Forage tree legumes and sustainable upland farming in Timor Island – Indonesia

Y Ngongo, D K Hau, N Kotta and J Nulik

Researchers at Assessment Institute for Agriculture Technology East Nusa Tenggara (AIAT-ENT) Jl. Timor Raya Km. 32, Kupang, Nusa Tenggara Timur - INDONESIA.

E-mail: yohanisngongo@gmail.com

Abstract. Upland farmers in semi-arid region of Timor Island have frequently facing low and uncertain food crops production and chronic forage shortage during long dry season limiting livestock (cattle) production. This study explores forage development, particularly Leucaena and the dynamics of upland farming management among farmer groups in West Timor – Indonesia. The study mostly use forage data of ACIAR and AIAT-ENT collaboration research on forage development, particularly Leucaena conducted in ENT. The data were mostly analysed descriptively. The study showed that adoption of forage legume innovation, particularly Leucaena by upland farmers have solved forage shortage problem during long dry season in semi-arid region of Timor Island, it allowed farmers to do cattle fattening/shortening fattening period and improving crops (maize) production. Drawing on information regarding traditional farming (mixed-cropping) practices for food crops production and traditional local agro-forestry (Mamar) for perennial crops production, the research suggested that incorporated forage tree legume of Leucaena into both traditional farming system can improve/sustain crops and cattle production as well as environment.

1. Introduction

The main constraints in increasing cattle population and ruminant livestock in general in East Nusa Tenggara (ENT) are forage. Forage availability in semi-arid area mostly dictated by rainfall which are low, seasonal and erratic. Forage availability is abundant enough during short rainy season (November – March), low quality of forage (April – May) and it considered forage shortage during June – October. Semi-arid environment affects very much production and quality of ruminant livestock in traditional raising system that heavily dependent on common grazing land.

Since first introduced in Timor by the Dutch colony in the beginning of 20C, Bali cattle population increased rapidly and become major inter-island commodity from Timor. The East Nusa Tenggara (ENT) province has contributed around 65,000 head of cattle annually for national market. Cattle population in ENT in 2018 was 1,027,286 head [1]. In the last 5 years, cattle population grows around 3.75% per year which mostly contributed from the Bali cattle population. Government of ENT have programmed to increased population up to 2 million head of cattle in the next five year.

Besides its contribution to the ENT regional economy and to the farmers’ income, introduction and fast increase of cattle population have also blamed as main factor contributing to the environment problems in semi-arid area of East Nusa Tenggara. Therefore, fragile semi-arid ecosystem needs to be taken into consideration in cattle raising system.
Colonial (Dutch) government response forage shortage in semi-arid areas for cattle production system by introduced Leucaena forage in 1930s. This program has very much success in Amarasi region of Kupang Districts, however it very slow response outside of Amarasi. Until recently, Leucaena have distributed/dispersed across Islands in ENT, Leucaena as forage is mostly used by farmers in Timor, while in other Islands particularly in Flores Island mostly used as shadow tree for perennial estate crops (e.g. Coffea and cocoa).

This paper explores forage development, particularly Leucaena and the dynamics of upland farming management among farmer groups in West Timor – Indonesia. The paper organised into six main sections. After this Introduction, the next section discussed Methodology shortly. The next three sections discussed results of the research. The last section (Sixth) is a conclusion drawn from previous sections.

2. Methodology
The study was conducted in two villages (Camplong II and Oebola Dalam) of Fatule’u Sub-district, Kupang District. These two villages have been the ACIAR and AIAT-ENT collaboration research sites in forage development, particularly Leucaena. Farmers and farmers groups have chosen purposively based on the farmers’ involvement in the forage development. There are four farmers group voluntarily participated in the planting Leucaena such as Setetes Madu, Tunas Muda, Sabu Bani.

Farmers use two main systems in planting Leucaena such as monoculture in dominated rocky land, and alley cropping system in maize farmland. Survey method employed for data collection. Primary data collected from the farmers involved in planting Leucaena and use Leucaena forage for cattle development. Secondary data gathered from the previous forage research/report in ENT, Statistical Bureau and livestock Office reports. The authors’ involvement in related provincial cattle programs and experiences on forage development, particularly Leucaena in Timor were also used to enrich the narratives. Data and information analysed using simple statistics and descriptively.

3. Results and discussion
3.1. General information of the research sites.
Camplong II and Oebola Dalam villages are the two villages in the Fatule’u sub-district – Kupang District. The region of Fatule’u sub-district dominated with hilly and rocky landscape which limited food crops production. Bio-physical characteristics of both villages have almost similar: dominated rocky landscape, limited arable land suitable for food crops, low and erratic rainfall.

Total area of Fatuleu is 351.52 km$^2$ or 6.63% of the total district area. Total population of Sub-district Fatuleu in 2020 was 28,000 people that majority belongs to Meto ethnic group. General information of Fatuleu Sub-district and two villages of study sites shown in table 1.

| Item                  | Fatule’u Sub-district | Camplong II Village | Oebola Dalam Village |
|-----------------------|-----------------------|---------------------|----------------------|
| Number of Villages    | 10                    |                     |                      |
| Land area (km$^2$)    | 400.29                | 48.63 (12.15%)      | 19.00 (4.75%)        |
| Population            | 28,948                | 3,557               | 1,180                |
| Household             | 6,139                 | 880                 | 251                  |
| People forest land    | 4028                  | 1010                | 200                  |
| Cattle population     | 10,993                | 1531                | n.a                  |

Source: Fatuleu in Figures, 2020; Village (Camplong II and Oebola Dalam) Monograph.
The study area receives around 1500 mm/year rainfall during short period of December – March with the peak rainfall on January. Most farmers do upland farming with maize as main food commodity or staple, however some household have access for lowland rice outside of the villages or in nearby sub-district.

3.2. Leucaena forage and cattle production.

Ruminant livestock play important roles for livelihoods of people in marginal semi-arid areas. Although introduced later into semi-arid region of ENT, cattle are growing fast and become prominent among ruminant livestock. Cattle population in 2019 predicted closed to 1 million head. Indeed, present Provincial government wanted to double the present population to become two million head in the end of 2023. Herewith, forage will be a main constraint to be solved.

Since forage and by-products of crop production are essential for cattle production, it is crucial to improve upland farming management and incorporated forage into farming system [2], particularly Leucaena leucocephala both for forage and to improve soil quality. In the two research sites of Camplong II and Oebola Dalam villages, Leucaena planted in two different systems such as monoculture or dense population in dominant rocky land or unsuitable for food crops land, and alley cropping system in dominated soil land or suitable for food crops land. Monoculture Leucaena from the dominated rocky land becomes the main source of forage to feed cattle during long dry season.

Small-scale farmers in semi-arid environment of Timor Island have constantly facing low food crops production and forage shortage during long dry season. Within this semi-arid environment, Leucaena leucocephala have proven as the important source of forage for cattle production and ruminant livestock in general [3],[4]. Leucaena leucocephala is a long lived perennial legume tree. It is non-climbing, erect, thornless shrub or small tree, grow in arid and semi-arid areas. It is a multipurpose tree such as for food, forage, fuel wood, construction, shade and improve soil fertility [4],[5],[6]. The flexibility of their use makes them especially significant for smallholder subsistence farms and large-scale commercial farms alike [4].

Bali cattle were introduced to Timor Island from Java and Bali Islands in 1912 as part of the Dutch colonial government’s ‘Ethical Policy’. This policy aimed to strengthen Timor’s economy, both in terms of local beef consumption and beef exports to Java [7],[8]. Within 50 years of their introduction, the number of Bali cattle in West Timor increased to 108,000, effectively replacing the cultural and socio-economic roles of water buffalo [8],[7]. Bali cattle became the main commodity export from Timor to both Hong Kong and Singapore until the 1960s, after which domestic demand, primarily from Java, has dominated cattle marketing.

Good quality of cattle for export or inter-island trade has been mostly feed with Leucaena forage. Unfortunately, this Leucaena species have attached by Leucaena psyllid in 1980s that have negative impact to the cattle production and upland farming in general in ENT. To overcome the problem, new varieties of Leucaena was developed and one and very prominent in semi-arid area of ENT is Leucaena leucocephala Var. Taramba [6]. Nowadays, this variety is widely developed in ENT and beyond ENT province [6]. By reviewing successful adoption of forage tree legumes in farming systems, Shelton et al. [9] showed that successful adoption through a process of on-farm and participatory research was a consistent theme.

Since L. leucocephala Var. Taramba have been established by upland farmers in two villages of Camplong II and Oebola Dalam or when forage available enough, some investors does invest in cattle fattening by profit sharing arrangements with local farmers. Two farmers groups that established earlier were able to do bull fattening 86 head in last five year by profit arrangement and also do fattening for their own cattle. Following the successful of early adopter farmers in planting Leucaena, almost all farmers nowadays have planting Leucaena by their own initiatives for cattle and ruminant livestock production in general and as a new source of cash income by selling Leucaena forage particularly during the dry season. The number of bull fattening and sold by profit sharing arrangement showed in table 2.
Table 2. Number of bull fattening and sold by two farmers group in Camplong II Village.

| Item                                      | Farmers Group |
|-------------------------------------------|---------------|
|                                           | Setetes Madu  | Sabu Bani     |
| Started to plant Leucaena                 | 2014/2015     | 2015/2016     |
| Seed production up to 2020 (ton)          | 3             | 3             |
| No. of farmers involved in seed production| 15            | 15            |
| Bull Fattening in:                        |               |               |
| 2016                                      | 5             | 6             |
| 2017                                      | 20            |               |
| 2018                                      | 50            |               |
| 2019                                      | 3             |               |
| 2020                                      | 2             |               |
| Bull sold in:                             |               |               |
| 2016                                      | 5             |               |
| 2017                                      | 5             | 1             |
| 2018                                      | 20            | 30 *)         |
| 2019                                      | 23            |               |
| 2020                                      | 17            |               |

Source: Tabulated from In-depth interview.
*) Including farmers own cattle/bull fattened.

3.3. Leucaena forage and sustainable upland farming.

Food crops development in ENT is generally follow national food crops policy that emphasize in intensification by using external agro-inputs (chemical fertiliser, HYVs and pesticide) and extensification. While arable land for food crops in semi-arid areas is limited, intensification strategy is the only way to increase food production in ENT.

Implementation of intensification policy, particularly in application of chemical fertiliser is more reliable for wetland or irrigation crops lands, while it is less suitable for semi-arid upland in ENT that characterised low and erratic rainfall. Therefore, majority of upland farmers got less benefit of government support on fertiliser subsidy. Relying on chemical agro-input for food crops production in semi-arid areas is also disturbing balanced ecosystem of semi-arid areas.

Traditional practices are actually implemented by local farmers to overcome soil marginality or to maintain soil fertility for sustainable crops production in semi-arid areas at least for household’ self-sufficient. Previous government interventions on agriculture development, including on introduction of cattle have disturbing or changes traditional agriculture production systems and balanced ecosystem on semi-arid areas.

Since Bali cattle population increased and in the same time weed infestation of Lantana camara into pasture land, forage become the main problem for cattle development in semi-arid areas of East Nusa Tenggara. To overcome the forage problem, the Dutch introduced the tree legume Leucaena leucocephala, referred to locally as Lamtoro, in the early 1930s [7],[8],[10].

Leucaena planting in Timor began in Amarasi subdistrict [8],[7] and it has been considered as main adopted innovation to provide forage for cattle raising and improve/transforming traditional upland farming in Amarasi region of Timor Island. Introduction of forage (Leucaena) innovation through social system/local rulers become the key success for widely adoption of forage innovation in Amarasi region as Metzner [11] points out: “the great authority of the local traditional leader of adat (local customary law) who succeeded in maintaining a remarkable discipline among the inhabitants of Amarasi was essential” to this transformation.

To make sure that Leucaena innovation implemented, local ruler (Raja) made an adat regulation in 1932 that all farmers must plant Leucaena spaced three metres apart along the contour lines of swidden plots before the plots were fallowed. A further adat decision was made in 1938 to zone land to separate
livestock from farming. Zoning allowed the farming plots to be clustered and communally fenced. Farmers were thereby freed from the task of fencing crops against cattle encroachment that, according to Ormeling [7] consumed 25-30% of famers’ labour.

Since Leucaena started introduced in Amarasi region, this legume tree *Mutatis mutandis* spread across Timor Island and other Islands in ENT province. The existence of Leucaena allows Amarasi farmers to do cattle fattening system and enable them to improve maize production and upland farming in general. Nevertheless, the use of Leucaena outside of Amarasi region is quite vary like to improve soil fertility for maize and upland rice in TTU and mainly as shadow tree for estate crops in Flores Island.

After almost 50 years well established, Leucaena in Timor was attacked by Leucaena psyllid (*Heteropsylla cubana*) in the early 1980s. As the cattle fattening system have been heavily relying on Leucaena forage, this psyllid has deteriorated cattle raising system, particularly fattening system in Amarasi region and Leucaena based upland farming in Timor. According to Lach [12], Leucaena psyllid (*Heteropsylla cubana*) resulted in decreased plant growth and seed production by 22% and 35%, respectively.

To overcome the psyllid problem in Timor, ACIAR with collaboration with AIAT-ENT have developed psyllid resistance Leucaena. One of the promising new introduced *Leucaena leucocephala* var. Taramba. According to Nulik et al. [6], the superiority of *L. leucocephala* var. Taramba is preferred by cattle over local leucaena; was less affected by psyllids; provided better dry season growth; and produced poles suitable for construction.

| Aspect/s                        | Before                                      | Present                                      |
|---------------------------------|---------------------------------------------|----------------------------------------------|
| Dominant upland farming practices | - Shifting Cultivation                      | - More permanent farming                     |
|                                 | - Use fire for land preparation             | - Less or no fire used for land preparation  |
| Barren/dominant rocky land       | Abandoned/grazing land                      | Main plot for monoculture Leucaena plant/main source of forage. |
| Maize production                | Low and sometimes fail to harvest           | High and guarantee to harvest                |
|                                 | Deficit for household consumption.          | Surplus and enable to sell excess production.|
| Cattle Production System        | More extensive system.                      | More extensive system/fattening.             |
|                                 | More extensive system/fattening.            | Cattle gain weight even during long dry season. |
| Capacity for fattening/HH       | 1 – 2 head                                  | 3 – 7 head                                   |
| Fattening period                | 9 – 18 month                                | 4 – 6 month                                  |
| Investment/financing            | None                                        | Yes:                                         |
|                                 |                                              | - Village Infrastructure (road, water).      |
|                                 |                                              | - Private business (profit sharing for cattle fattening). |
|                                 |                                              | - Credit from the Bank (KUR).               |

Source: FGD and field observation.
Success story of farmers groups involved in *L. leucocephala* var. Taramba in two villages and other farmers in some areas of Timor Island, have encouraging other farmers, government institutions and NGOs to develop and disseminate related Leucaena forage innovations. Hau and Nulik [13] reported that since 1915 *L. leucocephala* Var. Taramba have been planted under farmers own initiatives around 500 ha in two villages of *Camplong II* and *Oebola Dalam*. The Leucaena seeds have been distributed to other Districts in ENT province and other provinces and neighbouring State of RDTL as well.

Establishment of *L. leucocephala* Var. Taramba in two villages helps farmers to eliminate shifting cultivation practices and to improve crops production, particularly maize in the upland farming. By planting Leucaena, forage available enough that allows farmers to do cattle fattening or minimize traditional cattle raising system that heavily dependent on grazing land or forest.

Under the traditional upland farming practices, maize productivity before Leucaena introduced was only $\pm 1.0$ ton/ha. After Leucaena introduced and implementation Conservation Agricultural (CA) practices, maize productivity of farmers in both research sites was increased more than doubled (3.8 ton/ha). Some farmers who implemented Permanent Planting Holes (PPH) and using compost/cattle manure for planting maize have able to plant maize during the dry season and got reasonable maize productivity (2.6 ton/ha) which never practiced before Leucaena established [14].

Using Leucaena forage for cattle fattening have significant impact to increase cattle body weight and shortening fattening period. An economic analysis of a leucaena-fattening system in a village in West Timor conducted by Waldron et al. [15] showed that feeding cattle with Leucaena is profitable enough. Forage improvement by introducing Leucaena has positive impact for food crops intensification and improvement of upland farming ecosystem. Beside maize as staple planted, some farmers were able to plant vegetables crops during dry season which never experienced before. Using fire for land preparation has almost eliminated from the land dominated planted with Leucaena. Leucaena forage legume have positive impact of environment in terms of improving soil fertility/soil properties (symbiotic nitrogen fixation), high nutritive value and deep-reaching tap-root system [16], [17]. As [18] pointed out that “Improved forages can lead to the sustainable intensification of mixed crop-forage-livestock-tree systems in the tropics by producing multiple social, economic and environmental benefits. Sustainable intensification not only improves the productivity of tropical forage-based systems but also reduces the ecological footprint of livestock production and generates a diversity of ecosystem services (ES) such as improved soil quality and reduced erosion, sedimentation and greenhouse gas (GHG) emissions.”

4. Conclusion

Ruminant livestock, particularly cattle play important roles in for livelihoods of people in marginal semi-arid areas. Nevertheless, forage shortage during the long dry season limited cattle production. Since forage and by-products of crop production are essential for cattle production, it is crucial to improve upland farming management and incorporated forage into farming system. The existence of Leucaena allows upland farmers to do cattle fattening system and enable them to improve maize production and upland farming in general. Nevertheless, as the cattle fattening system have been heavily relying on Leucaena forage, Leucaena spilled has deteriorated cattle raising system, particularly fattening system and Leucaena based upland farming in Timor.

The existence and adoption of new introduced Leucaena variety (*L. leucocephala* Var. Taramba) have solved forage shortage problem during long dry season in semi-arid region of Timor Island, it allow farmers to do cattle fattening/shortening fattening period and improving crops (maize) production and improving upland farming environment.

Acknowledgments

The authors would like to thanks to ACIAR’s forage research technicians for data collection. Thanks also for all farmers group in Camplong II and Oebola Dalam villages for providing the Tim with data and information during the research program. We also thank Village apparatus for providing village Monograph data. Any remaining errors are authors’ responsibility and they have equal contribution in writing and publishing this paper.
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