Innovation Of The Fallow System With The Legume Cover Crop A Season For Improved Physical Properties Of Soil Degradated On Dryland Farming

Rupa Matheus, Donatus Kantur, Naema Bora

Abstract: The productivity of dryland farming volatile and relatively low, it is because the productive agricultural land continues to degrade due to mis management. To that end, the need for innovation in soil fertility management easier and cheaper for dryland farmers in degraded lands. Such innovation is through the fallow system with legume cover crop a season. Innovation fallow system with legume cover crop a season is possible to do by dryland farmers because it has the potential to restore soil quality and land productivity in a short time through increased soil organic carbon stock. This study aimed to determine the effect of the innovation fallow system with legume cover crop a season to the improvement of soil properties and corn yields in degraded soils. Research in design Randomized Completely with 6 types of treatment, namely: (1) land left open (without LCC a season) or practice farmers; (2) fallow with Phaseolus lunatus (Pl); (3) fallow with Mucuna pruriens (Mp); (4) fallow with Calopogonium monocoides (Cm); (5) fallow with Crotolaria juncea (Cj) and (6) fallow with Cajanus cajan (Cc). The results showed that the innovation fallow system with LCC significantly capable of restoring the fertility of degraded physical soil, namely the use of LCC type Crotolaria juncea, Mucuna pruriens and Phaseolus lunatus as fallow crops, improving real C-organic content of 1.57% to 2.21-2.25% > of the type Cayanus cajan and Calopogonium monocoides and lower clay content from 72.47% to 70.2-70.37% clay, as well as improving total pore, Aeration pore and water available pore in the soil. Using LCC type Crotolaria juncea, Mucuna pruriens and Phaseolus lunatus markedly increase the average yield of corn karnels of 1.56 times > of the control treatment, which only reached 2.27 t ha^{-1} corn karnels.

Index Terms: Fallow systems, Legume cover crops a season, physical restoration of degraded land, maize yields.

1 INTRODUCTION

Historically, agricultural systems continue to evolve, when no human intervention in managing land resources to meet their needs. Consequently there is a change in the ecological farming system (Doran and Smith, 1991) and the process of land degradation in a sustainable manner. The process of land degradation in the system of farming dry land big enough, because in addition located in the dry areas with erosion rates are high, also due to lack of soil management such as utilization of seasonality, the system of crop rotation is low, and the management of crop residues that are not appropriate (discarded or burned). Continuing land degradation causes crop yields and decreased production of organic material, so that the input of organic matter derived from plant roots and stover are returned to the land is getting smaller. The low production of oragnik followed by loss of material oragnik due to tillage, transported harvest, removal of crop residues, and lost through erosion, causing greater the reduction in levels of soil organic carbon and resulted in a decrease in aggregate stability. Process of soil degradation almost kept up accompanied by a decline in the status of carbon organic soil. Agricultural land that has experienced an average degradation processes of soil organic carbon content of <2%, so the impact of the decline in soil productivity.

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The content of organic carbon in the soil become an important indicator and determinant of the quality of soil, because it will affect the model of land use, vegetation type and especially carbon storage (carbon sequestration). Organic carbon in the soil plays an important role especially in the improvement of soil physical properties as a granulator to improve soil aggregation (Stevenson, 1994). Therefore, a fundamental understanding of the dynamics of soil organic carbon is important to know especially in improving degraded soil quality and productivity projection capability and land use (Lal, 2006;). Whereby the use of organic materials with good quality and in sufficient quantity is the key to the maintenance and restoration of degraded lands. Various studies show that organic matter both as a fertilizer and soil conditioner, proven efectif improve soil quality and crop productivity when given in very high doses (Dariah et al., 2007, 2010, Matheus et al., 2017). For dryland farmers use fertilizers oganik who is ex-situ extremely difficult adequate for a variety of reasons. To that end, the need for innovation in soil fertility management easier and cheaper for dryland farmers in degraded lands. Such innovation is through fallow system with legume cover crop season. Innovation fallow system with legume cover crop a season is possible to do by dryland farmers, because it has the potential to restore soil quality and land productivity in a short time through an increase in the stock of soil organic carbon (Hairiah and Rahayu, 2007; Olson et al., 2010 and Matheus, 20014). Fallow pattern with legume cover crop a season, also did not sacrifice farmers' land, because fallow very short time, which is between 6-8 months (Figure 1), compared with natural fallow that require a relatively long time (5-7 years). Picks crop legume cover crop season as a form of innovation in the management of soil fertility naturally, because it has a rapid growth in biomass production is relatively high as a source of organic material, adaptable to the conditions of low soil fertility, plant is a supplier of nitrogen soil, effectively absorb carbon through photosynthetic activity, and has the quality of high biomass compared to the type of non-legumes (Rahman et al., 2006; Power, 1987; Steenwerth et al.,2008; Wang et al.,2010; Olson et al., 2010) and is in situ (Matheus et al., 2017). This study aimed to study the effect of the innovation system pemberaan land with legume cover crop season to the improvement of soil properties and yield of maize on Vertisol degraded.

2 MATERIALS AND METHODS

2.1. Site description

This study was conducted at experimental field of Agriculture Polytechnic in Kupang-East Nusa Tenggara-Indonesia for 12 months, from April 2017 to March 2018. This area was located at 9º19"-10º57" Lat. and 121º30"-124º11" Long, under subtropical climate with total rainfall 1.400 mm.yr^{-1} and mean annual temperature 27^{0}C. The land used in this experiment is degraded moorland due to continuous cultivation. In addition, the soils used in this experiment was Vertisols that has characteristics: clay soil (72.74% clay), C-organic 1.56% (low) pH 7.35 (neutral), N total 0.16% (low) and Ratio C:N is 9.75.

2.2. Research design

The method used in this study is the experimental method. The study was designed by Design Randomized Completely (DRC), treatment tested was the innovation fallow system with different types of legume cover crop a season, that is: (1) land left open (without LCC) or farmers practices; (2) fallow land with Phaseolus lunatus (Pl); (3) fallow land with Mucuna pruriens (Mp); (4) fallow land with Calopogonium monocoides (Cm); (5) fallow land with Crotolaria juncea (Cj) and (6) fallow land with Cajanus cajan (Cc). Six treatments in stacking randomly with three replicates for each treatment, in order to obtain 18 units or experimental plots. The future fallow land carried out for 8 months (April-November). Model application of innovation system adjusted to the pattern of fallow land farming dry land, such as in Figure 1. Further biomass legume cover crop annuals in each experimental plot is harvested, cut into pieces 3-5 cm long, back scattered evenly over the plot and buried in the ground along with tillage. Unless the control treatment, the biomass of plants (weeds) slashed and burned dry and continued after tillage (way farmers). Biomass incubated for 20 days recently planted with corn.

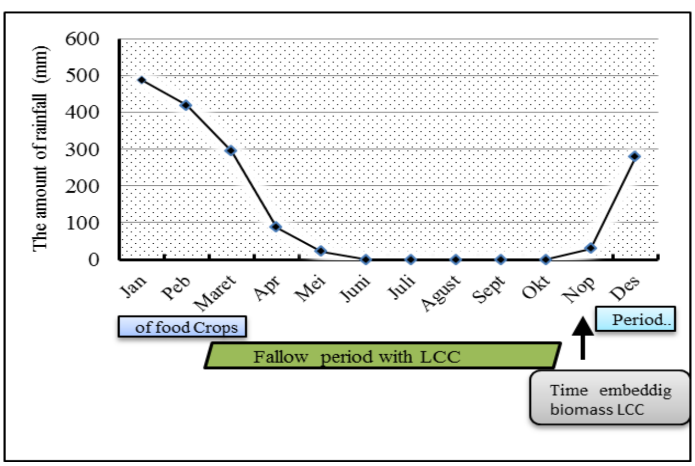

Figure 1. *Model Innovation fallow system with LCC a season to repair degraded soil properties.*

2.3. LCC Analysis biomass-specific characteristics, soil properties and yield of corn

(1) The characteristics of biomass LCC, were analyzed at the end of the fallow period. LCC biomass samples of water were dried and then oven dried at 70^{0}C for 48 hours. Chemical analysis was conducted for carbon (Walkley and Black method), nitrogen (Kjeldahl method), phosphorus, potassiun, calcium, and magnesium content using spectrophotometer after wet digestion with $HClO_4$ and HNO_3 (Sulaiman et al., 2005), and LCC biomass production is measured in dry weight (t ha$^{-1)}$, Lignin and polyphenol contents were analysed also with the method of ADF & Follin-Denis (Anderson & Ingram, 1989); (2) Soil properties, including: soil clay content (hidrometri method), conten of C-organic soil (Walkley and Black method); bulk densty (g cm$^{-3)}$ and soil prosity (% vol.) with gravimetric method; fast drainage pore and pore water available (pressure plate mehod); and (3) The result of dry corn (t ha$^{-1).}$ Observations of soil properties and plant corn at the end of the experiment.

2.4. Statistical analysis

The observed data were analyzed by using variance analysis (ANOVA) according to the model randomized block design Complete with 95% confidence interval. To see a real difference influence of variables due to the treatment performed Duncan's multiple range test at 5% significance level (Gomez and Gomez, 2007). To know the relationship between between the content of C-organic and physical properties of the soil with the yield of corn (dried seeds dry weight) done by correlation analysis. The data processing is done by the statistical program using COSTAT and MSTATC while graphs using Exel.

3 RESULTS AND DISCUSSIONS

3.1. Characteristics of biomass LCC a season

Analysis of the quality of the biomass of LCC shows the differences in the characteristics of biomass (chemical and biological composition) between genders LCC a season attempted (Table 1).

Table 1. *. Average chemical quality of the five types of LCC a season is attempted on dry land.*

Characteristics LCC	LCC type				
	Pl	Mp	Cm	Cj	Cc
a. N total (%)	3 , 77	3,27	2,89	4,70	3,66
b. P total (%)	0.36	0.57	0.31	0.35	0.25
c. C total (%)	36.73	34.30	33.67	36.28	35.65
d. C / N	9.74	10.48	11.65	9.37	12.91
e. K (%)	1.37	1.21	0.57	0.59	0.62
f. Ca (%)	2.03	1, 57	1.46	1.35	1.20
g. Mg (%)	0.42	0.44	0.22	0.17	0.11
h. Lignin (%)	13.49	11.52	10.64	9.64	11.14
i. Polyphenols (%)	4.01	5.87	7.87	3.46	5.26

Note: *Pl: Phaseolus lunatus; Mp: mucuna pruriens; Cm: Colopogonimum monocoides; Cj: Crotolaria juncea; Cc: chayanus cajan*

The overall chemical composition of six kinds of biomass LCC tested as fallow crops have a high quality that is reflected in the content of total N, P, C, C / N, K, Ca and Mg. Judging from the content of C and N, it turns out to six types of LCC had higher levels of C and N are different. Biomass Cj, Pl, and Mp proved to have the content of C and N highest compared with other types, consequently Ratio C: N lowest level, namely to Cj (9.37), for Pl (9.74) and Mp (10, 48). The low C/N in the biomass Cj, Pl and Mp resulted in rapid immobilization decompose and chances are very small. Table 1 shows that measured organic matter content of lignin, it appears that the six types of LCCs have lignin comprises average below the critical point of <15%. While polyphenols saw that kind Mp, Cm, Cc and Pl have a higher polyphenol level above a critical limit is >4%. According to Stevenson, (1994); Handayanto et al., (1997), the lignin and polyphenols in organic material can bind to proteins that determine whether or not the organic materials are easily broken down by soil microbes. Table 1 also provides an overview of biomass production (in dry weight) is different. LCC biomass quality or speed affect the rate of decomposition, Research Matheus et al., (2013), found biomass Crotolaria usaramoensis and Phaseolus lunatus in 10-20 days after the immersion, 50% have decomposed.

3.2. Production of LCC Biomass, C-Organic Content and Clay soil post-fallow

Use of LCC as fallow crops on degraded Vertisol provide a very real effect (p <0.01) on the production of biomass, the conten of C-organic soil and the soil clay content post fallow (Table 2).

Table 2. *Biomass production (in dry weight), C-organic and clay soil content after fallow with LCC a season*

LCC Type Treatment	Product Biomass (Dry weight)	Content of C-organic soil	Content clay
	..t ha^{-1}..	.... %	
Without LCC	2,65-d	1,57-d	72,74-a
P. lunatus	9.94-a	2,21-a	70,22-c
M. pruriens	10,87-a	2,23-a	70,28-c
C. monocoides	5,84-c	1,95-c	71,06-b
C. juncea	11,59-a	2,25-a	70,37-c
C. cajan	7,86-b	2,03-b	70,896-b

Note: *The numbers followed by the same letter in the same column are not significantly different at a distance test Duncan's multiple level of 5%*

Biomass production LCC (in dry weight) at the end of the highest fallow shown by Cj legumes, Mp and Pl, which respectively reached 11.59 t ha^{-1}; 10.87 t ha^{-1} and 9.94 t ha^{-1} or increased biomass production by an average of 3.07 times that of the control treatment (without LCC). Biomass production of the lowest LCC shown by Cc (7.86 t ha^{-1}) and Cm (5.84 t ha^{-1}) or just an increase in biomass production by 1.96 times and 1.20 times that of the control treatment (without LCC) Innovation fallow system with LCC was statistically significantly affected the content of C-organic soil at the end of the experiment. The highest content of C-organic demonstrated at treatment Cj, MP and Pl respectively 2.25%, 2.23%, and 2.21% and did not differ significantly. Through innovation, a fallow system with all three types of LCC (Cj, Mp, and Pl) increased the conten of C-organic soil an average of 3.26 times > of treatment control (1.56%). Unlike the LCC type Cc and Mc indicate the content of C-organic soil was smaller than other treatments, which is only an increase in organic C by 46.49% to 24.20% for the Cc and Cm from the control treatment. Similarly, the clay content, the innovation fallow system with LCC kind Cj, Mp and real Pl reduce levels of clay respectively clay 70.37%, 70.28% and 70.22% loamy clay of treatment control by 72, 74% clay). Increased content of the C-organic soil and decreased levels of clay Vertisol caused by a product of biomass LCC as a source of organic material quality is high, so that when it is returned into the ground easily decompose and increase the content of C-organic soil, which directly affects the composition of the clay fraction of land

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3.3 Soil Physical Properties

In general, fallow land inonasi by LCC have different effects on the physical properties of degraded land, which include: Bulk density, total pore space, pore fast drainage and pore water available (Table 3).

Table 3. *Influence of the type of LCC as crop-fallow to bulk density (BD), Total pore of the soil (TP), aeration pore (AP) and water available pore (WAP) at the end of the study.*

Treatment type LCC	Physical properties of soil			
	Bulk Density (BD)	Total pore (TP)	Aeration pore (AP)	Water available pore (WAP)
	..g cm^{-3}.	……………. % Vol……………….		
Without LCC	1.21-c	54.34-c	23,45-c	4,56-d
P. lunatus	1.06-a	58.21-ab	31,05-a	6,97-a
M. pruriens	1.05-a	60.25-a	30,91-a	6,98-a
C. monocoides	1.12-b	57.73-b	27,75-b	5,07-c
C. juncea	1.07-a	59.51-a	31,27-a	7,15-a
C. cajan	1.09-b	57.65-b	28,39-b	6,25-b

Note: *The numbers followed by the same letter in the same column is no different real on Duncan's multiple range test level of 5%.*

Table 3 shows that the vacated land with LCC good kind Cj, Mp, and Pl, have physical soil properties are not significantly different (P <0.05), and significantly different from the treatment Cc, Mc, and control (without LCC). Statistically shown that fallow land with LCC kind Cj, Mp and the biomass Pl embedded in the soil as a source of organic material, significantly reduced bulk density (BD) of 12.39%, increasing the total pore (TP) of (9.17%), increasing the aeration pore (AP) and water available pore (WAP) respectively (52.525% vol. and 54.23% vol.) of the control treatment. Legume type Cc and Mc showed a contribution to the improvement of soil physical properties of the smaller of the three types of LCC (Table 3). BD decline in soil and increased TP, AP, and WAP, probably caused by the high biomass production and the role of plant roots and the soil surface is always covered by fitomasa crops during fallow periods so as to create conditions of soil moisture that can increase the activity of soil biota. Increased soil biota in helping the process of destruction of the material in the soil resulting organic increase organic C in the soil, resulting in improved soil aggregation. Increasing soil organic C content directly affect the soil in a holding ability (water Holding capacity). In a state of good soil structure or BD are low, opportunities for water stress becomes small since the range of soil water content that can be utilized by the plants become larger. This condition is very important in dryland farming often experience drought stress. Hairiah and Murdiyarso (2007) states that the role of organic C in the improvement of soil physical properties is to create soil aggregation thereby providing a nest on the ground conditions and can reduce soil BD. Furthermore, Stevenson (1994); West and Post (2002); Baldock et al., (2009) suggested that soil organic matter acts as a grain-forming soil and increase soil porosity. BD decline in soil affect the increase in TP, ie an increase of 8.21% vol. Vertisol mineral soil left exposed (control treatment) have drainage pore low at 23.45% vol. and pore water available is also low, amounting 4.06% vol. Through innovation fallow with LCC, showed an increase of AP (29.27% vol) and WAP (20.78% vol.), As compared with control treatment (without LCC). With a period of 8 months and ita biomass fellow immersed in conjunction with tillage, it statistically affects physical variables such land, it means the type of LCC potential as a source of organic material in building the physical soil fertility because of the production of biomass and biomass quality is quite high.

3.4. Corn Yield

Innovation fallow farmland with LCC, statistically give a different effect on the yield of corn (dry seed grain weight and plant dry weight (Table 4)

Table 4. *Effect of LCC post fallow biomass management on the yield of corn kernels of 15% moisture content and result of dry stover.*

LCC type	Yield of corn kernels	Result of dry stover
	.... t ha^{-1}	
Without LCC	2,27-c	3,94-c
P. lunatus	5,83-a	9,83-a
M. pruriens	5,67-a	9,95-a
C. monocoides	5,16-b	7,27-c
C. juncea	5,95-a	10,36-a
C. cajan	5,19-b	8,44-d

Note:*The numbers followed by the same letter in the same column are not significantly different at Duncan's multiple range test level of 5%*

Duncan test results (Table 4) indicates that the innovation fallow system LCC land with significantly increased maize yields both yield of corn kernels and result of dry stover. Yield of corn kernels and dry stover achieved the highest corn on the type Cj, PL, Mp, each of 5.95 t ha^{-1},5.83 t ha^{-1} and 5.67 t ha^{-1} > compared with other types Cc and Cm and control. The use of LCC Cj, MP and Pl significantly increased the average yield of corn karnels of 1.56 times and dry stover by 1.41 times > of the control treatment, which only reached 2.27 t ha^{-1} dry Pipila seed. Increased yield for corn post fallow innovation LCC kind used as fallow crops has biomass production and high quality to build C-organic soil resulting in the recovery of soil physical properties, as well as a source of green manure so that it can provide nutrients, especially N for corn. Increased corn yields are also associated with a synchronization level of nutrients in the release by the biomass during decomposition to the needs of the corn crop. If the time of provision of nutrients is not in accordance with the needs of the corn crop, there will be a shortage or excess of nutrients. By Matheus et al., (2017) LCC biomass as a source of green manure should be done embedding 10-20 days before planting in order happen nutrient synchronization between the availability of nutrients released by biomass green manure and nutrient absorption by the roots need cor. This time of implantation significantly increases the growth and yield of corn.

Table 5. *Correlation (r) between the content of the C-organic soil soil physical properties with the results of dried corn on a Vertisol degraded as a result of innovation fallow system with LCC.*

	Prod. Bio. LCC	C-Org.	Physical properties of Vertosols				
			Clay	BD	TP	AP	WAP
Yield of corn Kernels	0.88**	0.92 **	-0.95**	-0.87 **	0.85**	0.94 **	0.81 **

Note: *** (P <0.05)*
BD: bulk density; TP: Total pore of the soil; AP: Aeration pore; WAP: Water available pore

In Table 5 is shown that the results of correlation between the production of biomass, organic-C content of the soil and the soil physical properties as a whole show a correlation (r) were highly significant ($p \leq 0.01$) with results corn (dry seed grain weight). Table 5 illustrates the negative correlation between soil clay content and BD on corn yields. The negative correlation between clay content and soil on the yield of corn BD states that the decreased levels of clay and soil BD maize yields would increase significantly. In low clay and soil BD conditions, soil porosity increases, so that organic matter added to the soil will be stored between the soil pores better (Siringoringo, 2007). Other variables, namely the production of biomass, the content of C-organic, TP, AP, and WAP showed a positive correlation ($P \leq 0.01$) were significant with the yield of corn. Positive correlation results indicate that the higher biomass production LLC returned to the ground, after experiencing the decomposition will increase the content of organic C in the soil. Increasing soil C-organic content can help improve the soil granulation direct effect on the increase in TP, AP, and WAP there by affecting the growth and yield of corn.

4 CONCLUSION

1. Innovation fallow system land with LCC a season significantly able to recover physical fertility Vertisol degraded.
2. At Vertisol degraded, use Type LCC Crotolaria juncea (Cj), Mucuna pruriens (Mp) and Phaseolus lunatus (Pl) as crop-fallow and its biomass immersed in the soil before planting crops, tangible boost the content of C-organic soil from 1.57% to 2.21 -2.25%> of the type Cayanus cajan (Cc) and Colopogonium monocoides (Cm) and lower clay content from 72.47% to 70.2 -70.37% clay, and to improve the TP, AP, and WAP in the soil.
3. Maize (dry seed weight) negatively correlated with clay content (r = -0.95 **; P <0.01) and bulk densty (r = -0.87 **; <0.01), which means decreasing bulk density (BD), clay content, maize yields would increase significantly, while the other variables are correlated positively to the results of corn, with the value of r, respectively: the products of biomass (r = 0.88 **), C-organic conten (r = 0, 92 **), Total

pore of the soil (r = 0.85 **), Aeration pore (r = 0.94 **) and Water available pore (r = 0.81 **).

4. The use of LCC Crotolaria juncea (Cj), Mucuna pruriens (Mp) and Phaseolus lunatus (Pl) significantly increased the average yield of corn kernels of 1.56 times > of the control treatment, which only reached 2.27 t ha^{-1} corn karnels.

REFRENCES

[1] Anderson, J.M., Ingram, J.S.I. Tropical Soil Biology and Fertility: a Hanbook of Methods. Wallingford: CAB International., 1989.

[2] Badan Klimatologi dan Meteorologi Nusa Tenggara Timur. Data Curah hujan 10 tahun (2003-2012) di Kabupaten Kupang. Kupang, NTT., 2012.

[3] Baldock, J.A., Skjemstad, J.O., Kurl, E.S. Functions of Soil Organic Matter and the Effect on Soil Properties. CSIRO. Publishing. Melbourne., 2009.

[4] Doran, J.W and M.S. Smith. "Overview: Role of cover crops in nitrogen cycling". P.85-90 In: W.L.Hargove (Ed.) Proceedings of an International converence "Cover crops for clean water". Soil Conser. Soc. Amer. Ankeny, IA., 1991.

[5] Daria, A., Nurida N.L., dan Sutono. "Formulasi Bahan Pembenah untuk rehabilitasi lahan terdegradasi". Dalam proseding Seminar Nasional Sumberdaya lahan dan Lingkungan. Bogor. 7- 8 November, 2007.

[6] Dariah, A., Nurida, N.L., Sutono. "Formulasi bahan pembenah untuk rehabilitasi lahan terdegradasi". Jurnal Tanah dan Iklim. No 11, 2010.

[7] Hairiah, K., Murdiyarso, D. Alih Guna Lahan dan Neraca Karbon Teresterial. Word Agroforestry Centre-ICRAF. SE. Asia. Bogor-Indonesia. 88p, 2007.

[8] Hairiah K., Rahayu S. Pengukuran 'Carbon Tersimpan' di Berbagai Macam Penggunaan Lahan. Bogor. World Agroforestry Centre - ICRAF, SEA Regional Office, University of Brawijaya. Indonesia. 77p, 2007.

[9] Lal, R. "Enhancing crop yields in the devolopping countries through restoration of the soil organic carbon pool in agricultural lands". Land Degrad. Devolopping. 17: 197-209, 2006.

[10] Matheus, R., Suwardji, IGA.Mas Sri Agung, IM Oka Nurjaya. "Rates of Decomposition and Nutrient Release from Biomass of Various Species of Tropical Legume Cover Crops in Dryland Soils of Eastern Indonesia". Journal of Biology, Agriculture and Healthcare. Vol.3(16): 107-104, 2013. www.iiste.org.

[11] Matheus, R., L M. Moy, D. Kantur. "Utilization of corn stover and pruned Gliricidia sepium biochars as soil conditioner to improve carbon sequestration, soil nutrients and maize production at dry land farming in Timor, Indonesia". International Journal of Agronomy and Agricultural Research (IJAAR). Vol. 10 (4): 1-8, 2017. http://www.innspub.net

[12] Matheus, R., M K. Salli, D. Kantur, M.R.S. Moata. "Synchronization between available Nitrogen and Maize (Zea mays) Need: Studi on different application time and type green fertilizers". International Journal of Agriculture, Environment and Bioresearch (IJAEB). Vol. 2 (5): 260-271, 2017. http://www:ijaeb.org

[13] Matheus, R.; D. Kantur dan M. K. Salli. "Potensi Legum Penutup tanah semusim sebagai tanaman bera dalam meningkatkan Simpanan Karbon Organik Tanah pada Usahatani Lahan Kering Secara Berkelanjutan". Makalah Seminar Nasional Pembangunan Pertanian Lahan kering Untuk Mewujudkan Kedaulatan Pangan. Prosiding Seminar Nasional Pertanian ke-4: p8-17, 2017.

[14] Olson, K.R., Ebelhar, S., Lang, A., James, M. "Cover crop effects on crop yields and soil organic carbon content". Soil Science. 175:89-98, 2010.

[15] Siringoringo, H.H. "Potensi Simpanan Karbon pada Jenis Tanah Archisols dan Ferarsols di Hutan Tanaman Acasia magium Willg. Dan Shorea teprosula Mig. Kabupaten Bogor". Jurnal Penelitian dan Konservasi alam. Vol. IV (5): 511-530, 2007.

[16] Power, J.F. "Legumes: Their potential role in agricultural production". Am. J. of Alter. Agric. 2(2): 69-7, 1987.

[17] Rachman, A., Dahria, A., Santoso, J. Pupuk Hijau. p.41-58. Dalam: R.D.M. Simanungkalit, D.A. Suriadikarta, R. Saraswati, D. Setyorini dan W. Hartatik (eds.). Pupuk Organik dan Pupuk Hayati. Balai Besar Litbang Sumberdaya Lahan Pertanian. Badan Penelitian dan Pengembangan Petranian. Bogor. 2006.

[18] Steenwerth, K., Belina, R.J. 2008, "Cover crops enhance soil organic matter, carbon dynamics and microbiological function in a vineyard agroecosystem". Applied Soil Ecology. 40:359369. 2008: www.elsevier.com/locate/apsoil.

[19] Stevenson, F.J. Humus Chemistry, Genesis, Composition, Reaction. Second Ed. New York: John Wiley & Sons. Inc. 496p. 1994.

[20] Sulaeman, Suparto, Eviati. Petunjuk Teknis Analisisi Kimia Tanah, Tanaman, Air dan Pupuk. Balai Penelitian Tanah. Badan Penelitian dan Pengembangan Pertanian. Departemen Pertaian R.I. 136p. 2005.

[21] Olson, K.R., Ebelhar, S., Lang, A., James, M. "Cover crop effects on crop yields and soil organic carbon content". Soil Science. 175:89-98. 2010.

[22] Wang, Q., Li, Y., Alva, A. "Growing cover crops to improve biomass accumulation and carbon sequestration": A Phytotron Study. J. of Environmental Protection. 1(2): 73-84. 2010.

[23] West, T.O., Post, W.M. "Soil carbon sequestration by tillage anD crop rotation": a global data analysis. Soil Sci. Soc. Am. J. 66 (1): 930- 946, 2002.