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A Litterbag Study: Decomposition Rate and C/N Ratio of Annual Crop Biomass Residues on An Ultisols in Natar Village, South Lampung, Indonesia

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ABSTRACT

To evaluate the decomposition rate and the C/N ratio of biomass residues from several crops that are the main food sources in Indonesia, a litterbag study was conducted from February to November 2016 on ultisols in Natar Village, South Lampung, Indonesia. There were four types of crops biomass residues used i.e., maize stovers, rice straws, shoots and leaves of cassava, and soybean stovers in the form of fresh or compost. A fifty gram dry weight of biomass was put into a litterbag, placed above the ground and at a depth of about 10-20 cm, and incubated for nine months. The remaining biomass (dry weight), the content of Organic-C, Total-N, and C/N levels of the remaining biomass in the litterbag were observed every month until nine months. The dry weight of biomass was obtained by an oven dried at 70°C for approximately 48 hours until reached the constant weight. The decomposition rates were measured as (k) = ln (X/Xo)/t. Results showed that the decomposition rate of the biomass residues of the four crops were different. The shoots and leaves of cassava biomass were most rapidly decomposed (k =-0.2830) and significantly different from others, followed by maize stover (k=-0.2066), rice straw (k = -0.1924), and soybean stover (k = -0.1675).

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Biomass of fresh or compost form and litterbag placement generally affected the decomposition rate of biomass residues.

Keywords: Biomass, carbon, crop residues, decomposition, nitrogen

INTRODUCTION

Agricultural land in Indonesia is dominated by Ultisols, which is characterized by the soil reaction (pH) is acidic, high clay content (>70 %) but low soil organic matter (SOM) (Yulnafatmawita & Adrinal, 2014). This condition brings the soil into low aggregate stability, slow infiltration and permeability rate. Therefore, the use of this soil type for agricultural land should be balanced with conservation efforts such as addition of organic matter or return of plant residues.

Crops such as rice, corn, soybeans, and cassava are seasonal crops which are widely planted as the main food source in Indonesia. The potential of biomass residues of these food crops reach 10 million tonnes per year which are usually used as animal feed or burned in piles after threshing. The potential of biomass per hectare for rice straw was up to 10 t ha^{-1}, maize and maize-soybeans inter-crops were 7,64 and 7,40 t ha^{-1} respectively (Almaz et al., 2017).

The biomass of plant wastes are easy to obtain and often abundant around farmland especially at harvest time. The plant waste/residues including the remaining biomass after the grains and other economic components are harvested. The biomass residues include the above-ground components of plant residues i.e., stems, leaves, cobs and seed shell.

Crops stover (e.g. corn stover) which is removed for producing bio fuel or animal feed gives great impact to agronomic productivity, soil and environmental quality (Blanco-Canqui & Lal, 2009; Lal, 2008; Wilhelm et al., 2007). But, there are limited information about the decomposed process of that crops residues.

Some harvesting residues are usually burned, but according to Rumpel (2008), that after 30 years, stubble burning as a regular agricultural practice did not change carbon storage or soil organic matter. Hence, return of crop residues into agricultural soils largely relates to soil biochemical and sustains organic carbon content (Chaudhary et al., 2014) and increases soil microbial biomass (Partey et al., 2014).

Utilization of plant residues as carbon (C) and nitrogen (N) reserves ready to use for soil depends on the level of decomposition and synchronization of nutrient mineralization (Murungu et al., 2011). The nitrogen availability from these residues depends on the amount of N mineralized or immobilized during decomposition. Mineralizable N is also an important indicator of the capacity of the soil to supply N for crops, in which organic materials with lower C/N ratio, N mineralization will be faster (Abera et al., 2012).

Returning plant biomass residues to the land will cause decomposition process at different rates. Decomposition was a key ecosystem process that plays major roles in determining carbon and nutrient accumulation in soils, as well as in regulating the rate and timing of nutrient release to plant roots and soil organisms. Decomposition of organic matter is a biological process that occurs naturally and determines the amount of nutrient release (cycles) (Sariyildiz, 2008; Sayer, 2006) and the C stock in the soil (Olson et al., 2014; Singh & Gupta, 1977).

C-organic content is one of the indicators of soil fertility that affects other soil properties to support plant growth, i.e. as a source of energy and the triggers of nutrient availability for plants (Bot & Benites, 2005). Furthermore, Organic-C soil plays an important role as source and nutrient sink and as a substrate for soil microorganisms (Tornquist et al., 2009), so that the balance in soil, environment and biodiversity is maintained and sustained. Moreover, soil organic matter content affected the population and activity of soil microorganisms. There is a positive correlation between soil organic-C and soil microbial biomass carbon (Dermiyati et al., 2017).

Variations in the litter decomposition rates are mainly caused by the differences associated by litter quality, micro climates, soil properties and microbial community composition (Gholz et al., 2000; Karberg et al., 2008). Litter quality refers to characteristics of the litter (chemistry and physical attributes) that influence the susceptibility of litter to decomposition. The rates of weathering and mineralization are largely determined by the quality of the substrates in biomass, the content of nitrogen, lignin, polyphenol and the accessibility of the organic material (Brovkin et al., 2012; Silva et al., 2008). Organic materials with high lignin content and low N concentrations (high C/N ratio) have generally low decomposition rates (Johnson et al., 2007; Zhang et al., 2008). The rate of N mineralization of some legum crops tested is positively correlated with the C and N ratios, phenol and lignin levels, and their ratios with P (Cattanio et al., 2008).

Beside the litter type, environment (above or below ground environment) and site, significantly affect the decay rates of organic material (Powers et al., 2009). Environmental factors include climate and air temperature (Bothwell et al., 2014), soil temperature and soil moisture (Prescott, 2010; Zhang et al., 2008), that affect microbial activity and soil respiration (Xiao et al., 2014).

The most common and simple method to determine level of decomposition rate of residues (organic material) is a litterbag technique (Karberg et al., 2008; Kriaučiuniene et al., 2012), which allows the experimental decomposition studies under field conditions, and it can determine the rate of litter decomposition and the releases of nutrients.

Therefore, this research aimed to investigate the decomposition rate and the levels of C and N in biomass remaining after incubation of biomass residues of some crops (rice, maize, cassava, and soybeans) which were widely planted as important food crops in Indonesia.

MATERIALS AND METHODS

This research was conducted from February to November 2016 (during nine months incubation) in Natar Village, South Lampung, Indonesia (5°19'17", 105°10'28", 128 m). The soil type was Ultisol with chemical properties as follows : pH 5.17; Organic-C 1.32 %; Total-N 0.11 %; P_2O_5 (Bray-1) 12,59 $mg.kg^{-1}$; Potassium (K), Calcium (Ca), Magnesium (Mg), and *exchangeable* Al (cmol kg^{-1}) were 0.16, 3.23, 2.85, and 0.68, respectively.

The litterbag method was used to observe the decomposition process as natural as possible and to estimate the rate of biomass decay and its mineralization. Four types of crops biomass residue i.e. maize stover, rice straw, shoots and leaves of cassava, and soybean stover were used in the form of fresh and compost. During the decomposition process, the biomass in the litterbag was placed at two different depths which were above ground and at a depth of 10 - 20 cm. As much as 50 grams dry weight of residual biomass put into the litterbag (a nylon mesh bag with a mesh hole of about 2 mm, with the length x width of 25 cm x 20 cm), then incubated during 9 months. All treatments were repeated three times and were arranged in Randomized Complete Block Design (RCBD),. The total of litterbag incubated were 432 (4 x 2 x 2 x 3 x 9).

The litterbag started to be placed in the middle of February 2016 and the first pick up in mid March 2016, thus, every month observations were carried out on 1) The dry weight of remaining biomass, and 2) analyses the Organic-C, and Total-N of the remaining biomass. The dry weight of the biomass was obtained by oven drying at 70°C for approximately 48 hours until constant weight. The biomass weighing and analysis of Organic-C (wet digestion in $K_2Cr_2O_7$), and Total-N content (Kjeldahl method) were conducted at Laboratory of Lampung Assessment Institute of Agricultural Technology.

Decomposition Rate Calculation

The decomposition of biomass residues was monitored by the simple exponential decay model developed by (Karberg et al., 2008; Rezende et al., 1999; Silva et al., 2008), based on field and laboratory evidence of decomposition rates:

$$k = \ln (X/Xo)/t$$

$$Xo \rightarrow Xt$$

$$-d[X]/dt = k[X]$$

$$d[X_t]/[X_o] = -kdt$$

$$\int d[X_t]/[X_o] = -k\int dt$$

$$Ln\ [X_t] = -kt + Ln\ [X_o]$$

where: X= quantity of dry matter biomass after a period of time t; Xo= quantity of initial dry matter biomass; k= decomposition constant; and t = time in days. The decomposition constant (k) is generally used to compare the rate of decomposition among plant species or between different environments.

Statistic Analysis

Linear regression analysis was conducted with equation Ln [X_t] = -kt + Ln [X_o], to get the value of k (as a decomposition rate), followed by analysis of variance and Duncan post hoc test ($P \leq 0.01$, SAS 9,2) to indicate a significant variation within the k values of treatments. Correlation coefficients (r) between remaining biomass residues with some chemical properties and rainfall was conducted using the software SPSS Statistics version 20.0.

RESULTS AND DISCUSSION

Chemical Quality Characteristics of Biomass Residues

The content of C, N, and P of pre-incubated plant biomass was different for the four types of crops biomass residue and treatments (fresh/compost) (Table 1). The highest carbon content was found in fresh of stem soybean biomass and the lowest in shoot and leaves biomass of cassava. On the contrary for N content, the highest was found in shoot and cassava leaves in both fresh or compost biomass.

Composting reduces the level of C/N plant biomass about 20 - 30 %, the lowest C/N was in compost of biomass shoot and leaves of cassava (15.72).

Carbon and Nitrogen ratio is commonly used as a guideline for predicting the relative decomposability of organic material. The highest C/N ratio for fresh biomass is found in soybean residues, but in compost biomass, the highes was in maize biomass and the lowest being in shoot and cassava leaves biomass. Several reports showed different on the result of chemical content analysis of crops residues, this is due to differences in plant parts being analyzed. The ratio C and N of shoot of *Glycine max* was 12.7 and *Zea mays* was 49.2 (Abbasi et al., 2015). The C/N of leaves and stem of soybean and corn were 27.78, 107.34 and 30.59, 78.16, respectively (Johnson et al., 2007). Further reported that the C/N of soybean biomass residue was 47.7 - 60 (Varela et al., 2014).

Reduction of Biomass Residues During Incubation and Decomposition Rate

The biomass remaining decreased at each observation period (month) with different rates of decrease in each biomass type and treatments (fresh/compost or depth

Table 1
Initial chemical composition of biomass residues of four crops

Biomass Residue	C (%)	N (%)	C/N	P_2O_5 (%)
Maize stover-fresh	52.79	1.24	42.54	0.45
Maize stover-compost	37.18	1.09	34.01	0.44
Rice straw-fresh	48.42	1.11	43.77	0.34
Rice straw-compost	31.15	1.06	29.28	0.30
Shoot and leaves of cassava-fresh	37,78	1.94	19.44	0.54
Shoot and leaves of cassava-compost	28.46	1.81	15.72	0.52
Soybean stover-fresh	55.31	1.22	45.33	0.30
Soybean stover-compost	37.58	1.21	30.97	0.32

of incubation). In the early weeks of decomposition, the weight loss of biomass was very rapid (Figure 1). The fourth month decomposition, almost half the biomass in litterbag had been decomposed, especially for shoot and leaves of cassava which were achieved more quickly (third months). After nine months of incubation, the biomass remaining of litterbag due to decomposition was 20% (soybean biomass), 16.47% (rice straw), 12.69% (maize biomass), and 5.85% (shoot and leaves cassava). For the same external environmental conditions, the large differences in decomposition rates of the individual plant species was dependent on the initial characteristics of the biomass.

Biomass remaining of shoot and leaves cassava was lowest associated to the highest of N and P content and lowest C/N, in this case, shoot and leaves cassava contains N and P relatively higher and lowest C/N than others (Table 1). The same result had been reported by Lynch et al. (2016) that after 112 days of incubation, less than 12% of the original mass of maize residue and and only 5% of initial sorghum-sudangrass mass remained stable. It could be further explained that the difference in mass loss rate between the two residues was likely due to the lower initial C:N ratio in sorghum-sudangrass compared to maize residue. Several studies reported that after 3 to 4 months, had been decomposed half of the amount of biomass that was returned (Cattanio, et al., 2008; Lan et al., 2012). Based on these results, it is necessary to return crops biomass residues in every planting season.

Based on the regression of *natural logarithm* dry weight remaining biomass residues with time of incubation (months), the decomposition rate was obtained (slope = k) (Figure 1). Decomposition rate of biomass residues of four crops were different from one and another. Shoot and leaves of cassava biomass was the most rapidly decomposed (k = -0.2830), the next were maize stover (k = -0.2066), rice straw (average k = -0.1924), and soybean stover (k = -0.1675) respectively (Table 2).

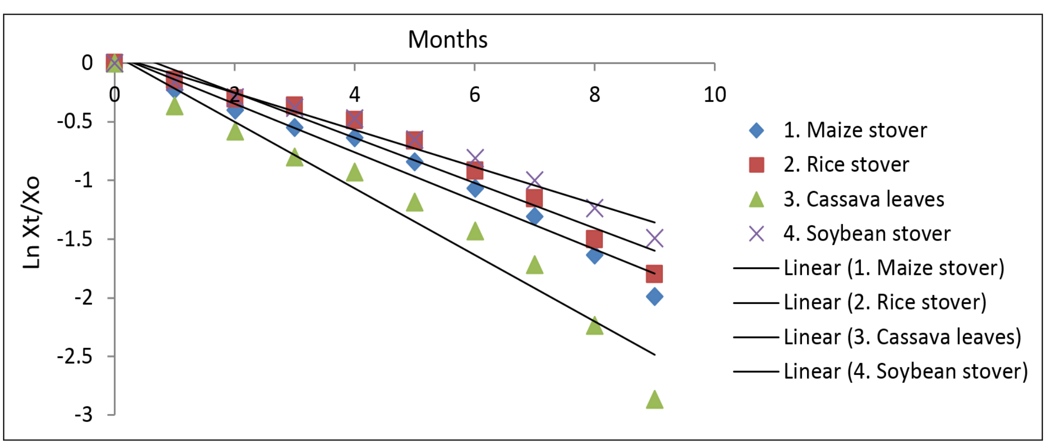


Figure 1. Regresion of *natural logarithm* dry weight of remaining biomass residues of four annual crops during nine months

Shoot and leaves of cassava biomass used in this study consisted of more leaves (about 75%) than stem and highest content of N and P, so it decomposed faster than others. After three month incubation, more than 50% shoot and leaves of cassava biomass had been decomposed (less than 50% biomass weight remaining). Whereas, soybean biomass residual used in this study consisted of more stems than leaves so that ratio of C and N was highest especially in fresh biomass. Stems showed a lower decomposition rate than the leaves of the same species, this was due to the higher C/N ratio (Lan et al., 2012). Rate of decomposition was higest for shoot and leaves of cassava biomass due to the high quality of this organic material, which had a relatively high N and P content, and had lowest C/N ratio.

The similar results had also been reported by Johnson et al. (2007) that decomposition of crop residues was strongly influenced by residues material quality that varied among species and organs within species.

Table 2
Regression equations and decomposition rate (k) of biomass residues of four annual crops

Crops Residues	Regression equations	R^2	k
Maize stover	y=-0.2066x + 0.0637	0.9713	-0.2066
Rice straw	y=-0.1924x + 0.1305	0.9535	-0.1924
Shoot and leaves of cassava	y=-0.283x + 0.0627	0.9554	-0.2830
Soybean stover	y=-0.1675x + 0.0594	0.9758	-0.1675

Decomposition rate of soybean stover biomass was lowest, related to the dominant part of the plant biomass used in this study which was the stem and only a few leaves. This was due to differences in the initial chemical composition of the crop residues, the most important is indicated by the C:N (Zhang et al., 2008). Organic matter decomposition rates are influenced by the quality of residues depending on the plant species. The initial quality of organic matter of cassava shoot and leaves biomass was better than others, indicated by higher initial N and P content. Lignin and N contents (C/N) of the plant residues play an important role in their decomposition, related to microbial cell synthesis requiring nitrogen. However, lower availability of nitrogen temporarily reduces soil microbial activity, and certainly affects the decomposition of plant residues.

The litter quality is the most important direct regulator of litter decomposition at the global scale. The data synthesis revealed that there was significant relationship between litter decomposition rates and the combination of climatic factor and litter quality (Zhang et al., 2008). Further, reported that plant residue decomposition under specific conditions of temperature and moisture was a function of a plant chemical and biochemical quality (Nourbakhsh, 2006). Decomposition rate was affected by both litter quality and stream. However, the relative importance of litter quality decreased through time, explaining 97% of the variation in the first week but only 45% by week 8 (LeRoy & Marks, 2006).

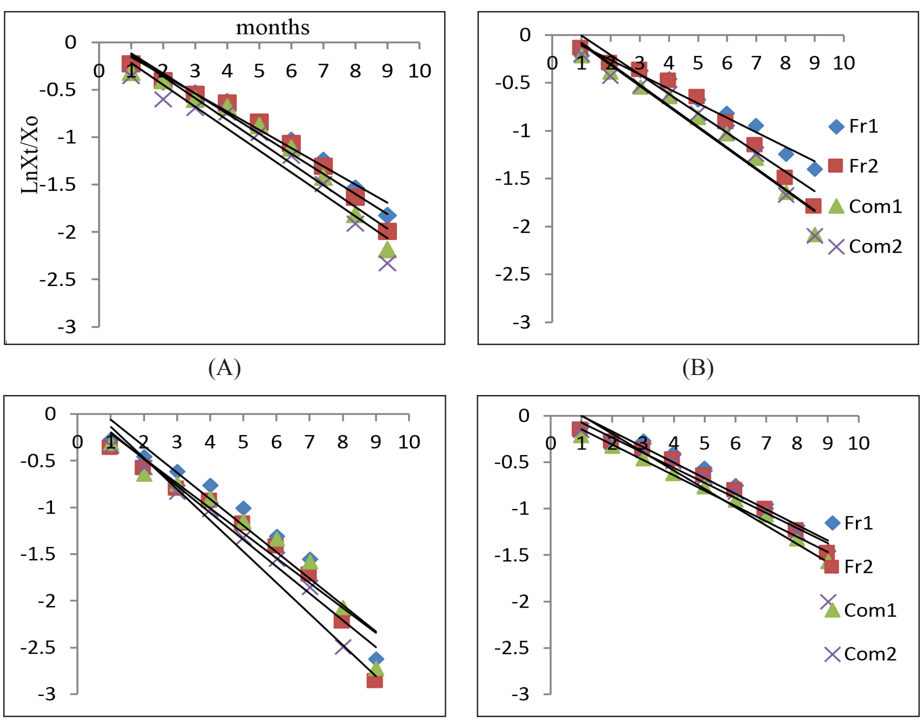
Effect of Type Plant Biomass, Fresh/Compost and Litterbag Placement

Based on analysis of variance, the main effect (four type plant biomass residues, biomass form (fresh/compost), and depth of application) on decomposition rate (k) were significantly different (Table 3). Further, the analysis of these three factors interaction (Biomass*Fresh/Compost*Depth) was also significantly different.

Table 3
*Analysis of variance of decomposition rate values (k) of treatments (significantly *P < 0.05, **P < 0.01,n=3)*

Source	DF	F Value	Pr > F
Replication	2	4.09	0.0268
Biomass	3	186.35	<.0001
Fresh/Comp	1	57.75	<.0001
Depth	1	41.83	<.0001
Biomass* Fresh/Comp	3	1.82	0.1641
Biomass*Depth	3	2.69	0.0641
Fresh/Comp *Depth	1	1.86	0.1827
Biomass*Fresh/Comp *Depth	3	5.44	0.0041

Based on Figure 2, compost biomass was decomposed faster than fresh biomass, and biomass placement above or below



(C) (D)

Figure 2. Regression of Ln Xt/Xo and time (months) of biomass residues of four crops (A = maize stover; B = Rice straw; C = Cassava leaves; D = Soybean stover), the treatments : fresh and above ground placed (Fr1), fresh and 10-20 cm depth (Fr2), compost and above ground placed (Com1), compost and 10-20 cm depth (Com2)

ground (10 – 20 cm) overall affected decomposition rate. Decomposition rate of fresh biomass of maize stover placed at a depth of 10 - 20 cm was significantly faster than above ground (Table 4), as well as of fresh biomass of rice straw and compost of soybean stover placed at a depth of 10 - 20 cm decomposed significantly faster than above ground. Compared to all treatments, shoot and leaves of cassava compost was the fastest decomposed biomass when placed at 10 – 20 cm depth (k = -0.3336). Litter type, decomposition environment, and site significantly affect decay rates (Powers et al., 2009).

Table 4
Decomposition rate (k) and correlation (r) of fresh and compost biomass residues of four annual crops during nine months incubation

Biomass Residue	Regression Equations	r	k
Maize stover			
Fresh, above ground	y=-0.1925x + 0.0403	-0.996**	-0.1925 c*
Fresh, 10 – 20 cm depth	y=-0.2119x + 0.0982	-0.996**	-0.2119 b
Compost, above ground	y=-0.2296x + 0.1021	-0.998**	-0.2296 b
Compost, 10 – 20 cm depth	y=-0.2312x + 0.0147	-0.992**	-0.2312 b
Rice Straw			
Fresh, above ground	y=-0.1507x + 0.0394	-0.996**	-0.1507 d
Fresh, 10 – 20 cm depth	y=-0.2033x + 0.1989	-0.997**	-0.2033 bc
Compost, above ground	y=-0.2184x + 0.1257	-0.997**	-0.2184 b
Compost, 10 – 20 cm depth	y=-0.2187x + 0.1385	-0.994**	-0.2187 b
Shoot and leaves of cassava			
Fresh, above ground	y=-0.2728x + 0.2197	-0.995**	-0.2728 a
Fresh, 10 – 20 cm depth	y=-0.2879x + 0.094	-0.991**	-0.2879 a
Compost, above ground	y=-0.2865x + 0.0558	-0.984**	-0.2865 a
Compost, 10 – 20 cm depth	y=-0.3336x + 0.195	-0.983**	-0.3336 a
Soybean stover			
Fresh, above ground	y1=-0.1678x + 0.167	-0.996**	-0.1678 d
Fresh, 10 – 20 cm depth	y=-0.1625x + 0.0908	-0.999**	-0.1625 d
Compost, above ground	y=-0.1656x + 0.0209	-0.997**	-0.1656 d
Compost, 10 – 20 cm depth	y=-0.1982x + 0.2046	-0.996**	-0.1982 c

*Mean values followed by same letter do not significantly different ($P \leq 0.01$), mean of three replicates

Theoretically, greater contact with the microbial community in buried residues was responsible for higher rates of decay in comparison to surface-placed residue. Further, it was reported that generally carbon losses through microbial respiration were significantly higher when litters were incubated with soils, than without soils, probably due to differences in biotic and abiotic factors (Silveira et al., 2011). Surface or buried-placed affect C and N mineralization, higher moisture content and retention is often associated with increased rates of decomposition in buried than surface-placed residues in laboratory incubation and litterbag field studies (Lynch et al., 2016).

Carbon Decomposition, Nitrogen Remaining and C/N

Carbon/Nitrogen ratio is commonly used as a guideline for predicting the relative decomposability or N mineralization potential of organic materials added to soil (Reddy et al., 1979). The decomposition process of biomass lowers carbon content. In this study, total C in biomass remaining after nine months incubated at litterbag study (in averages) were 13.84% for maize stover, and 13.79%, 9.98%, 16.64% respectively for rice straw, shoot and leaves of cassava, and soybean stover biomass (Table 5). C and N in compost biomass was faster mineralized than fresh biomass, this associated to high C/N ratio (low N) of the fresh biomass resulting in immobilization of inorganic N in microorganism. It can be further reported that organic material decomposition was negatively related to soil C/N ratio (R^2=0.66; $P<0.001$, the relationship was determined by two monoculture maize plots that both had a relatively high C/N ratio and slow SOM decomposition (Cong et al., 2015).

Table 5
Total C in remaining biomass at litterbag observed in nine months decomposition of biomass residues of four annual crops

Treatments	C (%)								
	1	2	3	4	5	6	7	8	9
A. Maize stover									
Fresh,above ground	46.64	35.82	32.06	30.74	28.58	25.59	23.08	19.25	16.59
Fresh,10–20cm	44.74	35.90	30.88	28.74	26.94	23.75	20.77	17.74	15.52
Compost,above	35.60	29.88	27.09	25.30	21.53	18.39	16.34	14.63	12.25
Compost, 10 – 20 cm	34.29	31.50	26.21	24.88	20.79	15.08	13.86	12.09	10.75
B. Rice straw									
Fresh,above ground	42.73	35.43	29.82	27.54	24.20	21.93	19.39	17.99	16.84
Fresh,10–20cm	41.48	36.78	28.58	25.20	22.82	21.73	19.24	16.53	15.36
Compost,above	32.22	29.06	21.62	21.38	20.00	17.77	15.77	14.77	11.66
Compost, 10 – 20 cm	30.00	28.01	21.05	20.96	19.43	16.98	14.89	13.67	11.30
C. Cassava Shoot									
Fresh,above ground	33.15	30.89	23.83	20.58	17.80	15.79	13.61	12.08	10.25
Fresh,10–20cm	31.65	30.06	22.09	20.14	17.42	15.34	12.97	12.16	10.53
Compost,above	28.00	26.41	18.61	17.77	16.03	15.36	13.04	11.38	9.74
Compost, 10 – 20 cm	27.34	25.88	18.58	16.96	15.29	1529	12.57	10.71	9.43
D. Soybean stover									
Fresh,above ground	46.49	41.50	33.82	31.20	28.53	25.37	23.04	20.12	19.17
Fresh,10–20cm	44.17	42.12	33.20	30.19	26.56	24.21	22.45	19.78	18.73
Compost,above	37.31	35.27	28.82	26.32	22.08	20.03	17.77	15.90	13.65
Compost, 10 – 20 cm	37.88	34.45	26.74	24.66	20.21	18.58	16.81	14.38	12.61

The decomposition of crop residues is the result of complex microbial processes controlled by numerous factors. Based on multiple regression analysis, combination of C:N ratio and lignin concentration in crop residues explains decomposition rates of 73% for the controlled variation (Kriaučiuniene et al., 2012). This indicates that this parameter could be used to predict decomposition rates. Decomposition rate is correlated with the amount of microorganism, there was a significant positive effect of internal N concentration on litter decomposition, mainly because the N requirement of the decomposers.

Carbon losses through microbial respiration were significantly higher when litters were incubated with soils, probably due to differences in biotic and abiotic factors (Silveira et al., 2011). A linear relationship between net N mineralization and CO_2 evolution was reported by Gilmour et al. (1985) for sewage sludge and four plant materials having a high total N content. A highly correlated linear relationship existed between N mineralization and CO_2 evolution during the study for digested biomass sludges but not for the fresh plant biomass.

During the decomposition carbon was used as an energy source by decomposers while nitrogen was assimilated into cell proteins and other compounds. Thus, with increasing decomposition time, the levels of C would decrease and nutrient released from the plant residues (especially N). The N mineralization pattern of the residues closely reflected the differences in their chemical composition (Chaudhary et al., 2014).

C/N of rice straw fresh placed at 10 – 20 cm depth decrease from 37.71% to 18.89% after nine months, as well as other biomass residues (Table 6). Decrease in C/N and a higher nitrogen content in the original biomass material promoted decomposition faster. A combination of N, C:N ratio and lignin concentration in crop residues explained decomposition rates of more than 70%, and the rest of it depending on the other factors such as plant type, part and environment (Kriaučiuniene et al., 2012).

This result agrees with some studies that litter with high N contents (low C/N ratios) decomposed significantly faster than litter with low N contents (Kara et al., 2014; Tripathi et al., 2006). Further, a study of leaf

Table 6
C/N in remaining biomass at litterbag observed in nine months decomposition of biomass residues of four annual crops

Treatments	**C/N (%)**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
A. Maize stover									
Fresh,above ground	37.61	34.01	32.51	31.39	29.98	28.76	26.32	22.13	19.14
Fresh,10–20cm	36.70	33.50	31.76	28.18	28.47	26.99	23.88	20.47	18.11
Compost,above	31.62	28.63	26.91	26.84	24.37	21.79	19.60	17.83	15.01
Compost, 10 – 20 cm	29.34	27.74	25.72	25.33	22.93	18.54	17.25	15.50	13.90

Table 6 *(continue)*

Treatments	C/N (%)								
	1	2	3	4	5	6	7	8	9
B. Rice straw									
Fresh,above ground	41.49	35.91	31.39	30.05	28.14	25.90	24.34	22.76	21.50
Fresh,10–20cm	37.71	35.72	30.61	29.17	27.28	25.99	23.37	20.09	18.89
Compost,above	30.69	27.67	25.81	25.34	24.09	21.67	19.87	18.45	14.82
Compost, 10 – 20 cm	27.78	26.26	24.47	23.60	23.22	20.53	18.61	17.09	14.37
C. Cassava Shoot									
Fresh,above ground	17.54	17.45	17.04	16.73	14.72	13.57	11.97	10.92	9.02
Fresh,10–20cm	17.08	17.08	16.57	15.91	14.28	13.08	11.21	10.93	9.21
Compost,above	16.05	15.85	15.05	14.95	13.55	13.03	11.24	9.95	8.45
Compost, 10 – 20 cm	15.71	14.90	15.33	14.62	13.30	13.30	11.00	9.54	8.33
D. Soybean stover									
Fresh,above ground	38.64	36.52	33.51	30.30	29.83	26.89	24.43	21.49	20.69
Fresh,10–20cm	37.23	35.61	32.66	30.50	28.25	25.48	23.63	20.90	19.78
Compost,above	30.11	28.06	27.88	27.93	24.17	22.09	19.60	17.61	15.05
Compost, 10 – 20 cm	29.08	27.10	27.93	25.86	21.67	20.49	18.68	16.28	14.23

litter reported that C/N ratio to be a better predictor of mass loss than the lignin/N ratio in a microcosm decomposition (Taylor et al., 1989).

Based on results of correlation test, remaining biomass (%)-significantly correlated with C, N, and C/N on the sixteen treatments (Table 7). The highest correlation was with the C/N. Average correlation coefficients (r) of remaining biomass (%) with C, N, and C/N were 0.948, 0.807, and 0.971 respectively.

To accelerate the decomposition of plant material whose high C/N ratio was composted first, as was often done. The same result was reported, that mixing maize

Table 7
Pearson correlation coeficients (r) between remaining biomass residues (%) and some chemical properties (C, N, and C/N) after nine months incubation (n = 3)

Treatments	C (%)	N (%)	C/N
Maize stover, fresh, above ground	0.96**	0.84**	0.97**
Maize stover, fresh, 10-20 cm depth	0.97**	0.88**	0.98**
Maize stover, compost, above ground	0.98**	0.90**	0.99**
Maize stover, compost, 10-20 cm depth	0.96**	0.92**	0.99**
Rice straw, fresh, above ground	0.91**	0.97**	0.96**
Rice straw, fresh, 10-20 cm depth	0.90**	0.76*	0.98**
Rice straw, compost, above ground	0.96**	0.73*	0.99**
Rice straw, compost, 10-20 cm depth	0.95**	0.76*	0.99**
Shoot and leaves of cassava, fresh, above ground	0.97**	0.80**	0.98**
Shoot and leaves of cassava, fresh, 10-20 cm depth	0.97**	0.83**	0.95**

Table 7 *(continue)*

Treatments	**C (%)**	**N (%)**	**C/N**
Shoot and leaves of cassava, compost, above ground	0.93**	0.67*	0.96**
Shoot and leaves of cassava, compost, 10-20 cm depth	0.97**	0.74*	0.95**
Soybean stover, fresh, above ground	0.92**	0.75*	0.98**
Soybean stover, fresh, 10-20 cm depth	0.94**	0.95**	0.99**
Soybean stover, compost, above ground	0.99**	0.76*	0.99**
Soybean stover, compost, 10-20 cm	0.92**	0.63*	0.99**
Avarage	**0.95**	**0.81**	**0.97**

residues with other plant residues whose C/N was lower (*V. Faba* or *T. Diversifolia*) could increase N mineralization and decrease C/N (Partey et al., 2014).

The Effect of Climate Factors on Decomposition Rate of Biomass Residues

Climate factors such as temperature and soil moisture (rainfall) affect litter decomposition. In this study, the first three months incubation, rainfall was high (> 300 mm every month) (Table 8), thus supporting the decomposition intensively.

Based on analyses of variance, rainfall significantly affects on biomass remaining (%) (p<0,05) and significant correlated (pearson correlation = 0.783) (Table 9). Rainfall affects soil moisture, according to a research report, monthly rainfall and soil moisture varied over sampling period but in similar patterns in both land uses observed

Table 8

Avarage remaining biomass (%) and rainfall (mm) during nine months incubation

	Month								
	1	2	3	4	5	6	7	8	9
Avarage remaining biomass (%)	78.82	66.35	58.86	52.67	43.00	35.21	28.05	19.86	13.75
Rainfall (mm)*)	330.8	305.7	332.7	195.7	185.1	118.5	107.9	54.4	103.2

*)Data was processed from the Meteorological Station at Branti village which is about 10 km from this research location

Table 9

Correlation coeficients (r) between avarage remaining biomass and rainfall after nine months incubation

Correlation			
		Rainfall	Remaining Biomass
Rainfall	Pearson Correlation	1	.783*
	Sig. (2-tailed)		.013
	N	9	9
Biomass (%)	Pearson Correlation	.783*	1
	Sig. (2-tailed)	.013	
	N	9	9

* Correlation is significant at the 0.05 level (2-tailed)

(Abera et al., 2012). Soil moisture was most important during the early decomposition stage rather than the late stages, but under field experimental conditions, however, it is difficult to detect the net effects of moisture on respiration or decomposition because all factors interact to affect the litter decomposition (Virzo De Santo et al., 1993).

Furthermore, litter decomposition increased with increasing temperature in the high moisture and decreased with increasing temperature in the low moisture (Butenschoen et al., 2011). The sensitivity of soil respiration and litter decomposition to soil temperature is influenced not only by soil water but also by various factors including soil nutrition and litter quality. Berrier et al. (2014) reported that both plant litter type and incubation site were important in determining decomposition rates and that when all litter types were considered, the mean decomposition rate for plant material placed in the wetland was significantly higher than for the upland site ($k_{wetland} = 0.42 \pm 0.02$, $k_{upland} = 0.29 \pm 0.02$).

CONCLUSION

Decomposition rate of residues biomass of the four crops was different from each other. After nine months of incubation, the biomass remaining and decomposition rate (k) of shoot and leaves cassava were the most rapidly decomposed (5.85%, k = -0.2830), followed by maize stover (12.69%, k=-0.2066), rice straw (16.47%, k = -0.1924), and soybean stover (20%, k = -0.1675), this due to initial characteristics (levels of C, N, and P) and C/N.

Decomposition of compost biomass was significantly faster than fresh biomass for maize stover and rice straw. Litterbag placement above or below ground (10 – 20 cm) overall affected decomposition rate. Fresh biomass of rice straw and shoot and leaves of cassava in litterbag placed at a depth of 10 - 20 cm decomposed significantly faster than above ground.

Remaining weight of biomass (%) most correlated with C/N compared to C or N content (%) after nine months incubation (the r value respectively 0.97; 0.95, and 0.81). Monthly rainfall has significant effect on decomposition rate (r = 0.783), where in the first months (with high rainfall each month) more intensive decomposition than in the following months.

This research will be continued with the application of the biomass residues in the field and will observe the microbial activity of the soil.

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