Farming land management on potato cultivation in sloping upland

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Abstract. This study aim was to obtain a potato farming conservation technology package that can increase productivity and income of potato farming, and to reduce soil erosion rate. The research had been conducted at area of 15,000 m² in the sloping upland of Tosari Village - Tosari Subdistrict - Pasuruan during the dry season of 2016. The experiment was designed in randomized block, consisting of 3 treatments of conservation agronomic practices with 4 replicates. The treatments: (1) improved technology package (uni-directional slope beds and ridges contour, combined with green leeks + Setaria Sp. feed grass + recommended fertilizer); (2) agreed technology package (uni-directional slope beds and ridges contour, combined with green leeks, and agreed fertilizer); and (3) farmer’s technology package (uni-directional slope beds, combined with green leeks, and farmer fertilizer). The results showed that the weight of potato tubers 14.17 t ha⁻¹ (increased 49.94%) and leek 0.84 t ha⁻¹ and the pruning of Setaria grass 117 kg ha⁻¹, while the agreed technology the increased of potato tubers weight by 41.05% compared to the farmer's technology package of 9.45 t ha⁻¹. Application of improved technology obtained the highest profit of Rp. 23,103,500 (equal to 1,714.80 USD), R/C 1.51, and efficiency of chemical fertilizers.

1. Introduction
Often neglected in agricultural cultivation is the problem of soil sustainability which if not managed properly it can cause soil degradation. Soil degradation does not only adversely affect land productivity, but also damages or disrupts of agricultural land function. Soil degradation is defined as a process, phenomenon or transformation that reduces soil quality, causing the physical, chemical, or biological properties of the soil to become less suitable for agriculture [1]. The occurrence of erosion has directly affected on decreasing the level of land productivity, infiltration capacity, soil moisture, and the erosion of the soil layer and the depletion of nutrients [2], so that in turn it will have an impact on decreasing the quantity and quality of yields and leaving chemical residues. in soil or on plant parts [3,4].

Sloping upland conditions in the highlands are generally classified as unstable and prone to erosion and landslides [5]. Planting potatoes along the slope on steep land is intended to facilitate drainage so that soil moisture does not increase because it affects disease intensity, although farmers are aware that this method can cause high erosion [6,7]. Therefore, soil conservation techniques that can be applied in potato cultivation must be pursued as little as possible to reduce soil moisture, so that it does not become a good
medium for fungi and fungal growth, as well as the rate of erosion can be controlled. It is argued that high soil moisture in the root zone led to the development of Phytophthora sp. which attacks vegetables [8,9].

Various technologies to control erosion on sloping land are available, but the problem is the lack of dissemination and the slow adoption of them by farmers [10]. The low adoption of land conservation technology in addition to the lack of support from government policies, social problems such as land tenure and rights systems, land fragmentation, limited cultivated land by farmers, and population pressure can also hinder the application of land conservation. The generally low economic conditions of farmers as well as cultural aspects or farmers' habits are often the reason for them to neglect soil conservation [11]. Therefore, efforts are made for soil conservation techniques that are cheap and easy to apply by to increase the productivity of potato crops, while controlling the rate of erosion.

Planting vegetables in beds that are parallel to the slope causes more nutrients and soil to be transported than in beds made parallel to the contour [12,13]. Planting in beds that increasingly leads to contours is more effective at reducing surface runoff and erosion [14,15]. Efforts are made to make beds in the same direction as the contour, equipped with rorak or deeper water channels so that water can immediately infiltrate the soil and reduce the high soil moisture [16]. The less clay and colloid content transported by the surface run-off reduces the concentration of nutrients and organic matter in the sediment. This situation can reduce nutrient losses which affect the growth and yield of potatoes [14]. Another way to reduce erosion in potato cultivation on sloping land is by dividing the length of the slope lined beds by making ridges in the direction of the contour that can be planted with leeks or chilies. The results of research that the cultivation of potatoes in beds with the direction of the slope by turn ridge contours planted with leek applying half the recommended fertilization dose resulted in 37.7 t ha\(^{-1}\) of potatoes and 1.54 t ha\(^{-1}\) of leek and reduced the erosion rate of 34.31% compared to cultivating potato on the bed in the direction of the slope [7]. Furthermore, the research results with contour beds produced slightly lower potato tubers, but the rate of erosion could be reduced by 27% compared to the method of making beds along the slope. In addition to reduced erosion, macro nutrient loss (N, P and K) could be suppressed [8]. To reduce the rate of erosion, you can also apply an outward sloping bench terrace which was able to reduce the run-off rate by 18.8% and erosion by 46.7%, but the tuber yield decreased slightly compared to planting potatoes in beds along the slope [6]. The amount of transported soils in potato plantations with beds at a 45° angle was able to reduce the erosion rate by 38%, although the tuber yield was slightly below the beds in the direction of the contour [17]. Thus the application of conservation farming systems can increase land productivity by decreasing the rate of erosion in addition to increasing potato production [18,19].

This study aimed to obtain a potato farming conservation technology package that can increase productivity and income of potato farming, and to reduce soil erosion rate

2. Materials and methods

This research activity was carried out in the potato production center of upland dry land with an altitude of 1,725 m above sea level and a slope gradient of 40% in Tosari Village, Tosari District, Pasuruan Regency, in Dry Season\(^{1st}\) (DS\(^{1st}\)) 2016. Research on potato cultivation conservation was carried out in 15,000 m\(^2\) of farmers' land, consisting of three technology packages with 4 replicate, namely: (1) improved technology package on potato cultivation (beds with alternating slope contour ridges + leek + animal feed grass + recommended fertilizer), (2) agreed technology package on potato cultivation (beds with slopes alternating contour ridges + leek + agreed fertilizer), and (3) farmer's technology package on potato cultivation (beds uni-directional of the slope + leek + farmer fertilizer) (table 1).
Table 1. The conservation farming technology package on potato cultivation in sloping upland, DS\textsuperscript{1st} 2016, Tosari-Pasuruan.

| No. | Activity     | Improved technology package | Agreed technology package | Farmer’s technology package |
|-----|--------------|-----------------------------|---------------------------|-----------------------------|
| 1.  | Beds         | Beds unidirectional slope with a length of 4 m by turn ridges contour | Beds unidirectional slope with a length of 4 m by turn ridges contour | Beds unidirectional with a length of 4 m and channel diversion |
| 2.  | Ridges around | - Ridges contour planted with green leeks around the embankment planted with grass \textit{Setaria} Sp. | - Ridges contour planted with green leeks | - Plant green leeks without ridges |
| 3.  | Spacing      | 80 cm x 30 cm               | 80 cm x 40 cm             | 80 cm x 40 cm               |
| 4.  | Fertilization| 150 kg Urea ha\textsuperscript{-1} + 200 kg ZA ha\textsuperscript{-1} + 100 kg SP-36 ha\textsuperscript{-1} + 50 kg KCl ha\textsuperscript{-1} + 7.5 t Organic Fertilizer ha\textsuperscript{-1} & Trichocompost | 100 kg ZA ha\textsuperscript{-1} + 50 kg SP-36 ha\textsuperscript{-1} + 450 kg Ponska/ha + 600 kg ZA ha\textsuperscript{-1} + 6 t ha\textsuperscript{-1} Organic Fertilizer & Trichocompost |}

Notes: the fertilizer content of Urea (46% N), SP-36 (36% P\textsubscript{2}O\textsubscript{5}), ZA (21% N + 24% S), KCl (60% K\textsubscript{2}O), Ponska (15% N + 15% P + 15% K).

The potato used were Granola ke mbang varieties with tubers measuring 30-60 g, while the Organic Fertilizers (OF) from chicken manure using Trichocompost (improved and agreed technology package). Making beds in the uni-directional of the slope with a width of 1 meter and a length of 4 meters planted with potato in two planting space of 80 cm x 30 cm (for improved technology package) and 80 cm x 40 cm (for agreed and farmer’s technology package), while the 0.4 m contour mound planted with 2 rows of green leek spacing 25 cm x 25 cm (improved and agreed technology package). Green leek on the farmer's technology package is planted 1 row on the lower lip of the bed with a distance of 25 cm. For the improved technology package, \textit{Setaria} grass was planted 1 row at a distance of 20 cm around the embankments.

Observations included transects of the research location, plant height, number of branches and leaves, number and weight of tubers, leeks and pruning grass. Financial analysis was based on the feasibility of conservation farming in potato cultivation using the R/C ratio [20], as follows:

\[
R/C = \frac{NPT}{BT}
\]

Where:
- \( R/C \): Revenue and Cost Ratio
- \( NPT \): Total production value (IDR/ha)
- \( BT \): Total cost value (IDR/ha)

If:
- \( R/C > 1 \) : Feasible to be developed
- \( R/C = 1 \) : Break even
- \( R/C < 1 \) : Not feasible to be developed
3. Results and discussion

3.1. Characteristics of research sites
The research location has an Andoso soil type with a clay soil texture class and an acidic soil reaction (table 2).

Table 2. Results of analysis of upper and lower soil nutrients before the experiment in the sloping upland, Tosari-Pasuruan [7].

| Analysis                  | Upper soil (20 cm) | Lower soil (20 cm) |
|---------------------------|--------------------|--------------------|
|                           | Content            | Information        | Content            | Information        |
| Texture (%) :             |                    |                    |                    |                    |
| Sand                      | 40                 | 51                 |
| Clay                      | 38                 | 36                 |
| Silt                      | 22                 | 13                 |
| Class                     |                    |                    |                    |                    |
| pH : H2O                  | 4.8                | Acid               | 4.9                | Acid               |
| C-organic (%)             | 1.34               | Low                | 1.54               | Low                |
| N-total (%)               | 0.16               | Low                | 0.197              | Low                |
| C/N                       | 8.37               | Low                | 7.817              | Low                |
| P2O5-Olsen (ppm)          | 221                | Very high          | 275                | Very high          |
| K (me.100 g⁻¹)            | 1.84               | Very high          | 1.22               | Very high          |
| Na (me.100 g⁻¹)           | 0.23               | Low                | 0.06               | Very low           |
| Ca (me.100 g⁻¹)           | 4.17               | Low                | 3.33               | Low                |
| Mg (me.100 g⁻¹)           | 0.54               | Low                | 0.45               | Low                |
| CEC (me.100 g⁻¹)          | 24.71              | High               | 23.05              | Moderate           |

* Soil Laboratory analysis results AIAT East Java (2014).

The contents of C-organic and N-total are classified as low, whereas P2O5 and K contents are classified as very high. The upper soil on sloping land has a lower nutrient content (C-organic, N-total, P2O5) than the lower soil.

Rainfall begins to approach 200 mm in November, so farmers generally start cultivating the land and planting vegetables in mid-November. The cropping pattern was dominated by potatoes and during DS 2nd the water was by supplied from reservoir (figure 1). So far, farmers have planted potatoes in beds along the slope with the excuse of accelerating tillage and planting so that it is efficient in the use of labor. However, the potato cultivation technology applied by these farmers will accelerate the rate of erosion.
Transects of sloping upland is dominated with vegetable around 75% to 85%, and pine tree of around 15% to 25% (figure 2). The conditions of sloping upland (gradients of 30% to 65%) are often planted with vegetables by planting in beds along the slopes without attention to soil conservation aspects.

Upland topography in Tosari Village generally has a slope gradient between 10% to 65%, and is dominated by potato cultivation. In general, potatoes is done by planting in the beds unidirectional of the slope, so that during heavy rains landslides often occur, especially on steep sloping land.

Figure 1. Distribution of rainfall and cropping patterns in the Tosari Subdistrict, Pasuruan Regency.
3.2. Growth and yield
Cultivating potatoes applying the improved technology package by planting potatoes in the direction by turn ridge contour leeks and Setaria grass around the embankment with the recommended fertilization dose, obtained better growth and yields. Furthermore, the results of potato tubers are followed by agreed technology package, namely planting potatoes in beds in the direction by turn ridge contour by planting leek and fertilizing according to the agreement. The lowest yields of potato tubers were found in farmer
technology packages by planting potatoes in beds along the slope and planting leeks on the lip of the beds (table 3 and table 4).

Table 3. Effect of technology packages on plant height, number of branches and number of leaves of potato plants, DS 1st 2016, Tosari-Pasuruan.

| No. | Technology packages | Plant height (cm) | Number of branches | Number of leaves |
|-----|---------------------|-------------------|--------------------|------------------|
|     |                     | 45 DAP 75 DAP 105 DAP | 45 DAP 75 DAP 105 DAP | 45 DAP 75 DAP 105 DAP |
| 1   | Improved            | 29.00 a 37.33 a 58.67 a | 21.33 a 27.33 a 36.00 a | 147.00 a 160.00 a 236.00 b |
| 2   | Agreed              | 25.33 b 34.67 b 47.33 c | 16.00 c 23.00 b 33.67 a | 122.33 b 155.67 a 341.67 a |
| 3   | Farmer’s            | 20.67 c 36.00 ab 51.33 b | 18.33 b 26.00 a 31.00 a | 100.00 c 148.33 a 202.00 c |

The numbers followed by the same letter on the same line are not significantly different from DMRT at the 5% level.

Treatment of improved technology packages in the conservation of potato cultivation obtained a significant increase in potato plant height starting from observations of 45 days after planting (DAP), 75 DAP and 105 DAP. Likewise, the number of branches and potato leaves from the treatment of the improved technology package showed a significant increase compared to the treatment of the agreed and the farmer’s technology packages. Thus, planting potatoes in beds in the same direction as contour intervals can reduce the rate of erosion, so that the loss of macro nutrients (N, P and K) can be suppressed and utilized for the growth of potato plants [8].

Table 4. Effect of technology packages on the number and weight of potato tubers, plant height, number of leaves and weight of leek, and height and weight of prunned Setaria Sp grass, DS 1st 2016, Tosari-Pasuruan.

| No. | Technology packages | Number of tubers plant⁻¹ | Weight of tuber (kg plant⁻¹) | Weight of tuber (t ha⁻¹) | Height of leek (cm) | Number of leaves of leek | Weight of leek (t ha⁻¹) | Height of grass (cm) | Weight of pruning grass (kg ha⁻¹) |
|-----|---------------------|---------------------------|-----------------------------|-------------------------|-------------------|--------------------------|------------------------|---------------------|--------------------------|
| 1   | Improved            | 5.67 a                    | 0.53 a                      | 14.17 a                 | 32.57 a           | 3.87 b                   | 0.84 a                 | 35.67               | 117                      |
| 2   | Agreed              | 6.67 a                    | 0.37 a                      | 13.33 a                 | 32.67 a           | 4.47 a                   | 0.74 a                 | -                   | -                        |
| 3   | Farmer’s            | 5.67 a                    | 0.43 a                      | 9.45 b                  | 32.23 a           | 4.10 ab                  | 0.80 a                 | -                   | -                        |

The numbers followed by the same letter on the same line are not significantly different from DMRT at the 5% level.

There was no significant difference between treatment packages of potato cultivation technologies on the number and weight of tubers per plant. The weight of potato tubers per hectare from the improved technology package treatment reached 14.17 t ha⁻¹ (increased 49.94%) and the agreed technology package was 13.33 t ha⁻¹ (increased 41.05%) and was significantly different from the farmer’s technology package of 9.45 t ha⁻¹. The difference in the yield of tubers from the treatment of the improved technology package compared to other technology packages was influenced by the use of different types and doses of fertilizers and the higher plant population with spacing of 80 cm x 30 cm.

The leek plants height from the technology package was not significantly different, while the number of leaves leeks from the treatment of the farmer technology package was not significantly different with the treatment of the improved technology package or the agreed technology package. The weight of leek from the technology package treatment was not significantly different from the farmer’s technology package, namely 0.84 t ha⁻¹ (increased 5%) from the improved technology, 0.74 t ha⁻¹ (decreased 7.5%) from the agreed technology and 0.80 t ha⁻¹ form the farmer’s technology.

Setaria Sp. grass found only in the treatment of the improved technology package was planted around the bund. Within 4 months period (potato planting season) the grass reaches 35.67 cm high and produces a total yield of 117 kg ha⁻¹ pruned grass that can be used for animal feed. In addition to stabilizing soil
aggregates, planting grass around the bunds can also reduce erosion and is a potential source of animal feed.

The treatment of the improved technology package as a whole produces 14.17 t ha⁻¹ of potatoes, 0.84 t ha⁻¹ leeks and 117 kg ha⁻¹ of pruning grass weight, so that it will have an effect on increasing farm income (table 5). Beside increasing the yield of potato tuber and lees leaves planting potatoes along the slopes by turn ridge contour applying ½ the recommended fertilization dose also reduces erosion and increases the income of potato farming [7].

Table 5. Analysis of conservation farming in potato cultivation by applying technology packages on sloping upland, DS¹st 2016, Tosari-Pasuruan.

| No. | Activity                  | x (Rp.000) |
|-----|---------------------------|------------|
|     |                           | Improved technology package | Agreed technology package | Farmer’s technology package |
|     |                           | Physic Value (Rp ha⁻¹) | Physic Value (Rp ha⁻¹) | Physic Value (Rp ha⁻¹) |
| A.  | Labor (WDP)               |             |             |             |             |
| 1.  | Tillage                   | 60 2,100    | 60 2,100    | 50 1,750   |             |
| 2.  | Planting                  | 65 2,275    | 65 2,275    | 60 2,100   |             |
| 3.  | Fertilization:            |             |             |             |             |
|     | - Basic                   | 15 525      | 15 525      | 12 420     |             |
|     | - Continuation            | 20 700      | 20 700      | 12 420     |             |
| 4.  | Spraying                  | 35 980      | 35 980      | 30 840     |             |
| 5.  | Irrigation                | 160 4,000   | 160 4,000   | 140 3,500  |             |
| 6.  | Weeder & pile             | 30 1,050    | 30 1,050    | 25 875     |             |
| 7.  | Harvest                   | 72 2,520    | 72 2,520    | 67 2,345   |             |
| 8.  | Transport                 | 20 700      | 20 700      | 16 560     |             |
| B.  | Prod. Facilities          |             |             |             |             |
| 1.  | Seeds (kg ha⁻¹):          |             |             |             |             |
|     | - Potato                  | 1,200 19,200| 1,150 18,400| 1,150 18,400|
|     | - Leek                    | 236 1,800   | 236 1,800   | 236 1,800  |             |
| 2.  | Fertilizer (kg ha⁻¹):     |             |             |             |             |
|     | - Urea                    | 150 270     | - 650 1,170 |
|     | - ZA                      | 200 320     | 100 600     | 960        |
|     | - SP-36                   | 100 200     | 50 100      | -          |
|     | - KCl                     | 50 325      | - -         |
|     | - Ponska                  | - 450       | 1,035       | -          |
|     | - Organic fertilizer *)    | 7,500 3,750 | 5,000 2,500 | 6,000 2,400|
| 3.  | Pesticide (l ha⁻¹)        | 38 4,566    | 38 4,566.5  | 28 3,341.5 |
| C.  | Prod. cost (Rp ha⁻¹)      | 45,281.5    | - 43,411.5  | - 40,881.5 |
| D.  | Yield (kg ha⁻¹):          |             |             |             |             |
|     | - Tuber of potato         | 14,170 63,765| 13,330 59,985| 9,450 42,525|
|     | - Leek                    | 840 4,620   | 740 4,070   | 800 4,400  |
|     | - Grass of Setaria        | 117 -        | - -         |
| E.  | Total income (Rp ha⁻¹)    | - 68,385    | - 64,055    | - 46,925   |
| F.  | Profit (Rp ha⁻¹)          | - 23,103.5  | - 20,643.5  | - 6,043.5  |
| G.  | R/C ratio                 | - 1.51      | - 1.48      | - 1.15     |

Information:

*) Improved and agreed technology packages: organic fertilizer from chicken manure mixed with Trichocompost.
Price of consumption potatoes: Rp. 4,500 kg⁻¹
Price of leek: Rp. 5,500 kg⁻¹.
The improved technology package through the application of soil conservation techniques by planting potatoes in beds in the same direction of the slope alternating contour ridges with fertilization and spacing as recommended, shows the highest yield of potato tubers and leek leaves, namely 14,170 kg ha\(^{-1}\) and 840 kg ha\(^{-1}\) respectively and also results in pruning grass 117 kg ha\(^{-1}\) to obtain a profit of Rp. 23,103,500 and an R/C ratio of 1.51. It is then followed by an agreed technology package by applying the same soil conservation techniques as the improved technology package, except for planting distance and fertilization. The agreed technology package yields 13,330 kg ha\(^{-1}\) and 740 kg ha\(^{-1}\) leek leaves with benefits Rp. 20,643,500 and an R/C ratio of 1.48. The lowest yield of potato tubers of 9,450 kg/ha and leek leaves 800 kg/ha\(^{-1}\) was found in the farmer model with the benefit of Rp. 6,043,500 and R/C ratio of 1.15. According to preliminary research on the wet season, soil conservation techniques by planting potatoes in beds in the same direction of the slope alternating contour ridges can reduce the rate of erosion to 26.98 t ha\(^{-1}\) (decreased 34.31%), thereby reducing the loss of chemical fertilizers carried by erosion, compared to planting potatoes along the slope (farmer’s technology) which produces 41.07 t ha\(^{-1}\) soil erosion [7].

4. Conclusions
The improved technology package by planting potatoes in beds in the direction by turn ridges contour accompanied by fertilization and spacing according to the recommendation obtained an increase in potato tubers by 49.94%, followed by an agreed technology package with tuber weight increasing 41.05% compared to the farmer’s technology package with potato tubers 9.45 t ha\(^{-1}\). In addition to increasing potato tubers, the improved technology package produced leek weight 0.84 t ha\(^{-1}\) and Setaria grass pruning 117 kg ha\(^{-1}\) for animal feed.

The improved technology package by applying soil conservation techniques, seedlings, fertilization and spacing as recommended, resulted in high yields of potato and leek tubers with a profit of Rp. 23,103,500 and R/C ratio of 1.15, in addition to reducing the rate of erosion to 26.98 t ha\(^{-1}\) (down 34.31%), compared to planting potatoes along the slope (farmer’s technology), which was erosion 41.07 t ha\(^{-1}\).

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