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Effect of Soil Conservation in Slash-And-Burn Agriculture on Surface Flow, Erosion and Maize Production (*Zea mays L.*) in Belu Regency (Case Study of Tulakadi Village)

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Abstract— *Slash and burn, a local wisdom tradition of dry land in East Nusa Tenggara, relies on fire for land preparation. The purpose is to open the land and planting seeds. Generally, maize is a predominant crop in* East Nusa Tenggara*. Slash and burn affects the rate of runoff, erosion and crop productivity. The research objective was to determine the effect of soil conservation on agricultural land with slash and burn on surface runoff, erosion, growth and production of maize (Zea mays L). The study was conducted in Tulakadi village, East Tasifeto sub-Regency, Belu Regency,* East Nusa Tenggara*, in 2019. The study used a factorial randomized block design, the first factor was rorak and kebekolo, the second factor was the spread of mulch (Imperata cylindrica). There were nine treatments and three replications. Measurement of surface runoff and erosion done using a small plots system (9,5 m x 5 m) with a sedimentation drum and maize plants were planted on each plot. The results of the research showed that rorak application with 120 kg mulch suppressed surface runoff ranging from 38.12 to 42.29%, erosion ranged from 66.73 to 78.35%, weight of seeds in one cobs was 182.333 g, the weight of seeds 6 cobs from sample plant was 0.876 kg, the total yield of a plot was 4,310 ton/ha. This indicated that rorak treatment with 120 kg mulch effectively suppressed surface runoff, erosion and good maize yield.*

Keywords— *Slash and burn, conservation, surface flow, erosion, mulch.*

I. INTRODUCTION

Dryland is a form of non-rice field farming or land in dry areas that depend on rainwater as a source of water (Minardi, 2009). Limited water and fluctuating rain patterns cause farming cannot be carried out throughout the year in East Nusa Tenggara.

Dariah et al., (2014) reported that erosion management on dryland such as East Nusa Tenggara has often been neglected due to the assumption of low total annual rainfall that will not cause erosion at a dangerous level. However, Wang et al., (2015) stated that soil erosion is influenced by rainfall, runoff speed and soil vulnerability to erosion. The report is supported by a previous study about erosion and water balance estimation in Belu regency East Nusa Tenggara using USLE. The result showed that erosion in the region is 97,383 tons/ ha/year. Soil texture in the region is clay loam to sandy clay with fine clay aggregate. The area has steep and long slopes with low vegetated areas and it frequently tramps by cattle. These effects on the soil surface that susceptible eroded (Widiyono, 2008).

Belu Regency dominates with ranging land slope from 0–15% to <45% and only 2.84% categories as steep land slope. Dryland covers 68.04% of the area and only 5.95% of the area that is used as paddy field area (128,494 ha). Dryland farming is prioritized for secondary crops such as maize (Statistics of Belu Regency, 2016). Subagio and Aqil (2013) stated that there are many limitations in developing maize varieties such as water availability, local varieties (78%), and less intensive cultivation technology that cause maize productivity in East Nusa Tenggara low. Statistics of Belu Regency (2016) recorded that from 2015-2016, maize harvested area in 2015 was 10,887 ha and 2016 increased to 14,853 ha. However, in 2015, it decreased to 2.81 ton/ha, while in 2016, it was only 2.67 ton/ha.

Land preparation for farming in dryland depends on climate conditions and traditional local wisdom such as slash and burn to open the land and sow the seeds (Suek and Randu, 2010). Kapa et al., (2017) stated that this habit causes an impact on forest destruction and leads to critical land, increases runoff, increases susceptibility to erosion, floods, landslides, and soil nutrients depletion. Also, it destroys soil structure and reduces biodiversity. Nama *et al.*, (2016) reported that critical land in East Nusa Tenggara is approximately 2,109,496 ha (44.55%) of the total land area (47,349.9 km^2) in 2004, with forest areas of 661,680 ha and non-forest areas of 1,447,816 ha. The rate of degradation reaches 15,613 ha/year. Dryland is very potential for the development of maize production. Generally, farmers cultivate maize without applying soil conservation techniques, so soil erosion is difficult to control and affects maize production (Nurdin, 2012).

Management efforts to overcome biophysical limiting factors of dryland are required, especially for conserving soil and water. Erosion control techniques in open land can be carried out by mechanical approaches, such as making gutters or holes in certain places to reduce runoff and mulching for water conservation (Sarief, 1988). Mulching is an effective method for plant growth that increases yield and product

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quality by controlling weeds, reducing soil temperature, maintaining soil moisture, reducing soil erosion, improving soil structure and increasing soil organic matter content (Awopegba et al., 2017).

This study analyzed soil conservations such as *rorak*, *kebekolo* and spread of mulch (*Imperata cylindrica*) that can effectively reduce surface runoff, erosion and increase maize (*Zea mays* L) yield on slash and burn agricultural system.

II. Materials and Methods

This study was conducted on dry land with slash-and-burn agricultural system in Tulakadi Village, East Tasifeto Sub-Regency, Belu Regency, East Nusa Tenggara, in 2019. Land slope is 15% and the study area was 1,372.5 m^2. The study area is close to 2 climate observation stations. soil conservations that were applied for erosion management in this study consist of *rorak* (hole for water canal), *kebekolo* (row of logs or twigs arranged or stacked cutting slopes), organic mulch (*Imperata cylindrica*) and control (without treatment). The study used a factorial randomized block design, the first factor was *rorak* and *kebekolo*, the second factor was the spread of mulch (*Imperata cylindrica*). There were nine treatments and three replications. Surface runoff and erosion were measured using small plots (9.5 m x 5 m) with a sediment drum and maize was planted on each plot with planting space of 75 cm x 5 cm. Six samples of maize were taken in each plot to determine maize yield.

In *rorak* plot, each plot had 5 rows of *rorak* (length = 1 m, width = 30 cm, and depth = 40 cm) with a zigzag position, each row had 2 to 3 *rorak*. The distance between *rorak* in the rows was 1 m and the distance between the rows was 1.5 m. In *kebekolo* plot, each plot had 5 piles of wood (length = 5 m and height = 25 cm), the wood was arranged horizontally across the slope. Mulch application (*Imperata cylindrica*) was applied above the soil surface (60 kg, 120 kg, and control/without mulch). Data analysis was performed by Analysis of Variance (ANOVA) and followed by Duncan test p = 0.05).

The observed parameter was daily rainfall (per 24 hours). Calculation of the average rainfall using the algebraic method (Utaya, 2013), Equation (1):

$$P = 1 / n (P1 + P2 + \dots .Pn) \quad (1)$$

Where: P = average rainfall; P1,2,3, ... n = rainfall at the station; n = Number of stations

Surface runoff and erosion were measured by collecting the water in the drum after rain event (1 liter) then filtered to separate the sediment and water (Triwanto, 2012), Equation (2):

$$Volume = h \times s \times l \quad (2)$$

Where: h = water level in the drum; s = length of the drum; l = width of the drum.

The volume of water collected was calculated based on Equation (3)

$$V = \pi x r^2 x t \quad (3)$$

Where: V = volume of water ; π = 22/7, r = the drum radius; t = the drum height

If there is no stored water, the water volume was calculated using the unit area (ha). The amount of surface runoff was calculated from the amount of remaining water then filtered and multiplied by the volume of stored water in the drum (liters). Erosion was determined based on the filtered sediment (oven at 105 ºC for 24 hours), multiplied by the volume of stored water in the drum (kg). Maize yield parameters consisted of dry shelled weight per corncob, dry shelled weight per 6 samples, and dry shelled weight per plot.

III. Results and Discussion

Study Site

The study site is located in a former farmer's field cultivated in the previous year's planting season, which always relies on seasonal crops and slash-and-burn. The study site located in the highlands (> 500 m above sea level) and the land slope is ≥15% (Statistic of Belu Regency, 2018). The soil texture is clay loam to sandy clay with low organic matter, so the soil structure is easy to breakdown and prone to landslides (Widiyono, 2008).

The average rainfall in the study site is 0-580 mm per year, with December and January having the highest average number of rainy days (Statistic of Belu Regency, 2018).

Rainfall

Rainfall observations were carried out during January-March by placing two rainfall measuring stations (Table 1). The highest average rainfall was in February (235.89 mm), while the lowest was in January (168.18 mm, see Table 1).

TABLE 1. Rainfall in the study site (mm)

Description	Month		
	January	February	March
Rainfall month (mm)	168.18	235.89	181.32
Average rainfall/day (mm)	12.94	13.88	16.48
SD	5.07	5.16	4.32
Max	21.69	23.25	21.34
Min	5.03	5.89	11.57

Source: Processed data (2020)

The highest number of rainy days was in February (17 rainy days), January (13 rainy days) and March (11 rainy days, see Figure 1). This result showed that Tulakadi village has dryland agriculture with a dry climate. Anny and Mamat (2019) stated that dry land with a dry climate is a land with rainfall <2000 mm/year.

Effect of Mechanical Soil Conservation on Surface runoff and erosion

Rain with high intensity will cause surface runoff. Efforts to overcome surface runoff can be made through proper conservation methods.

The results showed that mechanical soil conservation methods such as *rorak*, *kokobelo* and mulch spread had a significant effect on surface runoff and erosion (P <0,05) and there was a positive interaction (Table 2).

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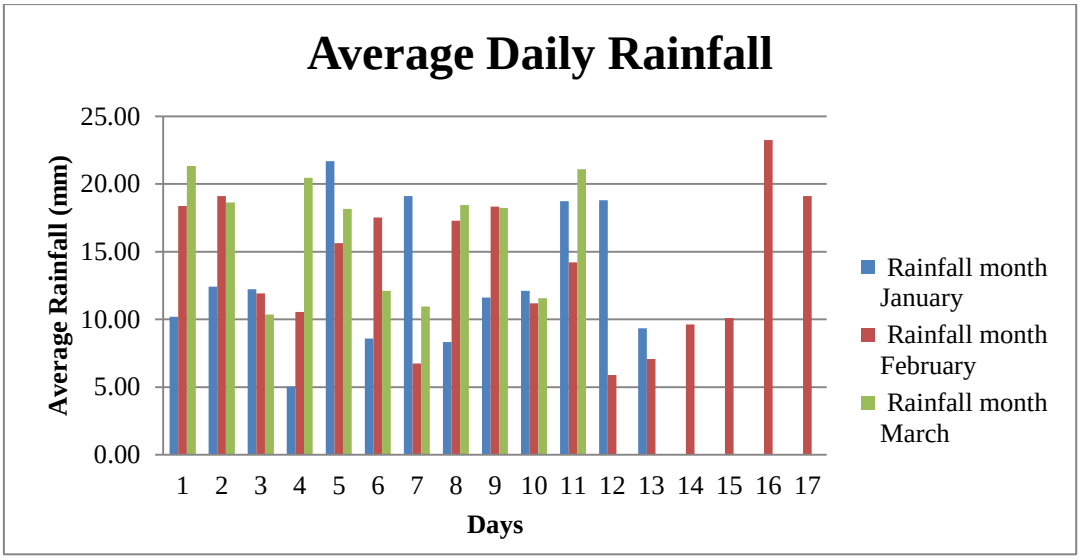

Fig. 1. Number of days and average rainfall (mm)

TABLE 2. Effect of Treatment on Average Surface runoff (m^3/ha)

Treatment combination	January			February			March		
	Rainfall	Surface runoff		Rainfall	Surface runoff		rainfall	Surface runoff	
KT_0KM_0	168.18	72.305	a	235.89	96.369	a	181.32	89.699	a
KT_0KM_1	168.18	59.617	bc	235.89	86.827	bc	181.32	78.619	b
KT_0KM_2	168.18	55.768	bc	235.89	81.380	cd	181.32	67.167	de
KT_1KM_0	168.18	43.164	de	235.89	74.962	ef	181.32	71.875	cd
KT_1KM_1	168.18	42.389	e	235.89	63.635	g	181.32	61.333	e
KT_1KM_2	168.18	41.728	e	235.89	59.631	g	181.32	53.977	f
KT_2KM_0	168.18	63.776	b	235.89	88.445	b	181.32	74.282	bc
KT_2KM_1	168.18	54.746	c	235.89	79.337	de	181.32	66.357	de
KT_2KM_2	168.18	51.444	cd	235.89	70.315	f	181.32	63.998	e

Note: The numbers followed by the same letter in the column are not significantly different at the BNT test level (α 5%)

Surface runoff fluctuates depending on the rainfall. In January, rainfall was 168.18 mm, resulting in surface runoff ranged from 41.728–72,305 m^3/ha. However, in February, rainfall was greater (235.89 mm) than in January, which increased surface runoff to 59.631–96,369 m3/ha. Meanwhile, in March, the rainfall was smaller than in February (181.32 mm) that reduced surface runoff to 53.977–89.699 m^3/ha. Thus, it can be concluded that an increase in rainfall will increase surface runoff.

Surface runoff was significantly low in KT1KM2 treatment (*rorak* and mulch 120 kg), namely 41,728 m^3/ha, 59,631 m^3/ha and 53,977 m^3/ha (P <0.05). This indicates that *rorak* and mulch 120 kg can suppress surface runoff and erosion ranging from 38.12 to 42.29%. Idjudin and Marwanto, (2008) stated that soil and water conservation techniques in dryland could prevent soil erosion, increase land productivity, improve critical land, prevent soil damage due to erosion, sustain the soil and ecosystem balance.

The results showed that the greater the rainfall, the greater the sediment level in the surface runoff. Rainfall in January was 168.18 mm and the erosion level ranged from 0.439–2.028 ton/ha. In February, rainfall was 235.89 mm (greater than January), the erosion ranged from 0.793-2.384 ton/ha. For March, the rainfall was 181.32 mm (lower than February), erosion that occurred ranged from 0.577-1.945 ton/ha (Table 3).

The results showed that erosion level was low in KT1KM2 treatment (*rorak* and 120 kg mulch), namely 0.439 ton/ha, 0.793 ton/ha and 0.577 ton/ha (P <0.05). This result indicates that the mechanical soil conservation treatment can reduce erosion rates ranging from 66.73 to 78.35%. Mulching with *Imperata cylindrica* can inhibit runoff and water infiltration. Endang (2013) stated mulching with *Imperata cylindrica* positively affects maize's growth and yield. Besides, mulch use in dryland agriculture is a water conservation and erosion control (Awopegba et al., 2017). This result follows Satriawan and Fuady (2014) who stated that the vegetative method is a method that uses plants and plant debris to (1) protect the soil against the destructive power of raindrops, (2) protect the soil against the destructive power of water flow above the soil surface, (3) reducing surface runoff velocity and (4) improving infiltration capacity and holding water which affects the amount of surface runoff and erosion.

Effect of Mechanical Soil Conservation on Corn Yield

Maize production

The results showed that KT1KM2 treatment (*rorak* and mulch 120 kg) had higher yields (P <0.05) in all parameters observed (Table 4), namely dry shelled corn weight per corncob (g), dry weight of 6 corncobs of sample plants (kg) and dry weight per plot (tons/ha). This result is because of *rorak* and 120 kg mulch application cause organic matter

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carried in the surface runoff trapped in the *rorak* and infiltrated to the soil to supply nutrients for plants. The weight of the plant biomass can characterize the increase in plant growth due to land arrangement and maintenance. This result follows Maulana (2011) who reported that *Imperata cylindrica* mulch can control weeds in maize on dry land. It can also increase water availability, plant height, the number of leaves, the dry weight of cobs with husks, the dry weight of corncobs without husks, and shelled weight of corn. Mulyono (2015) stated that *Imperata cyindrica* is resistant to decomposition. *Imperata cylindrica* as mulch on plants can positively affect increasing plant fresh weight, plant dry weight, and suppressing weed growth.

TABLE 3. Effect of Treatment on Average Erosion Rate (ton/ha)

Treatmen Combination	January			February			March		
	Rainfall	Erosion Rate		Rainfall	Erosion Rate		Rainfall	Erosion Rate	
KT_0KM_0	168.18	2.028	a	235.89	2.384	a	181.32	1.945	a
KT_0KM_1	168.18	1.516	b	235.89	1.812	b	181.32	1.514	b
KT_0KM_2	168.18	1.101	c	235.89	1.413	e	181.32	1.022	de
KT_1KM_0	168.18	0.921	cd	235.89	1.389	e	181.32	1.081	d
KT_1KM_1	168.18	0.762	d	235.89	1.121	f	181.32	0.874	f
KT_1KM_2	168.18	0.439	e	235.89	0.793	g	181.32	0.577	g
KT_2KM_0	168.18	1.488	b	235.89	1.646	cd	181.32	1.229	c
KT_2KM_1	168.18	1.175	c	235.89	1.478	e	181.32	0.917	ef
KT_2KM_2	168.18	0.702	de	235.89	1.062	f	181.32	0.689	g

Note: The numbers with the same notation in the same column are not significantly different in the BNT test (α 5%)

TABLE 4. Average Maize Yield

Treatment Combination	Shelled dry weight of maize					
	Seeds ear (g)		6 cobs of plant sample (kg)		In plots (ton/ha)	
KT_0KM_0	40.000	g	0.339	e	1.671	g
KT_0KM_1	42.667	fg	0.366	e	2.192	e
KT_0KM_2	44.333	f	0.354	e	1.934	f
KT_1KM_0	165.333	c	0.768	b	3.930	b
KT_1KM_1	177.667	b	0.867	a	4.066	b
KT_1KM_2	182.333	a	0.876	a	4.310	a
KT_2KM_0	92.333	e	0.501	d	2.993	d
KT_2KM_1	94.667	de	0.650	c	3.525	c
KT_2KM_2	96.667	d	0.521	d	3.052	d

Note: The numbers with the same notation in the same column are not significantly different in the BNT test (α 5%

IV. CONCLUSION

Soil conservation treatment, *rorak* with the spread of mulch 120 kg, was the best soil conservation method in this study. The treatment can suppress surface runoff rates ranging from 38.12 to 42.29% and erosion ranging from 66.73 to 78.35%. Maize yield in the treatment was 182.333 g one shelled corn corncob, 0.876 kg of 6 shelled corn corncobs (sample plant), 4.310 ton/ha yield per plot. It is recommended that farmers apply conservation with *rorak* and mulch to reduce runoff, erosion and increase yields of maize in slash-and-burn land.

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