ALTERNATIVE FALLOW MANAGEMENT THROUGH TREATMENT OF MULCH AND ENRICHMENT TECHNOLOGY ON SUSTAINABLE AGRICULTURAL SYSTEM IN SE SULAWESI

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Abstract

Huge secondary forests consisting of various species composition are still found in SU Sulawesi-a place situated in the eastern of Indonesia. Within the forests shifting cultivation characterized by low productivity is being practiced by more than 80% of the local farmers. The occurrences of secondary vegetation are predominantly caused by anthropogenic activities, resulted mostly from the slash-and-burn system which fallow as an integral part of the land-use productivity. Fallow plays an important role to accumulate biomass that may act as a source of organic mulch and restore nutrients into the plant tissues for the agricultural system. The objectives of this paper are to break the vicious circle as to reduce physical, chemical and biological degradation with the introduction of mulch technology and to shorten the fallow period with the introduction of fallow improvement. The potential use of biomass accumulation as organic mulch from secondary vegetation was described, as well as the screening of certain indigenous species which are capable of rapid accumulating biomass during fallow was studied, using ten 1x5 m square transects randomly set up in each fallow. The results of study show that eleven to 235 t ha-1 of biomass was accumulated in all fallow ages ranged from 2 to 15 years with and without enrichment. The high quantity of biomass provides sufficient amount of N, P, K, Ca and Mg nutrients to supply the demand of the following cultivated crop. The use of various indigenous species recorded in the study region such as Albizzia lebbeck Benth. (Fabaceae), Maranga hispida M.A. (Euphorbiaceae), Trichospermum sp. (Tiliaceae), Geunsia quaternifolius H. Hallier (Verbenaceae), Melochia umbellata L. (Sterculiaceae) and Chromolaena odorata L. (Asteraceae) is favorably a promising approach applied for enrichment fallow due to the rapid growth and high contribution to biomass accumulation. The proper application of organic mulch from secondary vegetation and the appropriate choice of indigenous plant species for fallow management, both increase crop productivity per unit area per unit time, are the most suitable alternatives for the management of fallow system in maintaining sustainable agricultural production of the study region.

Key words*: Enrichment fallow, indigenous species, Indonesia, slash-and-burn agriculture, sustainability.*

1. Introduction

Southeast Sulawesi, one of the five provinces in Sulawesi, covers the areas of 38.140 km^2. In this region, extensive secondary forests can still be found, but threatened due to the conversion to agricultural areas that predominantly by dry land agriculture. In 2001, SE Sulawesi was inhabited by about 1.7 millions dwellers (BPS, 2001) where about 80 % of the people are practicing shifting cultivation. The features of shifting cultivation is characterized by short cropping period (1-2 years) and long fallow period (7-10 years) as noted by Karimuna (2000). This conventional agriculture system can not so far be maintained because of low crop productivity and claimed as the major causes of resource degradation, even though many rural poor and indigenous people in developing countries depend very much on this agriculture system (Kleinmann, et al., 1996).

While growing population pressure, increasing demand for food and declining land availability have resulted in the expansion of short-fallow slash-and-burn agriculture that promotes soil erosin and results in depleting ecological productivity. The need to seek the most suitable alternatives to increase agricultural crop production has therefore become inevitable. During the past several decades, the search of viable alternatives to the conventional agricultural system has been the central focus of tropical agriculture. Many researches have attempted to replace it with modern system including continuous cropping with liming and chemical fertilization, and introduction of exotic crop species, but the outcome has not yet been satisfied.

Therefore, intensification through promoting the use of organic mulch derived from the secondary vegetation as revealed by Sanchez (1989); Karimuna (2001) and enrichment fallow using indigenous species prior to abandonment is considered the most appropriate approaches for the fallow management in maintaining sustainable agricultural production of the study region. The use of fallow vegetation organic matter as mulch could only be adopted if the land was managed by fire-free land preparation, as proposed by Kato (1998). Enriched fallow technology or controlled fallow, especially if N fixing legumes or grasses with accumulating high biomass (Brienza, 1999) are applied and may allow returning to cropping sooner. The main objectives of this paper are to break the vicious circle as to reduce physical, chemical and biological soil degradation with the introduction of mulch technology and to shorten the fallow period with the introduction of fallow improvement.

2 Materials and Methods

2.1 Location and Time

This research was carried out in Palangga and Tinanggea districts, SE Sulawesi. Geographically, Tinanggea and Palangga districts are located at $4^{o}00'$ – $4^{o}30'$ LS, while Tinanggea is at $122^{o}00'$ – $122^{o}15'$ E, Palangga is at $122^{o}15'$ – $122^{o}30'$ E. The distance between the two regions is about 15 km apart. A study of biomass quantities and potential use of indigenous species for enrichment fallow was undertaken in the different fallow vegetation ranged from 2 to 15-year old of ages at the altitude range from 180 to 220 masl, held from August 1997 to March 1998, and tested plant using different biomass as organic mulch was carried out in experimental garden of Faculty of Agriculture, Haluoleo University, held from April to September 2001. The soil types under cultivation are podzolic with generally low concentration of major elements, low pH and low soil organic content (Darwis, 1995), and soil erosion may occur on slight but long slopes.

2.2 Methods and analysis

Intensive quantitative survey was applied for the biomass collection and followed by appropriate vegetation analyses. Fourteen study sites were set up using 1 x 5 m^2 plots with ten replications of each age which were randomly placed in the selected sites of Amasara and Buke regions. The data collection of a similar fallow age of Amasara and Buke sites was then averaged, and for futher analysis, eight different age of fallows were considered. All plants growing within plot were recorded their Latin name and biomass of each species, then classified according to their growth form, such as trees, shrubs, vines, herbs, and grasses. The species of growth form of trees, shrubs and vines were separated into leaves and wood. Each fraction was weighed to determine the fresh weight biomass. A representative sub-sample was then taken by putting into paper bags and dried in an oven with a temperature of $80^{o}C$ for 48 hours. Thereafter the dried biomass was weighed to determine the dry biomass of each species.

The nutrient concentration was determined on the biomass collected to the six types of fallow while the nutrient stocks were calculated as the weighed average from the nutrient concentration of all selected species (leaf and wood) multiplied by the total biomass of each fraction. The determination of nutrient content of selected plant species for N, P, K, Ca and Mg, the standard methods in the Institute of Agronomy, University of Goettingen were used as illustrated by Juo, 1981. While the potential use of indigenous species for enrichment fallow was evaluated based on the dominant of plant species to accumulate biomass and high growth rate of species.

3 Results and Discussion

3.1. Biomass and nutrient stocks of fallow vegetation

The amount of biomass accumulated according to growth form fraction was differed significantly at the various fallow ages in Amasara and Buke (Table 1). The growth form of trees are predominant plant species considering the whole secondary vegetation of the study region. A distinct increase of biomass accumulation in the trees could be observed over time. Shrubs and grasses are the dominant biomass fractions in th early fallows but decrease considerably in the older fallows. Interesting to note is that the biomass production of vines in the late fallows is higher than that of shrubs, herbs and grasses, whilst the growth form of herbs remains constant. This finding is comparable to the study described by Nagy and Proctor (1997) on early secondary forest growth after shifting cultivation in the Ulu Barito area, Central Kalimantan; Uhl (1987), Riswan and Abdulhadi (1992).

Table 1. Total biomass accumulation of different fallow ages (t ha^{-1}) based on growth form recorded in SE Sulawesi.

Fallow age	Biomass (t ha^{-1})					Total
(yr)	Trees	Shrubs	Vines	Herbs	Grasses	(t ha^{-1})
2	1.1	7.5	0.4	0.5	1.2	10.7
3	9.4	9.4	0.7	0.6	1.5	21.6
4	20.4	10.8	1.3	0.7	0.4	34.2
5	31.4	6.9	0.8	1.5	0.7	41.3
6	61.5	4.9	1.4	0.4	0.3	68.5
8	102	2.0	3.0	0.4	0.3	108.0
10	132	1.5	6.9	1.3	0.2	141.9
15	209	5.8	19.7	0.6	0.3	235.0

Source: Karimuna, 2000 (after modification)

The high amount of biomass accumulated in different ages of fallow above could be functioned for the following cultivated crop if slash-and-mulch system is applied. This because most of nutrient contents restored into the vegetal matter are volatilized during burning in slash-and-burn system (Hoelscher, 1995). Therefore, all biomass of fallow vegetation are integrated and spreaded out as mulch in the soil and allowed microorganisms to decompose. The treatment of mulch plays a significant role on providing nutrient content into the soil and the estimated contribution of nutrient stocks derived from biomass of different ages of fallow was described by Karimuna (2000) as shown in Table 2. The results of study showed that each plant species behave differently in their ability to accumulate nutrients through biomass production. Biomass of fallow vegetation determines the amount of nutrient stock in a vegetation, whereas the nutrient concentration of each species depends upon the physiological and environmental factors where a species grows. Enormous amount of nutrient stocks are restored to the biomass of fallow vegetation, especially for N, P, K, Ca and Mg. The role of fallow biomass in nutrient storage have been discussed by SEUBERT et al. (1977), AWETO (1981), DENICH (1989) and BURGER (1991). In this study, the biomass accumulation in 4- and 6-yr-old fallows was 34 and 69 t ha^{-1}; respectively. This is similar to the study by DENICH (1989) reported that in 4-5-yr-old fallow vegetation the total biomass produced 28 t ha^{-1}. Considering the potential of plant biomass providing nutrients to the soil, it shows that annual crops such as maize, soybean, peanut, upland rice and other common crops can be sufficiently supplied with nutrients, particularly nitrogen for maize and upland rice after a fallow period of 4-6 years. That means that the farmers would not need to maintain a longer fallow up to 7 to 10 years to have a sufficient nutrient storage for the following crops if these nutrient stocks could be conserved.

Table 2. The total amount of nutrient stocks (kg ha^{-1}) in different fallow ages of secondary forests in SE Sulawesi region.

Fallow age (yr)	Nutrient stock (kg ha^{-1})				
	N	P	K	Ca	Mg
2	123	9.4	123	75.4	28.2
3	209	21.9	217	148	42.8
4	216	26	319	249	56.3
6	422	33.5	435	372	109
8	640	53.6	763	671	141
10	756	68.1	939	920	179

Source: Karimuna (2000).

3.2. Enrichment fallow vegetation

The management of fallow vegetation is increasing and the knowledge of understanding the role and function of fallow system is necessary to be studied. Maintaining fallow period up to 4 –6 years for the soil recovery has been a promising finding to improve the productivity of slash-and-burn system in the study region, but if one cropping season is cultivated 1 or 2 ha of land, then the completion of the cropping circle requires at least 4 to 12 ha of agriculture land. If we consider the trend of decreasing agricultural land belongs to each farmer of the region, this alternative has to be necessarily improved by the application of enrichment technology using indigenous legumes cover crops or trees which is capable of accumulation biomass and nitrogen-fixing plants. Some indigenous tree species have been proved to be efficient in accumulating biomass and rapid growth rate (Table 3). These plant species are recommended to use for enriched fallow plants species since they have a high adaptability to the local environment. In contrast to what is expected that *Chromolaena odorata* L. (Asteraceae), a shrub species, exceeds the amount of biomass production and the accumulation rate of tree biomass in 3-yr-old secondary forest.

Table 3. Potential indigenous tree and shrub species of 3-yr-old fallow including its biomass production used for enrichment fallow in SE Sulawesi

Tree species	Biomass (kg ha^{-1} yr^{-1})	Average height (cm)	Accum. rate (kg month^{-1})
Albizzia lebbeck Benth.	657	5.3	13.7
Chromolaena odorata L.	7200	3.9	200
Geunsia quaternifolius H Hallier	688	5.1	19.1
Macaranga hispida M.A.	1658	4.9	46.1
Melochia umbellata L.	1409	4.5	39.2
Trichospermum sp.	573	5.5	15.9

Source: Karimuna, 2000 (after modification)

Multi-integrated approaches through the combination of indigenous legumes tree species and planting cover crops may have a meaningful strategies to improve agriculture production of the region. Tian (1999) revealed that fallow period can be shortened the recovery of soil condition with planting cover crops. A comparison between continuous cropping, natural fallow and cover-crops-fallow on the yield of intercropping maize and cassava for 6 years experiments indicating a stagnant result was obtained, while in natural fallow and cover crop-fallow on the yield of selected crop increased (Table 4).

Continuous cropping without fallow and fertilizer application decreased maize production accounted to 80 percent, although the yield of maize for the first year is higher than that of natural fallow or consecutive cover crops-fallow. Moreover, the cassava yield is significantly increased in natural fallow and consecutive cover crops-fallow system, whereas the yield of cassava is rather stable in continuous cropping (Table 4). The effects of cover crops on soybean yield was studied by Hutchinson et al., 1986. The results showed that soybean yields were increased from 14.0 to 18.1 bushels acre^{-1} by a cover crop of *Vicia villosa*, but mostly were not affected by various rotations. Sorghum yields were lowest from continuous crop grown with a *Vicia villosa* cover crop. Karimuna (1991) demonstrated that organic matter from leguminous tree leaves as mulch had significant different on the growth and yield of maize and the yield might increase up to 28%.

Table 4. Yield of maize and cassava on intercropping pattern in continuous cropping, natural fallow and consecutive cover crops-fallow from 1996 to 1996.

	1991	1992	1993	1994	1995	1996
			Maize (t ha^{-1})			
Continuous cropping	2.33	1.21	1.61	1.10	0.63	0.32
Natural fallow	FY	2.12	FY	2.09	FY	1.44
Cover crop-fallow	FY	2,94	FY	2.56	FY	2.47
$LSD_{0.05}$		1.11		0.86		0.75
			Cassava (t ha^{-1})			
Continuous cropping	5.80	5.13	6.63	3.83	8.14	6.60
Natural fallow	FY	5.57	FY	8.83	FY	10.1
Cover crop-fallow	FY	3.89	FY	6.21	FY	14.2
$LSD_{0.05}$		3.30		5.40		6.4

Source: Tian (1999), Note: FY = Fallow period

The enriched fallow vegetation either using cover crop or leguminous trees followed by the treatment of fertilization and liming may prevent or eliminate the adverse effect of direct precipitation on the soil properties. Manipura (1972) revealed that mulch and Eragrostis curvula almost eliminated run-off and soil losses. Yogaratnan et al., 1984 found that legume covers such as *Pueraria phaseoloides*, *Colopogonium mucunoides*, *Desmodium ovalifolium*, *Centrosema pubenscens* and *Mimosa invisa* could be grown successfully in dry site and improved the growth in girth of rubber trees. The most representative finding of the enriched fallow role was studied by Mulongoy et al., 1985 that in the fields cropped for 6 seasons the lives mulches contributed up to 60 kg ha^{-1} to the maize and maize grain yields were 0.32-0.60, 1.20-1.84, 1.24-1.56 and 0.64-1.56 t ha^{-1} with no cover crop, *Centrosema pubenscens*, *Psophocarpus palustris* and *Arachis repens*; respectively. Therefore, the suitable management of fallow vegetation through fire-free land technique in term of slash-and-burn system using mulch and the application of enriched fallow using leguminous cover crops or trees and indigenous plant species is reasonable and turn into a promising approach in agricultural development of the study region in future.

4. Conclusion

Sufficient amount of biomass accumulation from secondary vegetation as a source of nutrient stock in the small-holder farmers could be taken into account in maintaining stable land-use system. Alternatives of fallow management through the utilization of organic matter as mulch and enriched fallow vegetation may improve physical, chemical and biological properties of the soil that can be guaranteed the high agricultural productivity. It is recommended that the proper use of organic mulch derived from secondary vegetation and the appropriate choice of cover crops or trees and indigenous plant species for fallow management, both increase crop productivity per unit area per unit time, are the most suitable alternatives for the management of fallow system in maintaining sustainable agricultural production of the study region.

REFERENCES

Aweto, A.O., 1981. Secondary succession and soil fertility restoration in South-Western Nigeria III. Soil and vegetation relationships. Journal of Ecology. Nigeria. 69:3; 957-963.

BPS, 2001. Sulawesi Tenggara Dalam Angka, Perwakilan Kantor Statistik Prop. Sultra, Kendari.

Brienza, S.J., 1999. Biomass dynamics of fallow vegetation enriched with leguminous trees in the eastern Amazon of Brazil. George-August-University Goettingen, Goettingen Cuvillier Verlag Goettingen, Germany.

Burger, D.M., 1991. Land use in the Eastern Amazon region in Studies on the Utilization and Conservation of soil in the Eastern Amazon region. Final report of the agreement between EMBRAPA-CPATU-GTZ. P.69-93.

Darwis, 1995. Pengelolaan lahan kering di Sulawesi tenggara, Prospek dan Permasalahannya, Prosiding Lokakarya Pendidikan Tinggi Pertanian untuk Kawasan Lahan Kering di Mataram.

Denich, M., 1989. Untersuchungen zur Bedeutung junger Sekundärvegetation für dir Nutzungssystemproduktivität im östlichen Amazonasgebiet, Brazilien. Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen 46. 265 p.

Hölscher, D., 1995. Wasser- und Stoffhaushalt eines Agrarökosystems mit Waldbrache im Östlichen Amazonasgebiet. Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen 106. 133p.

Hutchinson, R.L., J.L. Bartleson,, and R. Slaughter, 1986. Crop rotation study, Annual progress report, Lousiana State University, Baton Rouge, 184-187.

Juo, A.S.R., 1981. Automatic and semi-automatic methods for plants and soil analysis, Manual series No. 7, International Institute of Tropical Agriculture, Oe-yo Road, 5320, Ibadan, Nigeria.

Karimuna, L., 1991. The effects of phosphorus fertilizer and mulch on the growth and yield of corn (*Zea mays* L.) in RYP soil in SE Sulawesi, Kendari, Faculty of Agriculture, University of Haluoleo.

Karimuna, L., 1999. Analysis of floristic composition of the spontaneous vegetation in abandoned agricultural fields of Southeast Sulawesi in Proceeding, selected scientific papers Istecs-Europe, The 4th Indonesian Students Scientific Meeting, Oct. 8th–9th, 1999 Kassel, Germany.

Karimuna, L., 2000. Floristic composition and Biomass of fallow vegetation in abandoned agricultural fields of Southeast Sulawesi. Dissertation, Cuvillier Verlag Göttingen, Göttingen, Germany.

Kleinmann, J.A., R.B. Brzant, and D. Pimental, 1996. Assessing ecological sustainability of slash-and-burn agriculture through soil fertility indicators, Agronomy Journals, Vol. 88 No.2.

Kato, O.R., 1998. Fire-free land preparation as an alternative to slash-and-burn agriculture in the Brantagina region, Eastern Amazon: crop performance and nitrogen dynamics, George-August-University Goettingen, Goettingen Cuvillier Verlag Goettingen, Germany.

Manipura, W.B., 1972. The influence of mulch and cover crops on surface run-off and soil erosion on tea land during the early growth of replanted tea, Tea research institute of Ceylon, Talawakele, Tea Quaterly, 43:3, 95-102.

Mulongoy, K., I.O.Akobundu, B.T. Kang, and J. Van der Heide, 1985. Nitrogen uptake of maize in live mulch systems, Nitrogen management in farming systems in humid and subhumid tropics, 285-290.

Nagy, L. and J. Proctor, 1997. Early secondary forest growth after shifting cultivation, in Syst, P., C.Sebogel and Y. Byron (eds). Management of secondary and logged-over forests in Indonesia. Selected proceedings of an International Workshop. CIFOR, Bogor, Indonesia.

Riswan, S. and R. Abdulhadi, 1992. Succession after disturbance of lowland mixed dipterocarp forest by shifting agriculture in East Kalimantan, Indonesia in Goldammer, J.G. (ed.). Tropical forest in transition, 77-84. Birkheuser Verlag, Basel, Switzerland.

Sanchez, P.A., 1989. Properties and management of soil in the tropics. John Wiley and Sons, New York and London.

Seubert, C.E., P.A. Sanchez, and C.Valverde, 1977. Effects of land clearings methods on soil properties of an Ultisol and crop performance in the Amazon jungle of Peru. Trop. Agr. (Trinidad) 54, 4:307-321.

Tian, G., 1999. An improved cover crop-Fallow system for sustainable management of low acidity clay soils of the tropics, Soil Science, USA.

Uhl, C., 1987. Factors controlling succession following slash-and-burn agriculture in Amazonia, J. Ecol. 7(2): 371-437.

Yogaratnan, N., A.M.A. Parera, and G.J. De Mel, 1984. Management of ground covers for optimum production, Proceedings of the International rubber conference, 75 years of rubber research in Sri Lanka, Vol. 1 (part II), 521-527.