed of Cikapundung covers three areas, namely Bandung City, Bandung Regency and West Bandung Regency. The largest area of coverage is in Lembang Subdistrict, West Bandung Regency.

Based on the Bandung City Regional Regulation No. 18 year 2011 concerning the Regional Spatial Plan (RSP) of Bandung City for 2011-2031; Bandung Regency Regional Regulation No. 27 year 2016 concerning RSP of Bandung Regency for 2016-2036; and the Regional Regulation of West Bandung Regency No. 2 year 2012 concerning the RSP of West Bandung Regency for 2009-2029, the spatial pattern plan for the upstream of the Cikapundung Sub-Watershed is a water catchment area both in cultivation areas and in conservation areas.

In the cultivation area, vegetable crops are the most dominant type of agricultural business in the upstream of Cikapundung Sub-Watershed. The biophysical conditions of the soil and climate are very suitable for vegetable crops. In addition, vegetable crops have high economic value and shorter timeframe to harvest thus becoming the main source of household income for farmers. The area is one of the vegetable productions centers in West Java Province.
The cultivation area of vegetable crops in the upstream Cikapundung watershed is very susceptible to erosion because of the steep slope, high rainfall with the average of 2,500 mm year\(^{-1}\) and has a low aggregation (sandy loam soil texture) [1]. The impact of erosion is not only felt by residents around the location (upstream area), but also by residents in the middle and downstream parts, both directly and indirectly [2].

The direct impact of erosion at the scene is the loss of good soil layer where plant roots are anchored, damage to soil structure, decreased productivity or soil degradation and ultimately the land becomes critical. The land with critical status in the Citarum watershed is around 3,865 ha (including in the Cikapundung Sub-Watershed) [3].

Soil degradation occurs mainly due to the weak application of soil conservation techniques so that the rate of erosion increases [4]. According to Wicaksono [5], land degradation occurs due to a lack of knowledge of agricultural techniques in terms of erosion control, soil and water conservation, and a lack of public attention to the environment.

On that basis, it is necessary to have alternative management of vegetable cultivation land in the upstream Cikapundung Sub-Watershed so that soil and environmental degradation does not increase and to improve soil conditions that have already been degraded. On the other hand, local governments must continue to strive to maintain land functions according to The Regency Spatial Planning Map (RTRW Map).

The research objectives: (1) to evaluate the amount of erosion in existing land use), (2) to determine the level of soil damage by erosion and its effect on land productivity in the upstream Cikapundung Sub-Watershed, and (3) to formulate alternative management of vegetable cultivation in the upstream Cikapundung Sub-Watershed so that sustainable.

2. Materials and methods

The research was conducted in Lembang Subdistrict, Bandung Barat Regency from April to June 2020. Geographically, Lembang Subdistrict is located between 107°1.10-107°4.40 E and 6°3.73-7° S and administratively consists of 16 villages, namely Lembang, Kayuambon, Kahiripan Warehouse, Wangunsari, Mekarwangi, Pagerwangi, Langgensari, Cobogo, Cibodas, Sukajaya, Cikahiripan, Jayagiri, Cikole, Cikidang, Wangunharja, and Suntenjaya. The basis for selecting the location are: (1) Lembang Subdistrict, Bandung Barat Regency is the largest upstream area of the Cikapundung Sub-Watershed, which is about 7,438 ha or about 71.12% of the total area of the Cikapundung Sub-Watershed, (2) land use is mostly for vegetable cultivation, which is around 5,741 ha [6], and (3) Vegetable cultivation activities conducted on land with slopes of 25-40% or even more which are unsuitable for seasonal plants agricultural cultivation activities.

The materials used in this study include: (1) maps, consisting of topographic maps, land maps, land use maps, and administrative maps of the upstream area of the Cikapundung Sub-Watershed [7] and (2) materials required for soil observation, soil sampling, and samples required for soil analysis in the laboratory. The equipment needed in this research are an observation guide, soil drill, altimeter, Global Positioning System (GPS), Abney level, Munsell Soil Color Chart, shovel, hoe, knife, meter, camera, and composite sample bags.

This research used a Rapid Survey Method (RSM) and literature study. The rapid survey uses the Rapid Rural Appraisal (RRA) approach, which is a rapid rural assessment by verifying and checking through field observations, interviews, and soil sampling [8]. Literature study is carried out by searching for information and data, both online and directly collecting data and information in the form of reports from related agencies, institutions and agencies.

The survey was conducted in five villages, namely Cikahiripan, Cikidang, Suntenjaya, Mekarwangi, and Langgensari Villages. These villages were chosen intentionally from 16 villages based on administrative maps, land trim maps, and forest area maps [7]. The villages carry out vegetable cultivation activities on land with a slope of more than 25%.

The types of data collected consist of primary data and secondary data. Primary data includes existing land use, plant types, cropping patterns, land management techniques, fertilizer application,
conservation techniques, plant productivity, soil A horizon depth, soil physical properties (texture, structure, drainage), C-organic, and soil nutrients (N, P, K, and Ca). Secondary data were obtained from literature studies, including: standard A horizon depth of each soil type, soil physical properties (texture, structure, drainage), C-organic, and content of several soil nutrients (N, P, K, and Ca) fertilizers, and plant productivity cultivated in several years earlier.

Primary data collection was carried out through field observations of the horizon, structure, drainage, and composite soil sampling at each location and interviews with several farmers. The composite soil samples then analyzed in the laboratory include the fraction of sand, silt, and clay; C-organic; and the nutrient content of N, P, K, and Ca. Secondary data were collected through literature search and reports from agencies and/or agencies. The level of soil destruction by erosion, climate, and land use is determined by comparing the difference of the depth of horizon A at the time of observation to the standard depth. The difference in depth indicates the amount of erosion that has occurred or the thickness of the lost soil layer. The thickness of the lost layers is then calculated in percent.

The level of soil damage by erosion is determined by matching the percentage of soil loss to the criteria for erosion destruction (Appendix 1). Predicting the amount of soil erosion that may occur was used RUSLE (Revised Universal Soil Loss Equation) method. The equation for the amount of erosion that may occur is:

\[ A = R \times K \times L \times S \times C \times P \]  

Where:
- \( A \) = Amount of erosion (t ha\(^{-1}\) yr\(^{-1}\)),
- \( R \) = Rain erosivity factor,
- \( K \) = Soil erodibility factor,
- \( L \) = Slope length factor,
- \( S \) = Slope factor,
- \( C \) = Plant factor and
- \( P \) = Conservation action factor.

**TSL = Tolerable Soil Loss**

Erosion that can be tolerated (TSL = Tolerable Soil Loss) is calculated using the equation [8]:

\[ TSL = \frac{DE - D_{\text{min}}}{MPT} + PT \]  

Where:
- \( DE \) = equivalent depth (effective soil depth x depth factor),
- \( D_{\text{min}} \) = minimum soil depth,
- \( MPT \) = lifetime of soil,
- \( PT \) = soil formation rate.

The data on nutrient content, plant productivity, and changes in horizon depth obtained are tabulated, then processed/calculated into the average value or percent.

The data analysis was carried out descriptively, describing the results of verification and checking the biophysical conditions of the soil by comparing the biophysical conditions of the soil at the time of compiling the RTRW with current conditions. The data being compared are the results of the analysis of the amount of erosion, the threat of erosion (potential for erosion and erosion hazard index), the level of soil damage, and its impact on land productivity (decreased C-organic, soil nutrient content, and decreased productivity of vegetable crops) and recommended alternative land management.
3. Results and discussion

3.1. The amount of erosion that may occur on the existing land use

3.1.1. Use of existing land in the Upper Cikapundung Watershed. The field observations and interviews with several community leaders revealed that the most dominant use of existing land in the upstream Cikapundung Sub-Watershed is vegetable farming. This activity has been going on for more than 50 years, and more than 2 generations. In the beginning, farmers used flat land with slope lower than 8%. Currently, farming is carried on slope of 25–40%, even over than 40%.

Because the soil is fertile and the climatic condition is favorable, farmers used vegetable as the main commodity. Based on RSP data from Regional Development Planning Agency of West Bandung Regency [7], the types of soil in Lembang Subdistrict were mostly Brown Andosol and Brown Regosol, Brown Andosol, Brown Latosol, and Grey Regosol and Lithosol.

Meanwhile, the type of soil in the upstream vegetable cultivation area of the Cikapundung Sub-Watershed is dominated by Brown Andosols. According to Sukarman and Dariah [10], the Andosol soil type was formed from volcanic ash due to the eruption of the Mt. Tangkuban Perahu. Volcanic ash contains several essential nutrients needed by plants to soil fertile.

Andosol soil is characterized by the accumulation of organic matter on the black surface, loose soil structure and low bulk density. Soil chemical properties such as soil acidity (pH) around 5.4 and organic-C content of 4.23%, which both have strongly support on plant growth [11].

3.1.1.1. Land ownership. Ownership of farmer land in the upstream Cikapundung Sub-Watershed can be grouped into three: (1) less 0.5 ha, (2) between 0.5–1.0 ha, and (3) more than 1.0 ha. Most of the farmers have own land less than 0.5 ha, with an average of 0.3 ha. Initially, farmers owned an average land area of 1.0 ha, even had more than 5.0 ha. Currently, based on the survey, those with land > 1.0 ha were only dealers/traders or residents from outside.

The results of interviews with several farmers obtained information that the narrow land ownership among farmers was caused by: (1) being sold to meet family needs, such as school fees and/or looking for other works, (2) increasing the number of family, and (3) being sold for business capital. The increasingly narrow land ownership indicates that the pressure on land to meet the needs of family life is getting bigger [12]. As a result, land is exploited to obtain maximum results without regard to the capacity/carrying capacity of the land or by expanding arable land to other locations, such as protected area in private and government plantation.

Excessive exploitation of land without cultivation and conservation technologies has decreased land productivity. The expansion of arable land will also cause new problems, because it will lead to changes in land use, that have negative impacts on the environment, such as soil degradation, erosion, sedimentation, and flooding in the rainy season, and drought in the dry season.

3.1.1.2. Types of plants. The survey results showed that the types of plants cultivated in the upstream of the Cikapundung Sub-Watershed were dominated by palawija, vegetables, fruits, and wood crops (table 1). The results of interviews with farmers, fruit and timber plants that still exist such as Avocado, Jackfruit, Rasamala, Sanineten, and Puspa were mostly planted during the Agroforestry and Land Rehabilitation Movement program.

3.1.1.3. Planting system. The planting system is an inseparable part of farming activities. Each farmer applies a different cropping system independently. Based on field observations and interviews with respondents, around 63.6% of the farmers apply intercropping systems. The planting system is closely related to crop management in an effort to control erosion. According to [13], apart from erosivity, erodibility, land slope, and land management, plant management factors, including types of plants and planting systems, are one of the factors that greatly influences the amount of soil erosion by water.
The cropping pattern is also unclear, vegetables are always planted in the field (Figure 1). This pattern unbroken cycle of pests and diseases. To control pests or disease, farmers used by spraying pesticides every 4 to 7 days. The high intensity of spraying resulted in an excessive amount of pesticide doses being used. This method was not only costly but also has negative impacts on the environment, both upstream and downstream of the Cikapundung Sub-Watershed, such as on water pollution and even on humans who consume these vegetables.

The results of [14] show that several rivers in the Citarum watershed, including the Cikapundung Sub-Watershed, were in the top rank of the highest levels of pollution based on the measurements of Biochemical Oxygen Demand (BOD) and nutrients such as nitrogen and phosphorus. Otherwise, dissolved oxygen (DO) was getting lower. 80% of the source of pollution is caused by domestic waste, including pesticides, which contribute hazardous and toxic materials, such as heavy metals to river flow [3].

Table 1. Types of palawija plants, vegetables, fruits, and timber in the upstream cultivation area of the Cikapundung Sub-Watershed, 2020.

| Commodities        | Types of Plants                                                                 |
|--------------------|---------------------------------------------------------------------------------|
| Vegetables         | 1. Tomato (*Solanum lycopersicum* esc MILL)                                     |
|                    | 2. Red chilies (*Capsicum annuum*)                                              |
|                    | 3. Cayenne pepper (*Capsicum sp*)                                               |
|                    | 4. Broccoli (*Brassica oleracea var italic*)                                    |
|                    | 5. Cabbage (*Brassia oleracea*)                                                 |
|                    | 6. Beans (*Phaseolus vulgaris*)                                                  |
|                    | 7. Potatoes (*Solanum tuberosum* L)                                              |
|                    | 8. Cucumber (*Cucumis sativus* LINN)                                             |
|                    | 9. Long Beans (*Vigna sinensis* ENDL)                                            |
|                    | 10. Peanuts (*Pisum sativium*)                                                   |
|                    | 11. Petsai (*Brassica purpureum* SCHUM)                                          |
|                    | 12. Mustard (*Brassica rugosa* FRAIN)                                            |
|                    | 13. Ceisin (*Brassica melicum* L)                                                |
|                    | 14. Lettuce (*Lettuce*)                                                          |
|                    | 15. Pare (*Momordica charantia* LINN)                                            |
|                    | 16. Asparagus (*Asparagus officinalis* LINN)                                     |
|                    | 17. Paprika (*Capsicum sp*)                                                      |
|                    | 18. Eggplant (*Solanum Melongena* LINN)                                          |
|                    | 19. Carrots (*Daucus carota*)                                                    |
|                    | 20. Spring onion (*Allium fistulosum* L)                                         |
| Fruits             | 1. Orange (*Citrus sp*)                                                          |
|                    | 2. Guava (*Psidium guajava* LINN)                                                |
|                    | 3. Banana (*Musa acuminata* COLLA)                                               |
|                    | 4. Avocado (*Persea americana*)                                                  |
|                    | 5. Jackfruit (*Artocarpus integra* MERR)                                         |
|                    | 6. Petai (*Parkia speciosa* HASSK)                                               |
|                    | 7. Breadfruit (*Artocarpus communis* FORST)                                      |
| Types of Wood,     | 1. Suren (*Toona sureni*)                                                        |
| Plantation, and    | 2. Bamboo (*Bambusa Sp*)                                                         |
| Animal Feed        | 3. Coffee (*Coffea arabica*)                                                     |
|                    | 4. Elephant Grass (*Pennisetum purpureum* SCHUM)                                |

Source: Processed from primary data.
3.1.1.4. Topography. The area for cultivating vegetables in the upstream area of the Cikapundung Sub-Watershed has a varied topography, namely flat, wavy, hilly and mountainous with an altitude of 800-2,200 m above sea level (asl). The upstream slope class of the Cikapundung Sub-Watershed also varies, namely gentle, rather steep, steep, and very steep. The largest percentage of slope class is slightly steep with a gradient of 15-25% (Table 2). Land distribution based on slope class in the upstream Cikapundung Sub-Watershed is presented in figure 2.

Table 2. Slope class and extent in the upper Cikapundung Sub-Watershed.

| Slope % | Slope Class                        | Large          | %    |
|---------|------------------------------------|----------------|------|
| 0-8     | Slightly sloping or slightly sloped | 875,098        | 12.54|
| 15-25   | Little steep                        | 4,327,975      | 62.02|
| >40     | Steep and very steep                | 1,774,677      | 25.43|
|         | Total                              | 6,977,910      | 100.00|

Source: [3].

Figure 2. Map of land slope of Lembang District.
3.1.1.5. Land management. The survey results showed that the use of organic matter (OM) was a must in vegetable farming in the upstream Cikapundung Sub-Watershed, because without OM, plant productivity become lower. The OM made from livestock manure, both chicken and cow. The OM dose was very high, around 20-30 t ha\(^{-1}\) which was given by placing it in the middle of the mounds or given to each plant hole. If using plastic mulch, OM was spread over the bed so that the amount of OM needed become 40 t ha\(^{-1}\).

Beside organic fertilizers, farmers were used inorganic fertilizers, such as Urea, SP36, Phonska, KNO\(_3\), KCl, and NPK. The dose of inorganic fertilizers used is not as recommended. Mostly farmer used a dose less than recommended because of the expensive price. Only 10% of farmers who have enough capital, provide inorganic fertilizer that exceeds the recommendation. Excessive doses of fertilizer occurred because as addition to basic fertilizer as recommended. Farmers also gave additional fertilizer at least 6 times in one growing season at a rate of 10 kg NPK per application.

The results of interviews and field observations showed that only 15% of vegetable farmers in the upstream Cikapundung Sub-Watershed manage their land according to the conservation principles. Another 85% manage the land with a raised bed system and its direction follows the slope, as shown in figure 3 and 4.

![Figure 3](image3.png)  ![Figure 4](image4.png)

**Figure 3.** The implementation of soil conservation by farmers (the raised bed cuts across).

**Figure 4.** The implementation of soil conservation by farmers (the raised bed down the slope).

Land management that uses conservation principles was making terraces, planting grass or forage plants on the edge of the terrace, and using mulch. Farmers knew that terrace have impact to prevent erosion which can reduce land productivity. However, in fact the terracing technique has not widely applied. Many influencing factors were including highly cost of making terraces, thinking of farmers that terraces reduce the area of arable land and the yield were not immediately increased. Whereas land management without following conservation principles can increase the rate of erosion. The results of the research [14] showed that the level of erosion in the Citarum Sub-Watershed including the upstream Cikapundung Sub-Watershed was in very bad with an average value of 491 t ha\(^{-1}\) year\(^{-1}\) especially in the upstream. This means that the average subsoil reduction in the area is around 4.09 cm year\(^{-1}\).

3.1.2. The amount of erosion that occurs. The RUSLE method showed prediction level of erosion in several research locations in the upstream vegetable cultivation area of the Cikapundung Sub-Watershed as presented in Table 3. It shows that the largest erosion occurred on vegetable cultivation in Mekarwangi Village with slope of greater than 40%, and used for fields with agroforestry vegetation (fruit, wood, and vegetable crops). The prediction resulted that the level of erosion was 597.76 t ha\(^{-1}\) year\(^{-1}\) or there was a loss of soil with a thickness of 2.08 cm year\(^{-1}\). The lowest prediction of erosion occurred on vegetable cultivation in Suntenjaya Village that has a slope of 25-40% which was used for forage grass and vegetables (cauliflower, cabbage, chili, cucumber, beans, tomatoes, sweet corn, mustard greens). The prediction of the amount of erosion was only 22.57 t ha\(^{-1}\) year\(^{-1}\) or there was soil loss with a thickness of 0.33 cm year\(^{-1}\).
Based on those results, the most influence factors of erosion level were the slope of land, conservation measures, and vegetation. In the land with a slope of >40%, the erosion that occurred in the five villages was greater than in the land with a slope of 25-40%. Conservation measures for sloping terraces, rolling terraces and bench terraces have proven to be of great help in reducing the rate of erosion. The combination of forage grass and vegetable vegetation has also proven to be effective in controlling erosion, so that Suntenjaya Village has the lowest level of erosion. Thus, the success of erosion control was not determined by one action. Integrated conservation measures, both biological (vegetation), technical (mechanical), and chemical, will greatly determine the success of erosion control [15].

3.2. Soil destruction level and effects on land productivity
Level of erosion that occurs greatly determines the level of soil destruction, because erosion made loss of the top soil which is very important for plant growth. According to Simonato et al. [16] that soil destruction occurs for several reasons, but most importantly in the wet tropics and sloping land such as in the upstream Cikapundung sub-watershed, was erosion by water. Erosion cause destruction and loss of soil layers which are rich in nutrients and organic matter and have good physical properties for the anchor plant roots [17].

The results also showed that the level of erosion that occurred in the upstream vegetable cultivation area of the Cikapundung Sub-Watershed had exceeded the amount of erosion that was allowed (Tolerable Soil Loss = TSL). According to Arsyad [6], the TSL value of deep soil with a permeable bottom layer, above the substrate has decayed, such as in the upstream Cikapundung Sub-Watershed is 2.5. Soil weight in the upstream Cikapundung Sub-Watershed in the case of Mekarwangi 0.701 g cm⁻³, the level of erosion that is still allowed is 17.00 t ha⁻¹ year⁻¹. The results of calculations using the Hammer method (1981), the TSL amount was the same, namely 16,983 or rounded to 17.0 t ha⁻¹ year⁻¹. Thus, the upstream vegetable cultivation area of the Cikapundung Sub-Watershed urgently needs conservation action.

The results of observations in five villages showed that the level of soil destruction in the upstream vegetable cultivation area of the Cikapundung Sub-Watershed was mostly classified as a bit heavy based on the criteria for the level of soil destruction [13] and Environmental Regulation No. 20 of 2008, that is, more than 75% of the top layer is lost (thickness of solum is reduced >75%). Soil that has been destructed due to physical, chemical, and biological destruction has an effect on decreasing land productivity [18].

Soil erosion has resulted in a decrease in C-organic content and nutrient content of N-total, P₂O₅, K, and Ca in the case example in Mekarwangi Village (table 4). Erosion that is vanishing topsoil is bad for soil and crops. The results of Cuff's research (1978) in [19], erosion that erodes 1 cm of tillage in an area of 1 ha will carry an equivalent of 350 kg of nitrogen (N), 90 kg of phosphate (P), 1,000 kg of potassium (K), 650 kg of magnesium (Mg), and 1,050 kg of calcium (Ca).

Table 4 also shows that the decrease in soil organic C content was highest compared to other nutrients. This is presumably because the organic matter (OM) lost due to erosion is not proportional to the OM given in each planting season. In the long term, the reduction in its content will be even greater, along with other nutrients and will have an impact on plant productivity. The effect of decreasing nutrient content on the productivity of several types of vegetable plants that are predominantly cultivated in Mekarwangi Village is presented in table 5.

Table 5 shows that 66.67% of cultivated vegetable crops have decreased up to 26.58%. This proves that the land in the upstream vegetable cultivation area of the Cikapundung Sub-Watershed has been destruction. There were 33.33% types of vegetables increases up to 10.09% because of organic and inorganic fertilizers application. If the land destruction in upstream Cikapundung Sub-Watershed continues, without control action, the land will be critical. Land become unproductive because it can no longer be used for agricultural business, even if it is cultivated with very high input.
Table 3. Erosion occurring in the upstream vegetable cultivation area of the Cikapundung Sub-Watershed.

| Village   | Slope  | Conservation Measures                        | Land Use (Vegetation)                                                                 | Soil Erosion (t ha⁻¹ year⁻¹) |
|-----------|--------|----------------------------------------------|-------------------------------------------------------------------------------------|------------------------------|
| Mekarwangi| 25-40% | Not terraced; raised bed unidirectional the slope | Agroforestry: Forage grass; Mixed garden (coffee, avocado, mango, jackfruit), orange garden; Vegetables (Beans, Cauliflower, Lettuce, Tomato, Red Chili, Cayenne Pepper, Mustard, etc.); Rasamala wood, Suren, etc. | 100.84                      |
|           | >40%   | Not terraced; raised bed unidirectional the slope | Agroforestry: Forage grass; Mixed garden (coffee, avocado, mango, jackfruit), orange garden; Vegetables (Beans, Cauliflower, Lettuce, Tomato, Red Chili, Cayenne Pepper, Mustard, etc.); Rasamala wood, Suren, etc. | 141.23                      |
| Langgensari| 25-40% | Sloping terrace; raised bed unidirectional the slope | Agroforestry: Forage grass; Mixed garden (coffee, avocado, mango, jackfruit), orange garden; Vegetables (Beans, Cauliflower, Lettuce, Tomato, Red Chili, Cayenne Pepper, Mustard, etc.); Rasamala wood, Suren, etc. | 75.85                       |
|           | >40%   | Not terraced; raised bed unidirectional the slope | Agroforestry: Forage grass; Mixed garden (coffee, avocado, mango, jackfruit), orange garden; Vegetables (Beans, Cauliflower, Lettuce, Tomato, Red Chili, Cayenne Pepper, Mustard, etc.); Rasamala wood, Suren, etc. | 122.52                      |
| Suntenjaya| 25-40% | Gulud terrace; raised bed cut the slopes      | Forage grass and vegetables (cauliflower, cabbage, chili, cucumber, green beans, tomatoes, sweet corn, mustard greens) | 22.57                       |
|           | >40%   | Sloping terrace; raised bed unidirectional the slope | Forage grass and vegetables (cauliflower, cabbage, chili, cucumber, green beans, tomatoes, sweet corn, mustard greens) | 69.93                       |
| Cikahuripan| 25-40% | Sloping terrace; raised bed unidirectional the slope | Vegetables (Cauliflower, Chili, Cucumber, Chickpeas, Tomatoes, Sweet Corn, Mustard Greens, Kaboca, Lettuce, Cukini) | 42.56                       |
|           | >40%   | Sloping terrace; raised bed unidirectional the slope | Vegetables (Tomato, Cauliflower, Beans, Chili, Sweet Corn) | 76.18                       |
| Cikidang  | 25-40% | Not terraced; raised bed unidirectional the slope | Vegetables (Cauliflower, Chili, Cucumber, Chickpeas, Tomatoes, Sweet Corn, Mustard Greens, Kaboca, Lettuce, Cukini) | 56.83                       |
|           | >40%   | Not terraced; raised bed unidirectional the slope | Vegetables (Tomato, Cauliflower, Beans, Chili, Sweet Corn) | 106.7                       |

Table 4. Soil nutrient content in Mekarwangi Village, Lembang District (2008 and 2020).

| Type of Analysis | Unit     | Analysis Results | (%) decrease |
|------------------|----------|------------------|--------------|
|                  |          | Year 2008*       | Year 2020**  |                |
| C-organik        | %        | 2.16             | 1.69         | 21.76          |
| N-total          | %        | 0.22             | 0.19         | 13.64          |
| P₂O₅ (Bray 1)    | Ppm      | 12.90            | 11.40        | 11.63          |
| K                | me/100 g | 0.31             | 0.30         | 3.23           |
| Ca               | me/100 g | 3.56             | 3.27         | 8.15           |

Source: * = [19]; ** = Primary data analysis of soil samples.

3.3. Alternative management of upstream vegetable cultivation land in Cikapundung Sub-Watershed in order to be sustainable
The level of soil destruction, especially that caused by erosion, is one of the main problems in optimizing the use of sloping dry land including in the upstream vegetable cultivation area of the Cikapundung Sub-
Watershed. Various conservation techniques have been researched, produced, and developed by various research institutions in Indonesia.

Table 5. Development of productivity of several types of vegetable plants cultivated in cultivation land in Mekarwangi Village Upstream, Cikapundung Sub-Watershed.

| No. | Types of Plants                      | Productivity Year 2008* | Productivity Year 2020** | Decrease (-)/ Increase (+) |
|-----|--------------------------------------|-------------------------|--------------------------|-----------------------------|
| 1.  | Tomat (Solanum lycopersicum es Mill) | 21.25                   | 20.78                    | -2.21%                      |
| 2.  | Cabai merah (Capsicum annuum)        | 24.60                   | 18.06                    | -26.58%                     |
| 3.  | Cabai rawit (Capsicum sp)            | 23.30                   | 20.08                    | -13.82%                     |
| 4.  | Brokoli (Brassica oleracea var italic) | 12.70                   | 14.40                    | +13.39%                     |
| 5.  | Kentang (Solanum tuberosum L)        | 18.75                   | 15.76                    | -15.95%                     |
| 6.  | Mentimun (Cucumis sativus LINN)     | 22.45                   | 18.77                    | -16.66%                     |
| 7.  | Petsai (Brassica purpureaum SCHUM)  | 8.25                    | 8.50                     | +3.03%                      |
| 8.  | Sawi (Brassica rugosa FRAIN)         | 8.90                    | 9.24                     | +3.82%                      |
| 9.  | Ceisin (Brassica melicum)            | 6.54                    | 7.20                     | +10.09                      |
| 10. | Selada (Lettuce)                     | 12.67                   | 12.50                    | -1.34%                      |
| 11. | Wortel (Daucus carota)               | 15.00                   | 14.00                    | -6.67%                      |
| 12. | Bawang daun (Allium fistulosum L)    | 14.00                   | 15.00                    | -7.14%                      |

Source: * = [19]; ** = Results of interviews with farmers.

Mechanical conservation farming systems with bench terraces and bund terraces in accordance with the local agro-ecosystem zone can reduce erosion rates and increase farm productivity and farmers' income [21]. Conservation farming that combines mechanical and vegetative conservation measures with spatial arrangements for seasonal crops, perennial crops, legumes for conservation as well as producing organic fertilizers and forage, and grass; by paying attention to the face shape and landscape characteristics [15, 22]. Conservation of rice terraces, slope cutting beds, using manure + lime, installing plastic mulch, intercropping/overlapping vegetable planting systems group I + III or II + III are technically and financially feasible and recommended to be developed on land with a slope of 15 to 25% [23].

However, the application of the various conservation techniques (soil and water) mentioned above at the farm level is still faced with various obstacles and problems. The case in Mekarwangi Village, the farmers prefer applying land management that is carried out using a raised bed system in the direction of the slope. The reasons for farmers to apply this system include: the area of arable land is not reduced, the cost of making terraces can be diverted to buy production facilities (such as fertilizers and pesticides), and reducing water infiltration during the rainy season so that the soil is not too moist, especially if the crops are cultivated for potatoes. In humid conditions, potatoes are prone to late blight caused by Phytophthora infectants.

On this basis, the management of vegetable cultivation land in the upstream Cikapundung Sub-Watershed does not only apply appropriate, effective, and efficient conservation techniques and requires good and targeted planning. Apart from land biophysical factors, farmers' socio-economic and cultural factors are important factors that must be considered in land management planning. Thus, the alternative management in the upstream vegetable cultivation area of the Cikapundung Sub-Watershed is hedgerows technology, which is a component of conservation efforts combined with a series of technical, socio-cultural, and policy activities. One of the government policies, both central and regional, that is needed is the provision of incentives (rewards) for environmental services to farmers who apply appropriate, effective, and efficient conservation techniques according to local agroecosystem conditions.
4. Conclusions
Vegetable farming activities in the upstream cultivation area of the Cikapundung Sub-Watershed do not have a cropping pattern, vary in the planting methods, and >85% have not applied conservation techniques. Vegetables are planted on sloping land with a slope of up to 40%, so that it has a very large effect on the rate of erosion. The amount of erosion that occurs exceeds the Tolerable Soil Loss (TSL). The rate of erosion that exceeds the TSL has resulted in destruction to the land in the upstream vegetable cultivation area of the Cikapundung Sub-Watershed and the level of destruction is already quite severe. The case in Mekarwangi Village, soil destruction has reduced the content of C-organic and nutrient content of N-total, P₂O₅, K, and Ca. Soil destruction also affects vegetable productivity. About 66.67% of the productivity of several types of vegetables decreased by 26.58%.

Management of vegetable cultivation land in the upstream Cikapundung Sub-Watershed does not only apply appropriate, effective, and efficient conservation techniques according to local agroecosystem conditions but must also pay attention to the balance between conservation and use aspects. Apart from land biophysical factors, farmers’ socio-economic and cultural factors are important factors that must be considered in land management planning. Government policies, both central and local, regarding the provision of incentives (rewards) for environmental services to farmers who apply conservation techniques are needed so that the cultivation of vegetable land in the upstream Cikapundung Sub-Watershed can be used sustainably.

Appendix
Criteria for the level of soil damage (Arsyad, 2006)

| Symbol | Criteria | Indicator |
|--------|----------|-----------|
| e₀     | No erosion | The soil layer is intact |
| e₁     | Little erosion | Less than 25% of the top layer (horizon A) is lost |
| e₂     | Moderate | 25-75% of the top layer is lost |
| e₃     | It's a bit heavy | > 75% of the top layer is gone |
| e₄     | Heavy erosion | > 25 layers below are gone |
| e₅     | Very heavy | Gully erosion |

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