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Is Mulching a Cost-Effective System? A Case Study of Pineapple Farms in Togo, West Africa

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Abstract: One of the major constraints on agriculture in sub-Saharan Africa is the steady decline in the level of soil fertility and, consequently, crop yields. In this study, we assessed the impact of the application of grass mulch on the productivity, net income, soil parameters (soil organic carbon, pH, phosphorus, potassium, nitrogene, conductibility, moisture and bulk density) and plant biodiversity of pineapple-based systems in the ecovillage of Donomadé in Togo. Three systems were assessed: mulched pineapple from a local model farm, mulched pineapple from farmers who adopted the model farm system and non-mulched pineapple. Production-related data (e.g., number of plants, the number of productive individuals, and the harvested mass of edible products) were obtained. These measurements were combined with semistructured individual interviews with the producers on the history of the plots and production costs in order to assess the plots' profitability. Fruit production in the mulched plots (21,240 ± 11,890 kg/ha) was three times higher than that in the non-mulched plots (7840 ± 7890 kg/ha), corresponding to two-thirds of the model farm's production (33,838 ± 9460 kg/ha). The net incomes of the model farm and the mulched plots were 11 and 8 times higher than those of the non- mulched plots, respectively. Overall,except for the pH and the moisture, there was no significant diffenrence in soil parameters between the three cropping systems. The lowest pH and the highest moisture were found in the model farm. The highest pH and the lowest moisture were found in the mulched plots. The mulched plots had the highest diversity of associated crops and weeds (24 and 90 species, respectively), whereas lower values were found in the model farm plots (18 and 64 species, respectively).

Keywords: pineapple (*Ananas comosus*); sustainable production; alternative systems; Donomadé ecovillage; Togo

1. Introduction

The steady decline in soil fertility, combined with inadequate cropping systems, is one of the major constraints on agriculture in sub-Saharan Africa [1,2]. Declining soil fertility is a consequence of the overexploitation of land, which is driven by a growing population and the prevalence of inappropriate practices (e.g., slash and burn, short fallow periods and the preference for monocropping systems) [2–4]. Land degradation and population growth in sub-Saharan Africa have also led to farmland encroaching on forests [5,6]. To overcome this decline in crop productivity, water-soluble mineral fertilisers and synthetic pesticides are increasingly being used. However, these inputs are expensive [7,8] and can be harmful to human and environmental health [9–11].

Studies in agroecology have shown that the need for food for a growing population can be reconciled with the conservation of natural resources [12]. Such studies have shown how the adoption of agroecological practices (use of mulch, organic manures, biochar, cover crops, livestock manure, etc.) can improve the nutritional quality and shelf life of crops, soil health, biodiversity and the sustainability of agricultural land [4,7,11,13–15]. Although agroecology has been shown globally to address environmental and social issues [11,15], its monetary impact has not been sufficiently demonstrated in low-income countries in West Africa.

Many sustainable cropping systems have been tested in both pilot stations and farmers' plots [4] as alternatives to water-soluble mineral fertilisers and synthetic pesticides [11,16]. These innovative systems are usually based on crop rotation and the use of natural fertilisers, cover crops, legumes and mulching [4,17–20]. Mulching can improve production by reducing evapotranspiration, weeds and temperature; promoting microbial biomass, soil enzyme activities, soil aggregate stability and soil organic carbon (SOC); and increasing nutrient recycling [21,22]. Mulching is also known to improve the physical properties of soil, such as bulk density [23]. Bulk density is a physical parameter of soil that directly affects root development and is therefore likely to affect crop development and productivity.

The Donomadé ecovillage (a rural community with a vision of self-sufficiency based on three pillars: an alternative economic model, a focus on ecology and active community living) in southern Togo has been the site of a model farm. The model farm of Donomadé (FeMoDo) promotes grass mulching in pineapple systems. This mulching system can be used as an alternative response to soil fertility depletion in the area [24]. Understanding the impact of this mulch-based system on soil fertility, plant biodiversity and crop production at the plot and household level can help to scale up this practice to improve household livelihoods while conserving natural resources.

Is grass mulch a cost-effective system? How does grass mulch affect yield, SOC, bulk density and weed diversity? The aim of this study was to assess the multidimensional potential of mulching to improve crop production and increase household economic stability in West Africa. Specifically, we aimed to (i) quantify productivity, (ii) assess profitability, (iii) determine the impact of mulching on soil parameters: soil organic carbon, pH, phosphorus, potassium, nitrogene, Electrical conductibility, moisture and bulk density, and (iv) assess the phytodiversity of associated crops and weeds within the pineapple cropping systems of Donomadé ecovillage in Togo.

2. Materials and Methods

2.1. Description of the Study Area

Donomadé ecovillage is approximately 130 km from Lomé, the capital of Togo, West Africa (Figure 1) [25]. It is also a frontier village in the southern part of the Togodo Protected Areas Complex. In 2015, the Donomadé Model Farm (FeMoDo) was set up in Donomadé. Since its establishment, FeMoDo has promoted pineapple (*Ananas comosus* (L.) Merr.)- and passionfruit (*Passiflora edulis* Sims)-based agroforestry systems that use a mulch layer of cut grasses. Mulching consists of the complete covering of the ground with a carpet of grass. Therefore, it is not ploughed or tilled. Two varieties of pineapple are grown: the smooth Cayenne and the Brazza. Pineapple and passionfruit are cash crops. They are usually intercropped with other crops (e.g., maize, soya bean, cowpea, tomato and groundnut). The three main species used for mulching are *Pennisetum purpureum* Schumach., *Imperata cylindrica* (L.) P. Beauv. and *Panicum maximum* Jacq, all of which are from the Poaceae family. A total of 48 pineapple growers have adopted this mulching system to date.

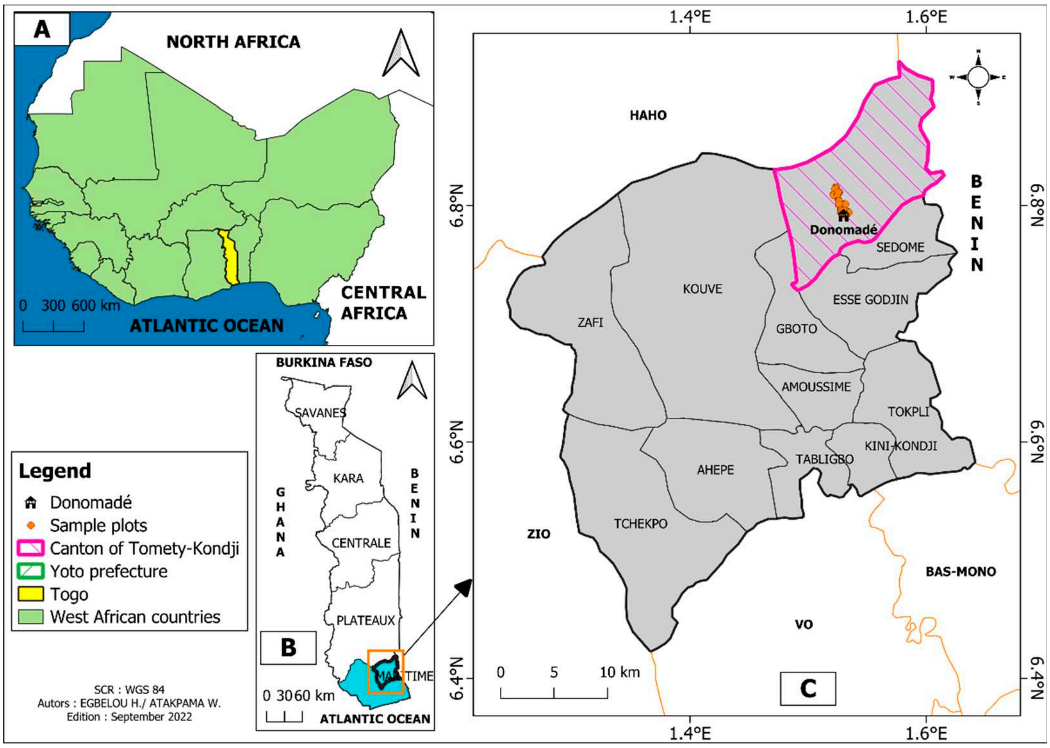

Figure 1. Location of the Donomadé ecovillage in Togo, West Africa: (**A**) Togo in West Africa; (**B**) Regions of Togo and the location of the Prefecture of Yoto; (**C**) Donomadé ecovillage in the canton of Tomety-Condji.

The topography of the area is flat. This soil has been degraded by intensive and slash-and-burn agriculture. The climate is subequatorial Guinean with two rainy seasons (March to July and September to October) and two dry seasons. Several crops can be grown in this climate. However, soil fertility is still low. This leads to low crop productivity. The low productivity of these crops increases the vulnerability of the population [24]. Maize, cassava and groundnut are the main crops grown in the area.

2.2. Productivity and Profitability Assessment at the Pineapple Plot Level

A total of 40 plots were selected and sampled according to three levels of pineapple cropping systems. The first level (n = 16) consisted of mulched pineapple plots managed by FeMoDo, which have been mulched since 2016 (Figure 2). The second level (n = 16) included plots managed by farmers who have been implementing the FeMoDo mulching system since 2018. The third level (n = 8) comprised non-mulched system. The non-mulched plots are ploughed before cultivation and during weeding. Plant residues are also burned before tilling the land. Samples were taken from a 10 m × 10 m (100 m^2) square to estimate crop yield, the total number of pineapple stems and the number of productive pineapple plants.

Figure 2. Field assessment within a plot mulched with *Pennisetum purpureum* Schumach.

Yield was estimated for different crops grown on the pineapple plots using a two-digit precision balance. Pineapple fruits were weighed directly in the field. Eight other crops were estimated in the mulched plots: maize (*Zea mays* L.), oil palm (*Elaeis guineensis* Jacq.), plantain (*Musa paradisiaca* L.), sweet banana (*Musa sapientum* L.), cassava (*Manihot esculenta* Crantz), cocoyam (*Xanthosoma mafaffa* Schott), tomato (*Lycopersicon esculentum* Mill.) and sugar cane (*Saccharum officinarum* L.). Seven crops were included in the FeMoDo plots: maize, oil palm, plantain, sweet banana, cocoyam, lemongrass (*Cymbopogon citratus* (DC.) Stapf) and pawpaw (*Carica papaya* L.). For the non- mulched plots, three crops were taken into account: groundnut (*Arachis hypogea* L.), plantain and tomato. The considered crops were those with a market value. For groundnut and maize, harvested seeds were sundried and then weighed.

Gross profitability was determined by estimating the sales revenue of all crops grown on the pineapple plots. For pineapple, the prices used in this study were 125 F CFA/kg for the smooth Cayenne variety and 115 F CFA/kg for Brazza.

The net income of crops was calculated by subtracting the production cost of the total value of the crops grown in association with pineapple. Crop production costs included ploughing; purchase of seeds; and labour for planting, mulching, weeding and crop harvesting/packaging. These estimations were derived from semistructured interviews [26] with household heads and the FeMoDo farm manager.

2.3. Assessment of the Impact of Mulching System on Soil Parameters

Individual soil samples were taken from the abovementioned plots in July 2021. The sampling depth was 0–30 cm. Five subsamples were taken from each plot in 1 m × 1 m subplots and mixed with one composite sample obtained from the five samples. Eight soil parameters were assessed: pH, phosphorus (P, mg/kg), potassium (K, mg/kg), nitrogene (Total N, mg/kg), Electrical conductibility 1/5 (EC, µS/Cm), humidity, bulk density (BD, g/cm^3) and organic carbon (SOC, t C/ha). A 3–8 SDT-60/ SDT-300 handheld digital soil pH moisture meter was used to assess soil pH and water content on 24 July 2021. The SOC was measured in the laboratory using a TA-1.0 total organic carbon (TOC) analyser. Analysis was performed in line with ISO 10694 (ISO, 1995). Each sample was analysed in

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triplicate, and the average was reported. The mean values of the others soil parameters were estimated according to the different treatments investigated in this study. A one-way ANOVA was performed to test the significant differences between means. These analyses were performed with R 4.2.2 software.

2.4. Assessment of the Diversity of Associated Crops and Weeds at the Plot Level

Considered ecological parameters were plant species occurrence and abundance. Each plant present within each plot was recorded and described by the abundance/dominance coefficient [27]. This scale has six levels: + (rare or very rare individuals and very low cover—less than 1%); 1 (fairly abundant individuals but low cover—less than 15%); 2 (very abundant individuals—at least 25% cover); 3 (any number of individuals—25 to 50% cover); 4 (any number of individuals—50 to 75% cover); and 5 (any number of individuals—more than 75% cover). Two kinds of plants were defined directly in the field with the help of owners: crops and weeds. Plants considered weeds were classified into four types: invasives/aliens, fertilisers, agroforestry trees and other plants [6,28]. Fertiliser plants are mainly from the Leguminosae. They enrich and improve the soil structure.

The cover of herbaceous plants and the canopy were estimated using the Canopeo application installed on a smartphone [29]. This application classifies image pixels into two categories: green cover (e.g., herbaceous canopy and grass) is indicated in white and everything else is denoted by black pixels.

The frequency and spatial representativeness of crops associated with pineapple were estimated using the Braun–Blanquet coverage scales [27]. The coefficients +, 1, 2, 3, 4 and 5 were replaced by 0.5, 7.5, 12.5, 37.5, 62.5 and 87.5, respectively. For a given scale, the corresponding value (x) is defined by the relation $x = (a + (b - a))/2$, where a = the lower-limit value, and b = the upper-limit value. For each species recorded in each target cropping system, the mean abundance corresponds to the sum of all abundance values divided by the number of plots. Then, the percentage of cover was calculated based on the obtained value.

The species richness (Rs), Shannon diversity index (H') and Pielou index (E) were used to assess the plant diversity of each cropping system [30,31]. Species richness is the number of species present in the target cropping system. H' ranges from 1 to 5. For single-species stands, H' is 0. In heterogeneous stands, H' is maximal when all species are equally abundant ($H'max$ = log2(Rs)). E corresponds to the ratio between the observed diversity and the logarithm to base 2 of the species richness (Rs) (E = $H'/H'max$) and has a value between 0 and 1. A value near 0 indicates a poor distribution of species, whereas a value near 1 indicates an even distribution of species. The Sorensen index (SI) [32] was used to measure the degree of species similarity between cropping systems and was assessed using the Community Analysis Package, CAP 2.15 software. The Sorensen index (SI) is defined as follows: SI = 2C/(A + B), where A and B are the numbers of species specific to the two cropping systems (A and B, respectively), and C is the number of species common to the two cropping systems.

3. Results

3.1. Impact of Mulching on Pineapple Crop Productivity and Profitability

The pineapple density in the FeMoDo system (4.23 ± 1.13 plants/m^2) was twice as high as in the mulched plots (2.03 ± 0.90 plants/m^2) and almost three times as high as in the non-mulched plots (1.51 ± 0.51 plants/m^2). The productivity per hectare was highly correlated with the density (p = 0.00). Fruit productivity was three times higher in the mulched plots (21,240 ± 11,890 kg/ha) than in the non-mulched plots (7,840 ± 7,890 kg/ha). Productivity in the FeMoDo plots was higher than that in the mulched plots: 33,838 ± 9,460 kg/ha (Figure 3). The one-way ANOVA Fisher test showed that there was no significant difference in yield per plant (p = 0.36). The yield was 1.15 kg/plant in the mulched plots and 1.07 kg/plant in both the FeMoDo and the non-mulched plots.

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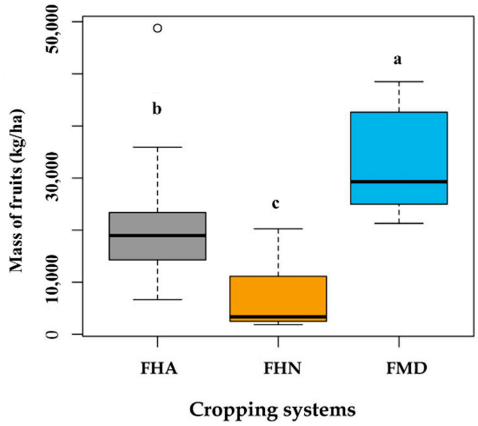

Figure 3. Mass of pineapple fruits in the three pineapple cropping systems in Donomadé ecovillage, Togo. FHA = mulched plots, FHN = non-mulched plots, FMD = FeMoDo, a = Highest, b = middle, c = lowest, white circle = outlier symbol.

A significant difference was recorded in terms of the production cost of pineapple between the FeMoDo plots and the other two types of pineapple growing plots (*p* = 0.00). The cost of producing 1 ha of pineapple was highest for FeMoDo (2,686,167 ± 438,819 CFA/ha), followed by mulched plots (902,529 ± 372,756 CFA/ha) and non-mulched plots (587,800 ± 175,687 CFA/ha). Net income did not differ significantly between mulched plots and FeMoDo but did differ between the mulched and non-mulched plots (*p* = 0.04) (Figure 4). The net income per 1 ha of FeMoDo (1,148,917 ± 873,997 CFA/ha) was higher than that of mulched plots (832,294 ± 672,125 CFA/ha) and non- mulched plots (107,225 ± 596,309 CFA/ha).

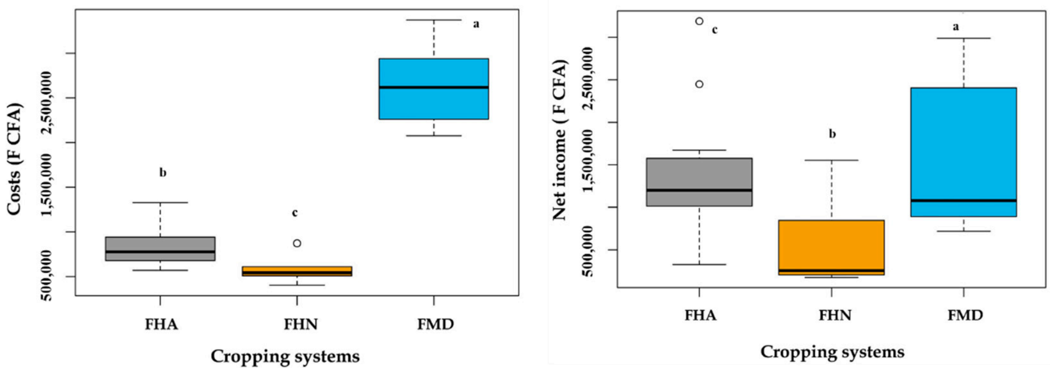

Figure 4. Comparison of costs and net income of the pineapple crop of the Donomadé ecovillage in Togo. FHA = mulched plots, FHN = non- mulched plots, FMD = FeMoDo, a = Highest, b = middle, c = lowest, white circle = outlier symbol.

Considering crops associated with the pineapple, there was no significant difference in terms of income (*p* = 0.91). All associated crops brought in an additional profit of 127,127 ± 123,381 CFA/ha and 11,991 ± 96,924 CFA/ha within the FeMoDo and mulched plots relative to 96,250 ± 51,265 CFA/ha for the non-mulched plots.

3.2. Impact of Mulching on Soil Parameters

The highest soil moisture level was observed in FeMoDo plots (moisture = 28.62 g water/100 g wet soil). For the other systems, the soil moisture was higher in the non-mulched plots (moisture = 21.25 g of water/100 g of wet soil) and lower in the mulched plots (moisture = 18.00 g of water/100 g of wet soil). Moisture was significantly different between the three cropping systems (*p* = *0.01*), especially between FeMoDo and the mulched plots. The pH also differed significantly (*p* = *0.01*). It was higher in mulched and lower in FeMoDo plots (Table 1).

Regarding soil organic carbon (SOC), there was no significant difference between FeMoDo, mulched and non-mulched plots (p = 0.99). SOC values were 36.03 ± 16.19 t C/ha, 36.21 ± 16.31 t C/ha and 36.41 ± 16.27 t C/ha in FeMoDo, mulched and non-mulched plots, respectively. The trend remained the same when considering the bulk density (p = 0.29), with values of 1.18 ± 0.22 g/cm^3, 1.18 ± 0.21 g/cm^3 and 1.26 ± 0.25 g/cm^3 for FeMoDo, mulched and non-mulched plots, respectively (Table 1).

The highest mean values for phosphorus (3.82 ± 7.15 mg/ha) and electrical conductivity 64.86 ± 40.53 PS/Cm) were found in the mulched plots. The non-mulched plots had the lowest values (Table 1). In contrast the FeMoDo plots had the highest K amount while the lowest corresponds to the non-mulched plots. For the total N, the highest amount was obtained from the non-mulched plots (0.16 ± 0.24 mg/ha) and the lowest from the mulched and FeMoDo plots (0.07 ± 0.01 mg/ha). The four parameters (P, K, N and EC) were not significantly difference (Table 1).

Table 1. Soil parameters values in the three pineapple cropping systems of Donomadé ecovillage in Togo.

	FeMoDo	**Mulched plots**	**Non-mulched plots**	p	F
Total N (%)	0.07 ± 0.01	0.07 ± 0.01	0.16 ± 0.24	0.11	2.34
P (kg/ha)	3.38 ± 2.63	8.55 ± 16.02	2.95 ± 2.59	0.31	1.20
K (kg/ha)	184.55 ± 72.94	171.44 ± 87.88	144.77 ± 78.76	0.56	0.60
EC (µS/Cm)	61.14 ± 19.99	64.86 ± 40.53	54.74 ± 18.09	0.76	0.28
pH	6.19 ± 0.36	6.56 ± 0.31	6.34 ± 0.30	0.01	5.02
SOC (t C/ha)	36.03 ± 16.19	36.21 ± 16.31	36.41 ± 16.27	0.99	0.01
Moisture (%)	28.62 ± 12.45	18.00 ± 7.00	21.25 ± 8.07	0.01	4.90
BD (g/cm^3)	1.18 ± 0.22	1.18 ± 0.21	1.26 ± 0.25	0.29	1.27

3.3. Crops Associated with Pineapple

Each pineapple-based cropping plot had several crops associated with it. A total of 24 crops were observed in the mulched plots, with 18 associated crops for both the FeMoDo and non-mulched plots. In terms of the number of associated crops per plot, the average for both FeMoDo and mulched plots was five associated crops per plot, and for non-mulched plots, the average was four associated crops per plot. All cropping systems shared 57.14% of associated crops in common. There was more similarity between the associated crops of mulched and non-mulched plots (SI = 0.67) than between those of non-mulched and FeMoDo plots (SI = 0.57). The SI between FeMoDo plots and mulched plots was 0.63. The distribution of crops associated with the three targeted pineapple growing systems is shown in Figure 5.

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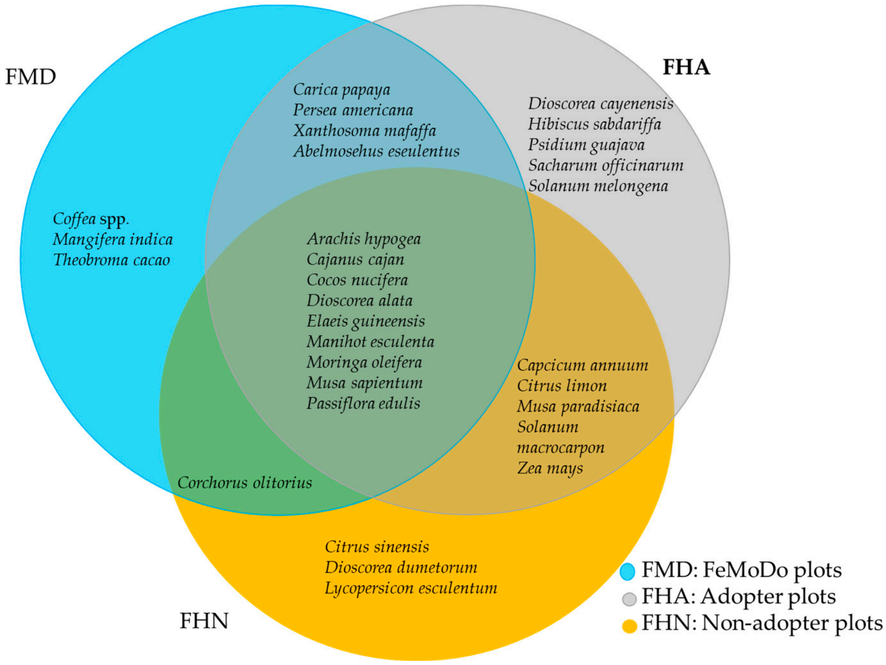

Figure 5. Distribution of associated crops according to the three pineapple cropping systems.

Maize and oil palm were the most dominant associated crops in the mulched plots, covering 16.83% and 16.39%, respectively, followed by pigeon pea, plantain, cocoyam, cassava, sugar cane and okra, covering 11.70%, 10.00%, 10.00%, 7.80%, 7.50% and 07.50%, respectively. Other crops accounted for less than 7%. Groundnut and oil palm were the most dominant associated crops found in the non-mulched plots, covering 44.00% and 27.50%, respectively. The other crops occupied less than 8%. Within the FeMoDo plots, the most associated crops were oil palm, cocoyam, passion fruit and pawpaw, occupying 30.64%, 23.50%, 19.00% and 15.72%, respectively. Sweet plantain, mango tree, moringa and pigeon pea were moderately represented, covering 11.83%, 11.00%, 09.83% and 08.25%, respectively. The other crops accounted for less than 6%.

3.4. Diversity of Weeds

The herbaceous cover was lower in FeMoDo (25.74%) than in the other plots, covering 50.73% in the mulched plots and 55.31% in the non-mulched plots. Canopy cover was more significant in FeMoDo and mulched plots (18.87% and 18.27%, respectively) than in non-mulched plots (1.78%).

The most diverse plots were the mulched plots (Table 2), followed by the non-mulched plots. The Sorenson index (SI) showed a higher degree of similarity between the three cropping systems. Each cropping system shared 62% of plant species, with more similarity between the species recorded within the non-mulched plots and the FeMoDo plots (IS = 0.72) than between the FeMoDo plots and the mulched plots (SI = 0.62). The similarity between the mulched and non-mulched plots was 0.68.

Table 2. Important diversity indices in the three pineapple cropping systems of Donomadé ecovillage in Togo.

	Species Richness (Rs)	Shannon Diversity (Rs, bit)	Pielou Index
FeMoDo	64	4.84	0.81
Mulched plots	90	5.35	0.82
Non-mulched plots	70	4.74	0.75

The most spatially represented weed species in the non-mulched and the mulched plots were invasive/alien species (65.07% and 31.91% respectivily). The three most common in the mulched plots were: *Euphorbia heterophylla* L. (7.90%), *Tridax procumbens* L. (6.77%), and *Mariscus cylindristachyus*

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Steud (5.00%). By far the most abundant was *T. procumbens* (29.36%), followed by *Rottbellia exalata* L.f. (04.49%), *M. cylindristachyus* (3.99%). In contrast, within the FeMoDo plots, agroforestry trees were prominent. Overall, agroforestry trees were most abundant in the FeMoDo plots, followed the mulched and non-mulched plots (Figure 6). The trees most prominent agroforestry trees in FeMoDo were: *Albizia chevalieri* Harms (09.88%), *Senna siamea* (Lam.) H.S. Irwin & Barneby (08.49%), *Margaritaria discoidea* (Baill.) Webster (05.90%). In terms of diversity, the mulched plots contained 14 agroforestry tree species, followed by the FeMoDo (12) and non-mulched plots (9).

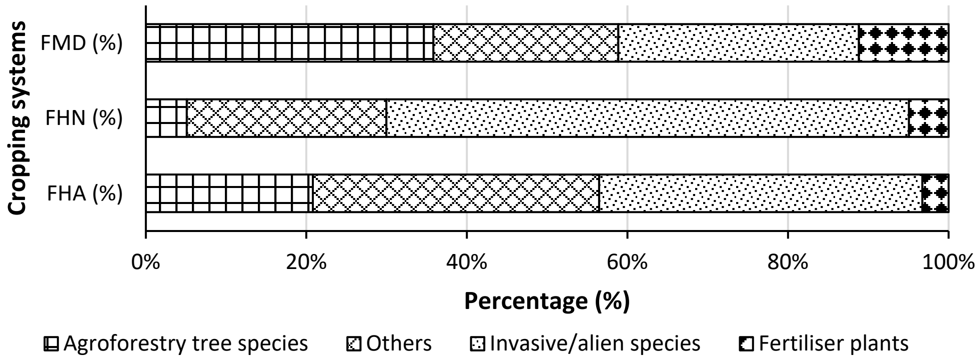

Figure 6. Abundance of weeds in the three pineapple cropping systems of Donomadé ecovillage in Togo. FMD = FeMoDo, FHA = mulched plots, FHN = non-mulched plots.

4. Discussion

The pineapple productivity per hectare of FeMoDo was comparable to that previously reported for the study area [33]. In contrast, all three targeted pineapple production systems have yields lower than those found in hilly Assam, India, where yields are approximately 36.5t/ha [34]. This was due to soil fertility and the density of the pineapple plants. Especially in this study, FeMoDo plots with more yield are twice denser than mulched plots.

The costs of cultivation for mulcheds and non-mulcheds found in this study were lower than those reported for Allada District, Benin (1,600,000 to 2,500,000 F FCA) [35], whereas those of FeMoDo were slightly higher. In Allada, pineapple is grown with chemical fertilisers, which represent additional costs that did not apply in the case of mulched and non-mulched plots in Donomadé. For FeMoDo, mulching and weed control were more expensive than for mulched plots. The net income of non-mulched plots was lower than the average income reported in [35] in Allada (560,000 to 980,000 FCFA). In contrast, the net income of the mulched plots and that of FeMoDo was higher that reported in Allada. The use of mulch can explain the variation observed between the mulched and unmulched plots. However, the difference in the productivity and the net income between the FeMoDo plots and the mulched plots was due to the density of the pineapple stems.

The results show that the use of mulching was more costly than the conventional system. The high cost was mitigated by the net income, which was higher in the mulched and FeMoDo plots than in the non-mulched plots. The potential economic and biophysical benefits of mulching [22] make it attractive. However, its high cost is the main reason for its low adoption by farmers.

In West Africa, other than for cash crops, monocropping practice is not very widespread among farmers. Many associated crops are often found in the same plot. This practice helps to maximise income by reducing production costs. Combining pineapple with Leguminosae such as pigeon pea and a layer of mulch might also improve soil aggregation, stability and fertility [18,20,36].

Overall, the soils in the pineapple fields of Donomadé are non-saline (EC < 1000µS/cm) and have an acidic pH (6.1-6.5) [37,38]. This is favourable for plant nutrition. Soils have low exchangeable potassium (101 - 200 kg/ha) and relatively low assimilable phosphorus (51 - 100 kg/ha) [39]. Only the unmulched site had high nitrogen levels (> 0.08). The other two sites had low levels [40]. Potassium and nitrogen were well known to help plants grow [41]. Therefore, the development of the crops grown was adversely affected by their low levels.

The SOC and bulk densities found in this study were consistent with SOC contents reported for tropical soils [42–44]. The amount of SOC in the study area was higher than that reported in Allada croplands in southeastern Benin (28.8 ± 2.6 t C/ha) [44] and in Ethiopian [43] croplands and coffee plantations. According to these studies, cultivation leads to carbon loss.

Bulk density has been shown to decrease with litter availability [43], which could explain the slight increase in bulk density within the non-mulched plots compared to the other two cropping systems using grass mulch. This finding is consistent with a study conducted in Assam, a hilly region of India [34]. This study reported a decrease in bulk density with mulching within the pineapple production area. Bulk density was also shown to be higher in croplands than in coffee plantations in the valley rift of Ethiopia [43].

The use of grass mulch has previously been shown to regulate soil temperature, reduce crop evapotranspiration and increase water use efficiency in okra crop agriculture in Nigeria [22]. Herbaceous weed development is also dependent on the soil cover, which was higher in the FeMoDo cropping plots. Mulching can contribute to a reduction in weed development, which can consequently reduce the labour required for weeding. This finding corroborates previous studies that highlighted the weed control benefits of mulching in crop production [14,45,46].

By weed type, FeMoDo and mulched plots have more agroforestry trees. Agroforestry trees have been shown to be beneficial for soil moisture, soil biological activity, soil biodiversity and fertility parameters [47,48], and thus for productivity. Agroforestry trees also contribute economic, social, health and environmental benefits through their fruits, timber and plant parts. A number of researchers have emphasised the importance of various trees in West African farming systems [48–52].

Invasive/alien species were most abundant in the un-mulched plots. In contrast, weed diversity is higher in mulched than un-mulched plots. The Pielou index showed that weeds were more evenly distributed in the mulched than in the unmulched plots. A more even distribution and a more diverse weed community has been shown to reduce the competition between weeds and crops and thus to mitigate crop yield losses [53]. Besides the most represented invasive/alien species reported in this study, new harmful species to crop production have been reported in recent years in Togo [6,54]. The development of these species is mostly attributed to the use of herbicides as a weed control tool in agro-systems [53].

5. Conclusions

In the present study, we evaluated the effect of a grass mulch system on productivity, income, weed development, pH, potassium, phosphorus, nitrogen, electrical conductivity, moisture, soil organic carbon and bulk density in pineapple-based cropping systems. The finding showed that grass mulch is beneficial for pineapple production. However, its application is more costly than the conventional pineapple system. Despite its high cost, mulching of pineapple can improve incomes. In addition, grass mulch benefits the crop by maintaining soil moisture and reducing weeds. Overall, the assessment of soil parameters showed that there are low levels of soil nutrients for crop growth in Donomade, especially potassium, phosphorus and nitrogen.

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