Conservation agriculture in semi-arid area of Indonesia: lesson learnt to increase maize production and farmers’ awareness on environmental friendly land management

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Abstract. Dominated semi-arid area of East Nusa Tenggara (ENT) is characterized by low and erratic rainfall, poor soil fertility, diverse agro-ecosystem and dominant rocky lands. Crops production within this environment is generally low and uncertain. This paper aims to describe the impacts of Conservation Agriculture (CA) practices in ENT province. The data and information were mainly taken from FAO and IAARD’ CA collaboration research program implemented in ENT during 2014 to 2018. All farmers involved in the programs acknowledge that CA has increased maize productivity and indeed some farmers have able to plant maize twice a year and experienced good harvest even in long drought. Integrated forage into CA based farming in Timor enable farmers to provide enough feed for cattle at least 1 to 2 head/household. Nevertheless, most farmers showed some constraints in implementing and expanding the introduced CA concepts. The main constraint is lack of labor and equipment to make permanent planting hole in dominated rocky land. CA concepts related to permanent cover crops and mulching have not fully implemented due to crops residues mostly used to feed cattle. The complexity of semi-arid environments and indigenous knowledge of local people in managing semi-arid upland agriculture should be taken into consideration in incorporating suitable induced CA.

1. Introduction

The island of Timor and semi-arid region of East Nusa Tenggara in general have long been mentioned as the region that “unreliable and unfavorable for agriculture” [1] mainly due to low, erratic and uneven distributed rainfall and dominated rocky landscape and mountain and rugged hills that limit agricultural production of the region. The study of Ormeling [2] was also mentioned that increasing human population and expansion of agricultural lands/farming practices particularly for maize farming with poor soil/land management have contributed to the land degradation and deteriorating the environment.

Land degradation and environment related problems in semi-arid regions in ENT seems to have started when expansion of ladang (upland) for maize [3] introduction and fast increasing of Bali cattle population [4] and fast deforestation and inappropriate agricultural practices [5, 6] due to forest encroachment, extensive cattle grazing and burning in shifting cultivation practices [7]. Land degradation and resources depletion have become a major treat for sustaining food security for people living in semi-arid areas.
The main impact of land degradation in semi-arid region can be seen from the low productivity and production of maize and crops in generally. Although there have been land expansion for maize farming in recent years, low productivity and production of maize in semi-arid region is never meet the demand of maize as staple. Indeed, ENT has imported maize for home industry and feed.

Until 2013 maize production in ENT was 707,643 t from the harvested area of 270,394 ha and productivity was only 2.6 t ha\(^{-1}\) [8]. In 2018, maize harvested area in NTT was 341,264 ha and maize production 859,230 t which means productivity was only 2.51 or decreased compared to 2013 data [9]. As a comparison West Nusa Tenggara (WNT) province, until 2013 maize production in ENT was higher than WNT and ENT was one of the 10 major players in National maize production. Started in 2014 until present, maize production and productivity in ENT have been lower than that in WNT and ENT is no longer as major player in national maize production [10].

Above figures showed that there were serious problems of maize farming in ENT and one of the important aspects that needs to be taken into consideration is how to improve soil/land management practices to improve maize production in sustainable manner. This paper aims to describe the impacts of Conservation Agriculture (CA) practices among upland farmers in ENT province. The paper was organized into four main sections. After introduction, the next section was discussed methodology shortly. The third section elaborated main findings of the research. The last section is a conclusion drawn from previous sections.

2. Methods

The data and information were mainly taken from FAO and IAARD’ CA collaboration research project implemented in ENT during 2014 to 2018. The project entitled Reducing Disaster Risks caused by changing climate in West Nusa Tenggara and East Nusa Tenggara Provinces in Indonesia, (OSRO/INS/301/USA) through the implementation of conservation agriculture (CA). FAO program in ENT was conducted in 8 districts of two main Islands such as Sumba (West Sumba, Middle Sumba, East Sumba and Sumba Barat Daya or SBD Districts) and Timor (Kupang, Malaka, TTU and Belu). Kupang District was included later as collaboration research with AIAT-ENT. A baseline survey on socio-economy was carried out in early 2014 when project has not been implemented and the end-line socio-economic survey conducted during May and July 2018. The survey employs Focus Group Discussion (FGD) in every village and then continued with in-depth interviews involving beneficiary farmers of total 41 respondents in Sumba and 37 respondents in West Timor and not-beneficiary farmers of total 12 farmers in Sumba and 9 in Timor. After the end of the program, field conservation continued only in Camplong II Village of Timor Island as part of AIAT-ENT research site to observe continuation of the program when there was no project support.

The CA respondents were selected from the same sites as soil survey. The Non-CA respondents were selected randomly around or nearby CA respondents. Socio-economic survey data were processed in tabulation and analyzed descriptively to see changes and/or the difference between the initial conditions (the results of the Baseline Survey) and the present, or the differences that occur between CA Farmers and Non-CA Farmers in the current condition.

3. Results and discussion

3.1. Semi-arid upland farmers characteristics

Most farmers involved in the program have been in the productive age between 49 to 51 years old in Sumba and 44 to 46 years old in Timor. Younger productive generation below 40 years old seems to be less interested in working in the upland farming. Average family size of farmers in Sumba was 6 people and in Timor were 5 people. Nevertheless, only 2 to 3 family members directly involved working in upland.

Average cultivated land of CA farmers during baseline survey in Sumba was 1.09 ha and in Timor was 0.68 ha. Dry land farm area cultivated by CA farmer was larger as compared with non-CA farmer.
59% in Sumba and 52% in Timor. On the other side, as compared to the baseline survey results the current dry land farming area cultivated by CA farmers increased slightly, as much as 10% (Table 1).

Except for Non-CA farmers in Sumba, farmers perceived their dryland farming that was mostly flat and fertile. Indicator used by the farmers was fair crops performance and production even without external input use. It showed also that farmer adopted CA partially. Farmers mostly adopt the minimum soil tillage (50% to 100%). Only 16% to 39% farmers adopted soil covering and only 8% to 205% of farmers adopted crop rotation.

3.2. Conservation agriculture and maize production

FAO [11] stated that: “Conservation Agriculture is a response to sustainable land management, environmental protection and climate change adaptation and mitigation. FAO promotes the adoption of Conservation Agriculture principles (minimal soil disturbance, permanent soil cover and crop rotations) that are universally applicable in all agricultural landscapes and cropping systems” CA principles were also applied in CA program implemented in ENT, however some adjustment have been done to accommodate farmers’ preference and harsh environment of semi-arid region. Introduced Permanent Planting Holes (PPH) is one of the innovations being applied to eliminate shifting cultivation practices, optimize use of dominant rocky land and increasing water infiltration/soil moisture.

| Survey   | CA (ha) | Non CA (ha) | ∆ (%) | CA (ha) | Non CA (ha) | ∆ (%) |
|----------|---------|-------------|-------|---------|-------------|-------|
| End line | 1.127   | 0.708       | 59.2  | 0.726   | 0.461       | 51.5  |
| Baseline | 1.099   | na          | 2.5   | 0.677   | na          | 7.2   |

Note: ∆ = Difference; Source: Tabulated data; CA= Cooperator farmers of conservation agriculture project

Most maize farming in Timor and Sumba Islands were cultivated under the slash and burn cultivation. This traditional farming practice is considered to have contribution to the land degradation, deforestation, damaging soil and organic matters and biodiversity loses and global warm [12, 13]. Although this traditional practice require almost no external input use, maize production/productivity can no longer meet the subsistence level required by the farmer household.

Based on the baseline survey indicated although farmers have cultivated land 0.6 ha in Timor and close to 1 ha in Sumba, maize yield with traditional practice was only enough for household consumption for 6 to 9 months. During low rainfall or long drought, most farmers have even experienced fail to harvest. Farmers in Middle and East Sumba district were also experience frequent harvest failure due to grasshopper (*Locusta migratoria manilensis*) attack.

Within the fast depleting natural resources for farming, farmers in general accepted and enjoy with proposed CA innovation. Farmers all agreed that by implementing proposed CA innovations have improved significantly the productivity of maize, and even some farmers managed to plant maize twice a year which never experienced before. Participants farmers also acknowledged that they have able to improve their food security and even have surplus that are sold for cash.

In the use of commercial farming production inputs, CA farmers used commercial seeds more efficient than Non-CA farmers, especially in the rainy season. CA farmers also applied more manure compared with Non-CA farmers. Labor for CA farming was higher by 9.7% in Timor for the rainy season, and 3.3% for the dry season. This data was affirmed by most farmers who stated that applying CA techniques required more labor than the traditional farming. Participant farmers in Sumba and Timor did not use inorganic fertilizer anymore for upland farming. CA also reduced cost for pest and disease controls, in rainy season as well as in dry season.
Average maize productivity in Timor for CA in 2018 was 3.8 t ha\(^{-1}\) during rainy season and 2.6 t during dry season. This productivity was increased 2 to 4 times higher than baseline data. Based on the group discussion revealed that CA farmers in Sumba enjoyed better and sustained food crops production in the second planting season (dry season) which was never be conducted or practiced before the CA program implemented. As comparison, the result of the study in Mallende – Zambia revealed that implementation of conservation agriculture could increase corn yield from 4.0 to 5.5 t ha\(^{-1}\) to 6.5 to 8.0 t ha\(^{-1}\) dry seeds or increased by 45.5 to 62.5% [14]. Then, the result of research done by Erenstein [15] in Mexico for 10 years showed that corn productivity of around 4 to 7 t ha\(^{-1}\) of dry seeds with conservation agriculture systems (without tillage and crop residue utilization) was always higher and more stable than conventional maize planting methods (3 to 5 t ha\(^{-1}\) (dry seeds)).

Income of CA farmers was higher 57% in Sumba and 77.1% in Timor, respectively (Table 2). The contribution of dryland farming to total income of farmer was more than 50%. In Sumba Island, the role of dry farming as source of income and contribution of livestock for Non-CA farmers were higher than CA farmers. This indicated that Non-CA farmers were enjoying with their present upland status and less interested to adopt CA innovations. The income from livestock was quite high as much IDR 2.1 M (17.8%) in Sumba and IDR 2.8 M (23.2%) in Timor (Table 2).

### Table 2. Total income of farmers and contribution of dry land farming and livestock.

| Income                          | Sumba | Timor |
|---------------------------------|-------|-------|
| Total Income (IDR 000/Yr)       | CA 11,796 | Non CA 7,512 | CA 11,900 | Non CA 6,718 |
| Contribution of dryland (%)     | CA 47.1 | Non CA 53.2 | CA -11.5 | Non CA 47.9 |
| Contribution of livestock (%)   | CA 17.8 | Non CA 20.7 | CA -14.0 | Non CA 18.0 |

Source: Tabulated data

The dry land farming contribution to the family food sufficiency of CA farmers was better than that of Non-CA farmers, and the current condition was improved as compare with the baseline survey results. Family food sufficiency of CA farmers in Sumba was available for less than 6 months and in Timor available for 6 to 9 months. The Government assistance in the form of poor rice program was still reliable by most farmers to meet food shortages and then followed by selling livestock in Sumba and direct buying in Timor (Table 3).

### Table 3. Food security and fulfillment of food shortages by households (%).

| Parameters                        | Sumba | Timor |
|-----------------------------------|-------|-------|
| a. Food security                  |       |       |
| 1. Surplus                         | CA 4.9 | Non- CA 0 | CA 17.5 | Non- CA 0 |
| 2. 9 to 12 months                  | CA 31.7 | Non- CA 16.7 | CA 33.6 | Non- CA 37.5 |
| 3. 6 to 9 months                   | CA 19.5 | Non- CA 41.7 | CA 37.0 | Non- CA 62.5 |
| 4. < 6 months                      | CA 32.9 | Non- CA 41.7 | CA 15.5 | Non- CA 0 |
| b. Fulfillment of food shortages   |       |       |
| 1. Government Assistance (Rastra)  | CA 44.2 | Non- CA 41.7 | CA 60.9 | Non- CA 77.0 |
| 2. Selling livestock                | CA 9.6 | Non- CA 33.3 | CA 4.6 | Non- CA 0 |
| 3. Direct buying                   | CA 46.2 | Non- CA 25.0 | CA 34.6 | Non- CA 33.0 |

Source: Tabulated data
Farmers are well aware the benefit of the CA implementation. The main element of CA was considered very important for the sustainability of their farming. However, in general there was an impression that farmers understand or reduce the CA concept to only technical aspects of making permanent planting holes (PPH) and ripping so that many farmers found it hard to implement CA because it was difficult for them to make PPH on a large scale of upland farming. It was revealed that farmer needed around 156 to 173 man-days for making PPH ha\(^{-1}\), and 25 to 83 man-days for making Ripping ha\(^{-1}\). Considering this matter, it was not surprising that most farmers, i.e. 55% in Sumba, and 54.1% in Timor, stated that the main constraint faced in the implementation of CA was the lack of labour. The remaining obstacles were less equipment and or unsuitable biophysics particularly in dominated rocky land in Timor and Sumba.

3.3. Maize in the farming system context

Although maize is considered suitable for semi-arid region of ENT, marginal land per poor soil and low rainfall have contributed to low productivity or even fail to harvest. Farmers participants who applied permanent hole planting acknowledge that for the first time they can plant and harvest twice a year which was never experienced before in upland semi-arid region. They aware that the holes can conserve or retain more water that allows them do second maize planting soon before or after first planting maize harvested.

Maize normally is planted in the mixed cropping system once a year during short rainy season. Slash and burn system is a dominant system for land preparation for farmers that who enough land for shifting or rotating the cultivation, however farmers with small land ownership (\(\leq 1\) ha) have eliminated shifting cultivation or slash and burn and prefered practicing permanent farming.

Of slash and burn in land preparation, not all vegetation eliminated or cleared from the land. Some vegetation especially for forages like Leucaena and Sesbania glandiflora remains uncut in Timor. Most farmers in Timor do plant Leucaena both for forage and fast land recovery. Upland farmers plant several crops in a parcel of land and after 2 to 3 years (depending on crops performance) that parcel will be fallowed for several years (depending on natural vegetation recovery). Farmers will be back to the first parcel or fallowed land if there are enough materials to be slashed and burnt. Land dominated with Leucaena is more likely to have shorter fallow period compared to land dominated other vegetation.

Depending on rainfall; however, farmers plant maize soon after the first rainfall. Farmers in Sumba or in the midland/highland normally plant earlier than in the lowland or in the coastal areas. Therefore, some farmers in some areas in the midland/highland plant maize twice a year. Farmers in lowland or in the coastal areas plant maize normally in the end of November up to January and harvest it in March to May. After harvesting farmers simply left the Leucaena regrowth and used the land for forage.

Composition of crops in a parcel of land depends on the farmers’ preference and suitability of those crops. Although most farmers do planting maize, however, farmers in one CA program site of highland TTU district does not plant maize. They accept the concept of permanent planting holes, but those holes are planted with taro or other root crops. This is because this village has cold weather, high rainfall and bimodal rainfall pattern which are not suitable for maize. Further, farmers of this village prefers plants horticultural crops mostly to supply Kefamenanu and Kupang town. cropping pattern, maize productivity and farmers income before and after CA program are shown in table 4.

By adopting CA principels, all respondents can grow maize twice a year, the productivity was higher and around 46% of respondents are allowed to sell the surplus production of maize (Table 4). Most participants’ farmers in Kupang District were able to incorporate forage crops during rainy season and they are harvested during dry season to feed cattle. Average maize productivity before CA program was only 0.9 t ha\(^{-1}\) and even lower or failed to harvest during long drought. Farmers’ income was also higher 57% in Sumba and 77% in Timor during CA implementation compared to before CA was implemented. By this achievement for participants’ farmers, maize in the farming system is no longer simply a subsistence commodity, rather as one of the upland commodity for cash.
Table 4. Cropping pattern, maize productivity and farmers income before and after CA program.

| Item | Before CA Program/Baseline | During CA Program |
|------|----------------------------|-------------------|
| Cropping Pattern: | | |
| ➢ **Rainy season** | Maize + pumpkin + beans | Maize + Pumpkin + beans + forage |
| ➢ **Dry Season** | - | Maize + mungbean |
| Maize Productivity | | |
| ➢ **Rainy season** | 0.9 t ha⁻¹ | 3.8 t ha⁻¹ |
| ➢ **Dry Season** | - | 2.6 t ha⁻¹ |
| Average Annual Income | n.a | IDR 9.6 Million |
| % Income contributed from Upland Farming | n.a | 50 |
| % Respondents selling (surplus) of maize | Never | 46 |

Source: Tabulated data

3.4. Adaptation strategies

Present agricultural practices in semi-arid area of ENT are actually is process trial and error process by local farmers to find out the best suitable farming practices. However, the long contact with the earlier foreign traders particular from China and India who were looking for sandalwood (Santallum album) [16] and later contact with Western colonial particularly Portuguese and Dutch [16, 17] have also established agricultural practices and agricultural commodities of farmers in semi-arid areas. Agricultural practices and environment problems in semi-arid areas is also a products of colonial exploitation in favor of market orientation [18, 19].

The main factor contributed to the uncertainty in upland farming particularly in maize production is low and erratic rainfall. There were highly variations of rainfall pattern in the Islands that have direct impacts to the food crops production. High variation of rainfall pattern among regions even in the short distance has contributed to the high variation of maize production and food availability among regions. In general even in the good harvest season, there still spots areas with harvest failure in ENT [20]. Most common farmers’ adaptation strategies within these rainfall variations are by managing their planting calendar and planting drought tolerant crops in the mixed cropping system.

There are several soil types in semi-arid areas of ENT province. Soil types in Timor dominated with Bobonaro scaly clay [21, 22] which according to Basuki et al. [23] constitute about 30% and equally distributed. Farming practices in soils type with poor soil management have contributed to severe land degradation and worsening soil fertility [24]. Farmers adaptation in this soil type was by planting tree crops and forage legume tree like Leucaena. Local agro forestry or Mamar in Timor and Kalio in Sumba are important farming practice to protect land and minimize soil erosion.

After 3 to 4 years of the CA program implemented, based on the soil analysis it revealed that soils organic mattes increased considerably in all research sites and the highest occurred in West Sumba. This indicates that Nitrogen in the soil and organic matters increased if biomass and crop residues constantly returned to the soil. Besides increased C-organic, it also increased water holding capacity and soil aeration which lead to the development and activity of microbes that play important roles in nutrients availability for crops growth [25].

There were considerable different of CA innovation applied in the land dominated with rock and dominated or pure soil. Most farmers do ripping and or permanent planting holes (PPH) in the land dominated with soils were normally unrecognized anymore (or change) those holes and lines in the next planting season. For these innovation practiced in the dominant rocky land, farmers keep using similar PPH or ripping lines for the next planting season. Farmers in Camplong II village are aware of investing PPH once and then they enjoy with almost similar productivity of crops in next planting season.
The big challenge to realize that one of the CA purposes is to improve soil fertility but not all farmers left or returned the biomass into the soil or PPH. Forage is the main constraints for livestock production in semi-arid region particularly during the long dry season and therefore almost all biomass from the farming has been taken out to feed cattle. This situation was almost similar to what Jat et al. [26] found out in implementation of CA in Africa.

Determination of the location of the study, including the pilot location of CA was not all in accordance with the problems faced by farmers, while the choice of technology offered was almost the same for all locations. CA activities that were not running well in some farmer groups were more because the technology offered was not the solution to the problems faced by farmers. Based on the results of field observations and discussions with farmers, several obstacles to the development of CA were elaborated, as presented in Table 5.

Table 5. Constraints in applying the main pillars of the CA principles.

| The main pillars of CA | Constraints or Problems |
|------------------------|-------------------------|
| Without or minimum soil tillage | • If the main commodity being cultivated was root crops, farmers were difficult to accept because they assumed or believed that the growth of plant tubers would not be maximized.  
• Permanent planting holes (LTP) and ripping techniques were very heavy for farmers to do, especially in rocky land without adequate agricultural tools.  
• The need of manure was very large.  
• LTP was less suitable for areas with high rainfall, including in agricultural areas that often affected by river floods. |
| Use of permanent ground cover | • It was difficult to get evergreen cover crops. Mucuna plants could survive on marginal dry land, but generally not favored by local farmers because it was considered to require complex processes to be consumed safely.  
• Short rainfall limits amount of green biomass  
• Competition of its use for animal feed |
| Rotation of legume and non-legume plants | • Difficult to apply to areas with low and short rainfall.  
• The preference of farmers always gives the largest portion of non-legume crops, especially corn in each crop season. |

Source: Primary data and field observation

The selection of suitable locations and innovation was very important if the main pillars of CA could be applied by farmers. Local wisdom related to conservation agriculture, commodities that compatible with specific agro ecosystem conditions and the philosophy behind these practices need to be understood before the introduction of a new conservation agriculture system. In the field it was found that some farmers developed corn crops in areas with altitudes of more than 1,000 m above sea level because they felt that it was a recommendation from the authorities which was actually unsuitable with their specific condition.

Although farmers encountered some constraints in applying CA concepts, there was strong indication that farmers would continue to implement CA approach on their dryland farming after the CA Project termination. There were 72% to 95% of farmers who have made development plan to implement CA approach, either in the current dryland or in the other dryland farming. Post project study at CA site in Camplong II village indicated that, farmers keep practicing and developing CA principles in their upland farming. They have been modifying the CA system by planting forage legume tree and herbaceous forage that allowed them to feed cattle 1 to 2 head per household.
4. Conclusions
Conservation agriculture (CA) have been introduced and applied in semi-arid areas of ENT. The ideas of CA had been also incorporated in traditional farming practices. Nevertheless, land degradation and related problems is still a big challenge in agricultural development in semi-arid areas. Land degradation coupled with the nature of climate particularly in rainfall pattern in semi-arid area has contributed the uncertainty of food crops production. Despite some constraints encountered in implementation of CA, farmers in general is willing to adopt and keep practicing CA in upland farming. The main reason for this was the fact that CA farmers harvested higher yield of maize and other food crops compared to that of non-CA farmers. CA farmers in general were able to improve their household food security. Integrated forage into CA based farming in Timor have solved the main problem of feed during the long dry season and enable farmers to provide enough feed for cattle at least 1 to 2 head per household. There are prospect for scaling-up CA to the area or region with similar characteristics or agro ecosystem zone of semi-arid region. However, it should be always considered the local biophysical and socio-economic conditions, especially local wisdom so that problem solving solutions could be based on local resource potential.

Acknowledgments
The authors would like to thank CA program technicians assistants for helping the research team in data collections. Thanks are also conveyed to Debora Kanahau - AIAT-ENT researcher for providing valuable agronomic data of Maize from the research site in Camplong II village, Kupang District. Any remaining errors are authors’ responsibility and they have equal contribution in writing and publishing this paper.

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