Economic and environmental studies of conservation agriculture on dryland in Central Lombok, Indonesia

by E Lastariningsih

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E Lastariningsih[1*], T Sjah[1,2], I G L P Tanaya[1,2]

[1]Study Program of Dryland Agriculture, Postgraduate Studies, University of Mataram, Indonesia

[2]Study Program of Agribusiness, Faculty of Agriculture, University of Mataram, Indonesia

[*]Corresponding author : **elizalastariningsih@yahoo.com**

Abstract. Agricultural development needs to pay attention to environmental issue since the economic only focus of the development threatens. One of the moves into this environmental awareness is by practicing conservation agriculture. This paper aims to analyze the economic and environmental impacts of implementing conservation agriculture practices which is implemented with the application of manure, mulch of previous crop residue and legumes as cover crop comparing to non conservation agriculture which is implemented high chemical fertilizer, herbicide, no mulch and plants only maize on dryland in Central Lombok, Indonesia. Economic and environmental impacts of conservation agriculture are identified by comparing conservation agriculture with non-conservation agriculture practices. Data were collected through observations by researchers, farmers, and extension workers. The primary data are accompanied by data from secondary sources, such as literatures and research reports. Data were analyzed quantitatively and qualitatively, providing figures as well as descriptive explanation. The result of analysis showed that Conservation agriculture, implemented with the application of manure and mulch of previous crop residues, economically was able to reduce the purchase of herbicides and chemical fertilizer, save labor costs and time in plant maintenance. Conservation agriculture practice is environmentally friendly because was able to reduce air pollution, retain groundwater and add soil organic matter. In addition, farmers income increase in conservation agriculture through diversification of crop production and savings in production cost. The positive impact of conservation agriculture, economically and environmentally leads to the recommendation to expand the practice of conservation agriculture, in the location or elsewhere.

1. Introduction

Agricultural pattern supporting present and future life is by implementing a conservation farming system. Conservation agriculture is an agricultural system that integrates soil and water conservation techniques into existing agricultural systems with the aim of increasing farmers income, improving farmers welfare and simultaneously suppressing erosion and maintaining water balance so that the agricultural system can continue indefinitely[25]. In addition, conservation agriculture is an agricultural system that carried out to increase agricultural yields by reducing costs, to preserve land and water resources so that agriculture remains sustainable [6]. The application of the conservation model can be applied to dry land or critical land. Both of these lands can be conserved. One of the government's efforts to increase farmer productivity is to implement conservation agriculture. This principle is implemented not only to increase agricultural yields, reduce costs, but also to anticipate labor limitations and maintain the sustainability of agricultural system in the future.Sustainability contains two dimensions, i.e. time and interaction. Time

dimension is meant that sustainability is nothing but what will happen in the future. The second dimension is the interaction amonsts economic, natural resources and environment [8,5]. The principle indicators of resilience agricultural systems including are that there are no erosion, depletion of soil organic matter, and salinization. Conservation agriculture introduced by FAO and has been implemented in many locations in West Nusa Tenggara by combining the use of materials organic and crop residue mulch, and soil cover (cover crops) by various legumes, proven to increase production of maize and to storage water, so it can increase farmer's income [7]. Currently, many conservation farming patterns in dry land have been tested or introduced in several areas including Central Lombok. However, until now farmers have not been fully implemented conservation agriculture. Farmers are still unsure about the benefits that can be obtained when they implementing conservation agriculture, both in terms of economic benefits and environmental benefits. Therefore, it is necessary to do some in-depth studies related to the benefits of implementing conservation agriculture. This paper aims to analyze the economic and environmental impacts of implementing conservation agriculture in Central Lombok, Indonesia. This study is expected to bring benefits for the farmers in increasing their welfare and for the government in formulating policies for better agricultural practices, in Lombok, or in other parts of Indonesia.

Methods

This research was conducted in Pujut Village, Central Lombok Regency, West Nusa Tenggara Province, for the reason that this regency has a very large dry land areas with cracked soil conditions during the dry season. Within the regency, Pujut Village was selected on the ground as one of the areas applying conservation agriculture.

2.1. Design and procedure

This study aims to investigate economic and environmental impacts of implementing conservation agriculture. This impact is setected by comparing the consequences of practicing conservation and non-conservation agriculture. In conservation agriculture, three treatments were trialed, including P1, P2, and P3. P1 is the treatment with permanent Planting Hole with 40 x 40 x 40 cm area, added with manure, legumes and mulch. P2 is the treatment of ripping added with manure, legumes and mulch in Ripping area. P3 is the treatment with stick digging (*tugal*) with the distance of 20-25cm, manure, legume and mulch. In addition P0 is the non conservation agriculture, the farmers' currently usual way of farming, and this treated as the control.

2.2. Research variables

The variables measured to see economic impact of conservation agriculture in this study are production costs, farm yields and farmers income. The variables for environmental impact are erosion, soil moisture, weed growth, physical appearance of the soil and plant damage.

2.3. Data collection

Data used in this study are quantitative and qualitative , source from primary and secondary data. Primary data is obtained directly from observations in conservation and non conservation plots. Secondary data were obtained from literatures, such as journals and others. Collected data include quantitative and qualititave [11] to explain and interprete all findings [33] . Respondents of this research are farmers who have been practicing conservation agriculture for 2 years through FAO (Food and Agriculture Organization) program. Primary data were also colleceted from extension officers in the location of FAO program for conservation agriculture.

2.4. Data analysis

In determining the impact of conservation agriculture, this study descriptively compared the result of conservation agriculture to non conservation agriculture, followed by explaining the meaning of the study results. Preceeding the comparison of the two systems of agriculture, several calculations, including production cost, farm income, and efficiency[19].

3. Results and discussion

This section presents the result of conservation agriculture and non conservation agriculture in the terms of economic and environment. This is followed by the comparison of the two systems, before the conclusions were drawn.

3.1. Economic impact of conservation agriculture

Economic impact of conservation agriculture are identified by comparing number of labor, labor wages, production cost, gross income, net income and efficiency comparing to non conservation agriculture activities.

3.1.1. Labor use on conservation agriculture and non conservation agriculture. In conservation and non conservation agriculture, labor is a necessary factor of production in the production process, not only seen from the availability of labor but the quality and type of labor is also necessarily noticed. The number of workers is still much associated with the quality of worker and labor wages. Without attention to all of these, then there will be disturbances in production process [28]. The comparison of labour use between conservation agriculture (CA) and non conservation agriculture (non CA) is shown in Table 1.

Table 1. Comparison of labor use per 0.05 ha in conservation agriculture and non conservation agriculture

Activities	CA		Non CA	
	Labor (manday)	ValueRp)	Labor (manday)	Value(Rp)
Land Preparation				
Crop Residue Cleaning & Burning	-		1	25.000
Applying Planting hole/ripping	2	50.000	-	-
Crop Residue Management	1	25.000	-	-
Adding Manure	1	25.000	-	-
Herbicide Spraying	-		1	25.000
Sub total	4	100.000	3	50.000
Maintenance				
Fertilization I	1	25.000	1	25.000
Fertilization II	1	25.000	1	25.000
Fertilization III	-		1	25.000
Weed Cleaning	-		2	50.000
Sub total	2	50.000	4	125.000
Total	6	150.000	7	175.000

Table 1 shows that there was more labor use for land preparation in conservation agriculture than in non conservation agriculture, but this is reversed in maintenance activities. In total, non conservation agriculture required more labor than conservation agriculture, and hence become more expensive to run non conservation agriculture. Given the less use of labor in conservation agriculture than in non

conservation agriculture, then the farmers and their families can use those time for other activities, such as laboring on other people farms or on other non agricultural activities.

3.1.2. Costs of production facilities. Generally, production costs are formed of fixed costs and variable costs incurred by farmers in their farming activities. Production costs are all sacrifices incurred and used to produce a certain amount of production [19]. These principles also apply in conservation and non conservation agriculture. The costs of production facilities in conservation agriculture and non conservation agriculture are presented in Table 2, where the costs of production facilities for conservation agriculture were less than non conservation agriculture. This case occured since conservation agriculture did not apply herbicide and applied less chemical fertilizers than non coservation agriculture. The compensation for less use of chemical fertilizers and herbicides is the application of manure and legume; both are categorized as organic fertilizers. Manure in this study was identified from cattle manure.

Table 2. Comparison of costs of production facilities per 0.05 ha in CA and Non CA.

Items	Unit	CA		Non CA	
		Physic	Value(Rp)	Physic	Value(Rp)
Manure	Kg	150	100.000	-	-
Maize Seed	Kg	2	50.000	3	75.000
NPK	Kg	10	27.500	20	67.500
Urea	Kg	5	25.000	10	50.000
Ponska	Kg	-	-	10	50.000
Herbicide	Ml	-	-	0.5	40.000
Legume Seed	Kg	2	10.000	-	-
Total			212.500		282.500

The use of chemical fertilizers became half portion in conservation agriculture compared to non conservation agriculture. There were more corn seeds applied in non conservation agriculture relative to conservation agriculture. Farmers plant on average 2-4 corn seeds in non conservation agriculture, while 1-2 corn seeds in conservation agriculture. In conservation agriculture, farmers also plant legumes, such as short bean, mungbean, or other legumes, such that the farmers have various crops in their lands. This is not case for the non conservation agriculture, in which there was only 1 kind of crop, that is corn only. The planting of more than one crop is multiple cropping system, including intercropping, such as practiced in this conservation agriculture. Intercropping of maize with some legumes increase farmer income from various production. Intercropping is the cultivation of two or more types of plants on a plot of land at the same time [31]. The purpose of the intercropping system is to take optimal advantage of the factors production, including land, labor, and working capital. The system uses fertilizers and pesticides more efficiently, reduce erosion, increase land conservation, increase soil biological stability, and get a bigger total production compared to monoculture planting [32]. All of these lead to increased income for farmers as shown in the next section.

3.1.3. Economic analysis of conservation and non conservation farmers. Net income is obtained from the results of revenue minus total cost of production. When revenue is not substracted with production cost then it is called gross income, thus revenue equals gross income. Production efficiency is measured by comparing revenue to cost of production [30]. All of these measures are compared between conservation agriculture and non conservation agriculture (Table 3). It shows that conservation agriculture in practice give better performance than non conservation agriculture, all data show that both activities gave low returns. The non conservation agriculture even generate negative return, the indication that leads non

adoption of the practice. However, it is possible that larger farming would show more different between the two practices of agricultural systems, and increases the efficiency of the practice. It was in line with [24] stated that conservation agriculture reduces agricultural operational costs while increasing yields and utilizing natural resources properly.

Table 3. Gross income, net income and efficiency of CA and non CA

Item	Unit	CA	Non CA
Maize production	Kg	55	53
Legume Production	Kg	45	0
Maize price	Rp/kg	5000	5000
Legume yield price	Rp/Bundle	2000	0
Cost of production	Rp	362.500	457.500
Gross Income	Rp	365.000	265.000
Net Income	Rp	2.500	-192.500
Efficiency (R/C)	%	1.00	0.58

Yield is an indicator of dryland farming management impact, environmental factors influenced the yield. cover crop, residues as mulch and manure application are part of the modified environmental factors which support soil quality for maize growth. Conservation agriculture practices using crop rotation, ground cover and minimum tillage practiced in Malawi, Southern Africa increased maize yield by 35% [22] until 40% [34]. It was in line with this study which was shown on table 3 that planting maize after a legume cover crop increase gross income compare to no cover crop. [12] also mentioned that Among the poorest farmers in Indonesia, the smallholders involved in conservation agriculture increased their corn production to over 4 tons by taking up conservation agriculture during the El Niño drought in 2015 and 2016, when traditional methods gave only 2.5 tons or even less.

2. Environment impact of conservation agriculture

Conservation agriculture is an approach to designing and managing sustainable agricultural systems through resources conservation. This method seeks to conserve, enhance and utilize natural resources more efficiently through integrated management of soil, water, plants and other biological resources. Conservation agriculture has emerged as a new paradigm for achieving sustainable agriculture. The major step of transition to sustainable agriculture occured because of conservation agricuture benefits. Direct benefits of conservation agriculture to farmers include reduced cultivation costs through labor savings, reduced agricultural time and labor (Table 3) and increased efficiency by reducing inputs used (Table 3). More importantly conservation agriculture practices reduce resource degradation.

Conservation agriculture leads to continuous improvement in more efficient use of water and nutrients by improving nutrient balance and availability, infiltration, soil retention, reducing water loss due to evaporation and improving the quality and availability of ground water and surface water [16]. There are 3 basic principles which emphasize conservation agriculture according to FAO namely: cultivating the soil lightly; covering the soil surface tightly and continuously every season every year; and implementing intercropping and crop rotation [17]. The second and third principle of conservation agriculture is shown in Figure 1.a and non conservation agricultural is shown in Figure 1.b.

1.a 1.b

Figure 1. Appearence of conservation agriculture practices (1.a), and non conservation agriculture (1.b), in Central Lombok

One method of conservation agriculture is applies planting in the hole. The working principle of this planting hole is similar to biopore infiltration holes by Brata [1], only the size of the biopore is small. It is explained further that biopore hole infiltration is a technology that use of organic waste to live microorganisms that are useful as water source to maintain soil moisture, then [10] added that biopore infiltration is one of the strategic efforts to minimize the occurrence of floods. The effectiveness of biopore infiltration holes on the rate of infiltration, which is strongly influenced by the type of hole, from the level of composting and rainy days [14]. When compared to the planting hole in conservation agriculture, that hole is big, given organic matter and used to produce various crops, especially maize and beans. With that planting hole, plants are more resistant to drought though on rocky land, compared to land without planting hole [7]. Planting hole and ripping required more energy, labor, time and contribute more cost for farmers, But, zero tillage (tugal) and other components conservation agriculture mainly focuses on disturbing the soil to lowest possible amount. In turn, this requires less inputs considering the soil management like labor. This might be influencing the farmers more to use different conservation agriculture practices. Previous studies also suggests that, farmers adopt retention of crop residues, crop rotation and less soil alteration (zero and minimum tillage) more than other practices [35].

Environment impact of conservation agriculture in this study was analyzed through the results of conservation agriculture and non conservation agriculture observation with farmers and extension workers. Field observations were carried out under several conditions, in conditions without rain, land conditions during heavy rain and land conditions a few days after rain. Table 4 shows the results of field observation on the conditions of conservation agriculture (CA) and non conservation agriculture (non CA).

Table 4. Physical condition comparison of CA and non CA.

Indicator	CA	Non CA
Erosion	No Erosion	Erosion Occures
Soil Moisture	More Moist	Dry
Weed Growth	Less	More
Plant Damage	Less	More
Crop Residue	Mulch	Burned
Soil Organic Matter	Increase	Reduce

3.2.1. Erosion and plant damage. Conservation agriculture is one of the methods that must be done by farmers in order to maintain agricultural land so that it can be usefull for the next generation. Conservation agriculture practice is very environmentally friendly, judging from the condition of the land when it rains. Table 4 shows that non conservation agriculture land is eroded to the bottom and covered maize trees. while in conservation agriculture plots, the eroded soil can be dammed by ripping rows and restrained by crop residues and legumes, in other words, it is able to withstand the rate of surface water, even in the planting hole plots, apart from the soil being driven away by crop residues and rainwater can be captured and tied by manure that has been mixed into the planting hole.

When the rain no longer falls, the plants on conservation agriculture land still look green and fresh because of water available and mulch presence on the planting holes. Meanwhile, the maize plants in non conservation agriculture plots look yellow and weak and more damage caused by rain and covered by soil erosion, so farmers need more effort on maintenance again, they need to replant the damage maize and add fertilizer again to improve maize growth. The causes of land degradation can be divided into five groups, including erosion and sedimentation, salting, pesticide residues, pollution of waste, inorganic and heavy metals by industrial activities, excessive use of fertilizers. From this grouping, it can be seen that soil erosion is the main cause of land degradation [26].

3.2.2. Soil moisture and crop residue. The easiest conservation farming practice is to cover soil completely with crop residues such as straw, because stated Straw mulch helps to moist the soil profile and reduces the soil crack width by 32% [2]. Straw mulch minimizes soil shrinkage by reducing evaporation from the soil surface. Rice straw can reduce soil density and increase water absorption, increase porosity and decrease bulk density [4]. Straw residue management affects soil physical properties such as soil moisture, temperature, aggregate formation, bulk density and hydraulic conductivity [17].

Management of crop residues is an important activity in conservation agriculture because it reduces air pollution. Due to the cessation of straw and other plant residues burning activity, the more plant residues that become mulch will contribute high soil organic matter so that over time the soil becomes more fertile and more friable, and these are sought by farmers who carry out agricultural activities on dry land. The practice used mulch on their own land so that this activity is also an effort to stop burning activities and air pollution in various regions. Mulch can improve plant growth in landscapes by enhancing soil quality, such as conserving soil moisture and increasing soil nutrients [9]. It is also reported that mulching, especially with organic mulches, can improve growth and yield of plants [13] , it was in line with other journal stated that Cover crop residue application gave higher grain yield of maize by 34% [21]. Mulches have been widely used in agriculture lands, orchards, forests, and landscapes in many parts of the world [15]. Generally, mulches reduce competition from weeds, maintain soil temperature, and reduce evaporation from soil [39]. They protect the soil from wind, water, and traffic induced erosion. Further, fugitive dust from soil is suppressed by mulching. Mulches also improve soil properties by improving moisture retention capacity, releasing different nutrients, and enhancing biological activities [23]. Similar with [3] reported that application of organic matter through mulching with the application of minimum tillage could reduce soil penetration resistance. Therefore, with the improved soil properties, plants grow better [16]. However, returning crop residue as mulch can increase soil organic matter [40].

3.2.3. Soil organic matter. Conservation agriculture practices in which there is an activity of adding manure and perfect cover with plant residues will naturally be able to cover the depth of the soil cracks and stop soil evaporation. Dry land area with a dry climate has a neutral to slightly alkaline PH [20], organic matter content and bases mostly moderate to high. This location has carried out conservation farming practices that applying organic matter and compost in the planting hole, minimum tillage and intercropping between maize and beans and covers by mulch which is very useful as water holding [7].

Conservation agriculture practice is very suitable to be implemented by farmers for dry and cracked soil conditions such as in research location of Central Lombok. For plants, the presence of organic elements on the soil contributes a considerable advantage because it is not only able to increase soil fertility but also helps plants to have good roots so that plants are able to absorb nutrients better. [37] Stated that the optimal absorbtion of nutrient would increase the yield of maize. According to observation result of this study , the roots of maize planted on conservation agriculture are more numerous and longer than those in non conservation agriculture. Even from physical appearance, maize stalks look bigger and stronger than maize plant on non conservation agriculture land. It is line with the previous studied which was mention that the extent to which plant roots can enter the soil is influenced by several factors, i.e. ability of plant root its, soil structure, soil texture, soil density, soil cracks, soil organic matter content, and soil moisture. Shortage of soil organic matter can make the soil becomes compact, and clotted making that make roots difficult to penetrate [36], Organic matter from prunings of legume hedgerow trees could increase soil organic C content [38] . Conservation Agriculture is aligned in realizing several principles of sustainable development, which is improving the community's economy and ecological or environmental balance.

Conservation agriculture offers opportunities and missions to move to the next phase. It is a challenge for all stakeholders, farmers, extension workers and industry to understand the opportunities, and call for different strategies from those that have been adopted by farmers over the last few decades through conventional agriculture. The biggest challenge is to overcome farmers' mindset where agriculture is almost synonymous with the practice of tilling the land. Conservation agriculture paradigm call for an innovation systems perspective to address diverse, flexible, specific and site specific technology requirements. A Perspective on innovation systems that involves understanding of organizations and individuals responsible for the generation, diffusion, adaptation, socio economic knowledge and the institutional contexts the way these conservation agriculture interactions and processes take place [39]. The results of soil analysis before implementation conservation agriculture in 2014 and after agriculture conservation in 2018 shows that conservation agriculture by applying those three pillars can improve soil fertility and water retention [20] and increase production of maize [7].

4. Conclusion

The result of analysis showed that Conservation agriculture, implemented with the application of manure and mulch of previous crop residues was able to reduce the purchase of herbicides and chemical fertilizer, save labor costs and time in plant maintenance, reduce air pollution, retain groundwater and add soil organic matter. In addition, farmers income increase in conservation agriculture through diversification of crop production and savings in production cost. The positive impact of conservation agriculture, economically and environmentally leads to the recommendation to expand the practice of conservation agriculture, in the location or elsewhere.

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