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Climate situation and measure of sustainable land management with agroforestry system, adoption and benefits perceived by farmers: Case of the Mafele village, Bougouni region in Mali

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Abstract

The climate of the Bougouni region is tropical dry with a rainfall greater than 1100 mm / year. The climate has been characterized since the 71s by a great interannual variability of rainfall. Over the period 1984-2022, Rainfall deficits were recorded in 1988, 2002, 2009 and 2017 with an average of 850 mm. This situation is linked to climate change, which is a major handicap for development. We encountered in Mafele village, natural agro-forestry system dominated by *Butyrospermum parki*, *Parkia biglobosa*, and *Tamarindus indica*. This group consists of natural *Butyrospermum parki*, *Parkia biglobosa* and *Tamarindus indica* species that are associated with annual cultivation (cotton, maize and sorghum). It is more simply the agricultural plots on which scattered trees are present. Semi-natural agro-forestry system dominated by *Butyrospermum parki*, *Mangifera indica*, and *Anacardium occidental* trees. Despite the presence of natural species in this group which is *Butyrospermum parki*, the farmer has himself planted some *Mangifera indica* and *Anacardium occidental* trees, which are associated with the annual crop (cotton, maize, rice). In the Agro-sylvo-pastoral system, the animals that are housed and fed by fodder gathered in the fields, in return the organic manure of these animals are taken to the field whose plants (cotton, maize, rice) benefit for their good growth. These trees encountered in the three systems play an ecological function or a complementary production function. Many Sustainable land management (SLM) measures was practiced such as: Manure spreading, crop rotation in the fields, growing legumes, fallow, crop residue management.

Keywords: Agroforestry, Climate change, Mafele, Rainfall, Sustainability.

1. INTRODUCTION

Climate change is real in Mali, where the population and economy are mainly dependent on agriculture, livestock and fishing. Mali will face a sharp temperature increase of 2°C in 2050 and 4°C in 2100 [2] . The climate of the Bougouni region is tropical dry, called "South Sudanian", with a rainfall greater than 1100 mm / year. The climate has been characterized since the 71s by a great interannual variability of rainfall. Over the period 1995-2004, the total annual rainfall in Bougouni varied from 1437.5 mm to 871.3 mm [3]. This situation is linked to climate change, which is a major handicap for development. Agroforestry is considered as one of the ways to avoid deforestation in order to reduce CO2 emissions into the atmosphere and mitigate climate change [1,4,5]. Agroforestry is a system whereby a deliberate attempt is made to integrate and manage both forest and agricultural resources on the same landscape. This intermediary land use system is important for sustainable forestry and agriculture. Due to the various benefits of agroforestry many

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international bodies such as the United Nations and World Bank, government and non-governmental organizations (NGOs) have advocated for its adoption globally. Some countries have heeded the call and are employing agroforestry technology as a strategy to rehabilitate degraded forestlands, avoiding “slashand-burn” farming, reducing soil erosion, improving soil quality, enhancing vegetation cover, and improving the living standards of forest dependent communities [11]. Deforestation is a serious problem in many developing countries, mainly due to subsistence and commercial agriculture [6,7] . About 17% of global CO_2 emissions comes from deforestation [8], significantly contributing to climate change [9,10]. Therefore, it is important to adopt agroforestry practices to address the continuous depletion of forest resources and, also, improve the livelihood of forest communities.

In the village of Mafele, the different fruit trees encountered are: Shea (*Butyrospermum parki*), Mango (*Mangifera indica*), Cashew (*Anacardium occidentale*), néré (*Parkia biglobosa*), Tamarind (*Tamarindus indica*) which are currently divided between the two main types of agroforestry systems: The natural agro-forestry system dominates shea, nere, and tamarind in association with cotton, groundnut and maize. The semi-natural agro-forestry system dominates shea, cashew, mango in association with cotton, maize and groundnut. The agro-sylvo-pastoral system in association with cotton, maize, groundnuts, beans and animals. Shea is the most dominant and abundant species, followed by mango and cashew.

The benefit derives from these fruit trees in terms of economic and nutritional value is great, their fruits are very profitable after sale. Mango from the mango tree and cashew nut from cashew are eaten on the spot and a part is also sold whose income is used to meet the small expenses of the family. The seeds of the nere and the shea nuts are processed into soumbala and shea butter respectively by the women of the village. Soumbala and shea butter are used a lot in the preparation of sauce in the village and also women sell them to meet many of their expenses such as: pay for children's schooling, treat children and pay for valuables such as loincloths, shoes during village events (festivals, marriage, baptisms...). The fruit of the tamarind is used in the manufacture of drink that people like more, its dried fruit is sold and this makes money. Regardless of the economic and nutritional aspect, these trees protect the soil against water and wind erosion.

The characterization of the practice of agroforestry with the two main types of system, the producers of Mafele suggest that women participate little in this activity. Customary rules restricting women's land rights are the main cause of women's non-involvement in the village as a whole. In Mafele, only men can inherit the lands of the ascendants and pass them on in turn to their male descendants. Women most often have access to a portion of their husband's land. But more often than not, this portion of land is degraded and poor. Calculations of income estimates for fruit trees reveal that they are of considerable economic importance. Approximately 90% of their arable land is part of the agroforestry system.

Contrary to the vision of improving land fertility that is often given to agroforestry, the main reasons that motivate Mafele farmers to practice agroforestry is that trees provide insurance and security for the family in the future and contribute, in addition to crops, to improving their income. Indeed, trees cause changes in physical properties (improvement of structure, porosity and permeability), chemical (reduced acidity, salinity and strength) and biological (increased microbial and enzymatic activities, improved mineralization and nitrogen fixation and increased invertebrate populations) of agricultural soils [12]. More precisely, trees provide, through their litter, an essential amount of organic matter that ensures soil fertility [13]. To a lesser extent, leaf cover also provides some soil protection against wind and water erosion [14].

The diversity of woody and non-woody species is wider in the fields (11 to 25 species). With regard to the dynamics of agroforestry parks, shea and parkia are abundant in Mafele because of their economic, food and medicinal importance and compliance with the texts prohibiting the cutting of these species. The constraint that is currently acute in the village is the wandering of animals in the dry season. The rules in the village do not require the custody of livestock at this time. This wandering of livestock causes producers to lose nearly 70% of their young plants on a developed plot. To this constraint are added the lack of water, and the poor mastery of plant production techniques. Feedback from the field reveals that these constraints discourage many growers from planting.

The growers interviewed stressed the need for training, for example in the techniques of production and maintenance of fruit trees. the adoption of agroforestry techniques to avoid rampant deforestation has not been simple in the country due to existing challenges such as low literacy rate, insufficient credit facilities, the absence of farm inputs, and other sociocultural issues [15]. Studies show that agroforestry is one of the key sustainable management practices in many parts of Africa with great impact on food security through increased productivity [5,16,17,18] as well as biodiversity conservation [5] suggest that agroforestry is “a great candidate for achieving land sparing” and that it also provides opportunities for local people to engage in sustainable activities rather than deforestation.

This study involved 100 farmers in the village of Mafele, coordination CMDT and weather station of Bougouni in 2022.

2. Methods

2.1.Description of study area:

Mafele is an area between 11° 19′ 00″ N and 7° 46′ 00″ W isohyetes 900 mm–1000 mm Heavy rains have a degradation action on soils without vegetation cover. The temperature varies between 20°C and 35°C. Annual evapotranspiration reaches 2100 mm. The area is dominated by gravelly and lateritic soils, and sandy and clayey limono on the glacial stockings. The constraints at the soil level are numerous: risk of erosion, poor drainage conditions. This area is par excellence that of agriculture and incidentally a pastoral area.

It has a Sudano-Sahelian climate, hot and dry. The climate is characterized by a very pronounced alternation between a dry season, dominated by dry winds (Harmattan) and a rainy season of three to six months (between May and October), with humid winds coming from the Gulf of Guinea (Monsoon).

The dry season is divided into a warm season (March to May) and a cold season (December to February).

The village of Mafele has vegetation, which presents structures ranging from open forests to shrubby savannahs with a varied herbaceous mat. The forage potential is high. The village has a fauna, once rich and varied, today consists only of a few warthogs, antelopes, rabbits, birds (guinea fowl, partridges, ducks... nocturnal and diurnal). The aquatic fauna is not rich. The area is rich in pollination and melliferous insects.

2.2.Data Collection:

2.2.1. Sampling and Data Collection

Before the start of activities, a survey and exchange mission with the authorities and local populations of the study area were carried out. It will be done with the help of the Presidents of the Agricultural Cooperatives (CA) of intervention village. Thus, the agroforestry systems and SLM that was the subject of the study were identified. The objective of prospecting is to locate agroforestry systems so as to cover a large part of the study area so that the results was representative of the area. The survey mission was conducted by me in the village of Mafele accompanied by two other students, our target was male and female farmers. We have made such a way that for each speculation grown, the farmers who grows it is in our sample lot this implies that for each speculation grow in this village there was his participant in our investigation. The survey sheets were already prepared and it was in French but during the interview they were asked the question in Bambara because the level of literacy in this village was very low. The interviews took place in the farmers' fields because we moved to their fields to do our interviews, other interviews were done at home due to the absence of the farmer in his field. The participant during this survey for the collection of data were cooperative with us, they were precise and clear in their steps of explanation from where we can confirm the reliability of the results that resulted during this survey in the village of Mafele. With regard to climate data, it is through the meteorological station of the Bougouni region that we obtained these data.

2.2.2. Sampling

The simple random sampling technique [19] were used to allow us to retain in village the number of informants regardless of gender, ethnicity or religion. Thus, the sample size was based on the number of informants taken in village. An open-ended, semi-structured questionnaire [20,21] were used for information collection.

2.2.3. Data Collection

It was concerning experience and information on the agroforestry system, the perception of peasants on agroforestry systems in their fields, the perception of the quality of their soils, the SLM measures they use in Mafele etc…., the fluctuation of rainfall from 1951 to 2022 and the mains crops cultivated in Bougouni from 2013 to 2018. The fluctuation of precipitations was obtained from the meteorological readings

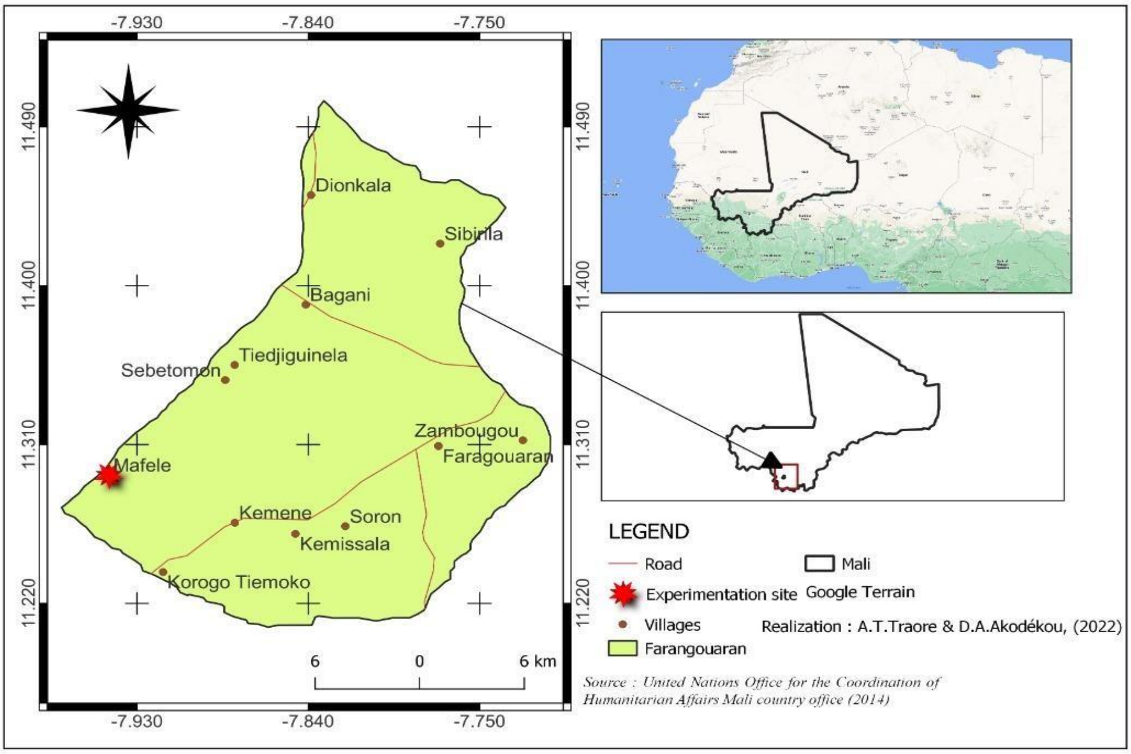

Figure 1: Farangouaran commune with Mafele village as study area in Bougouni region

made by the meteorological station of the region of Bougouni, it is through the meteorological station of the region of Bougouni that we obtained the fluctuation of precipitation from 1951 to 2022. The data on the crops were obtained through the survey we conducted in the village of Mafele and at the CMDT of Bougouni. The interviews were taken place during the months of August and September of the year 2022. They were carried out in the national Bambara language for the village of Mafele but in French for the CMDT of Bougouni.

2.3. Data analysis

For this purpose, the IBM SPSS STATISTICS version 25 program and excel was used. The data collected from the respective respondents were edited to correct any missing information on the questionnaires and to ensure accurate results; for that, after the data collection phase, the completed cards are checked at the office. Excel software was used to capture, codify and process the data. A database is established on the information collected in the course of the survey. For quantitative secondary data, the analysis was done on flattening. On the other hand, for qualitative data, a synthesis matrix was developed and used for better structuring of information. Later, the data were coded with the aid of SPSS v25. The coding of the data helped us to categorize the views of the respondents and analyze the data accordingly. Statistical analyses of averages and frequencies were used to analyze the data collected. Descriptive statistics that include frequency distribution, percentage, mean and standard deviation were used to determine the frequency and percentage of sustainable land management techniques, and the percentage of farmers' perception of agroforestry practice. The Pearson correlation coefficient allowed us to determine the income levels of agroforestry systems used in Mafele. Based on the results, we were able to make some inferences and provided appropriate recommendations for political action.

3. Results and Discussion

3.1.Climate situation in Bougouni region (1951-1996):

The climate of the Bougouni region has been characterized since the 71s by a great interannual variability of rainfall. Over the period 1995-2004, the total annual rainfall in Bougouni varied from 1437.5 mm to 871.3 mm [3]. This situation is linked to climate change, which is a major handicap for development. Data from the Bougouni station from 1951 to 1997 illustrate rainfall fluctuations (Figure 2)

Analysis of rainfall shows that rainfall heights remained high (above average) until 1971. After a certain deficit in 1972 and 1973, rainfall improved until 1982. A sharp decline occurred during the 80s, to recover afterwards. This considerable decrease in rainfall, predicted by the climate scenario, has had negative repercussions on the biophysical environment, agricultural production and food security. This decrease in rainfall has led to a weakening of ecosystems and a reduction in vegetation cover.

3.2.Climate situation in Bougouni region (1984-2022):

The analysis of this figure shows an increase in rainfall from 1984-1986 from 800 mm to 1200 mm to decrease in the years 1988 with a rainfall of 900 mm, between 1989 and 2001, rainfall increased again reaching a peak of 1400 mm in 2000. From the year 2001, rainfall began to decline to recover in 2007 before reaching 1400 mm in 2008. In 2009 the rainfall fell sharply from 1400 mm to 850 mm to recover in 2015 reaching an average of 1100 mm, from 2016 there was a decrease until 2018 and from 2019 the rainfall recovered to reach an average of 1500 mm in 2022. During the period 1984-2022, Rainfall deficits were recorded in 1988, 2002, 2009 and 2017 with an average of 850 mm while rainfall peaks were recorded during the years 1990, 2000, 2008 with a rainfall of 1400 mm and 2022 which had a rainfall of 1500 mm.

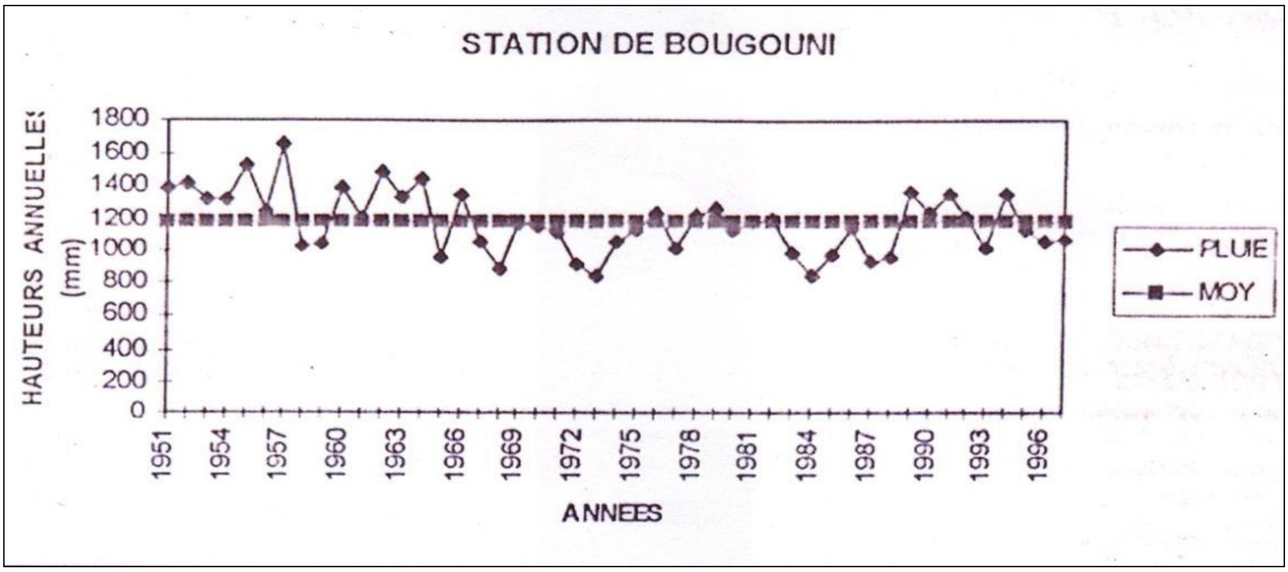

Figure 2: Evolution of rainfall, collected at the Bougouni station, from 1951 to 1996 (3)

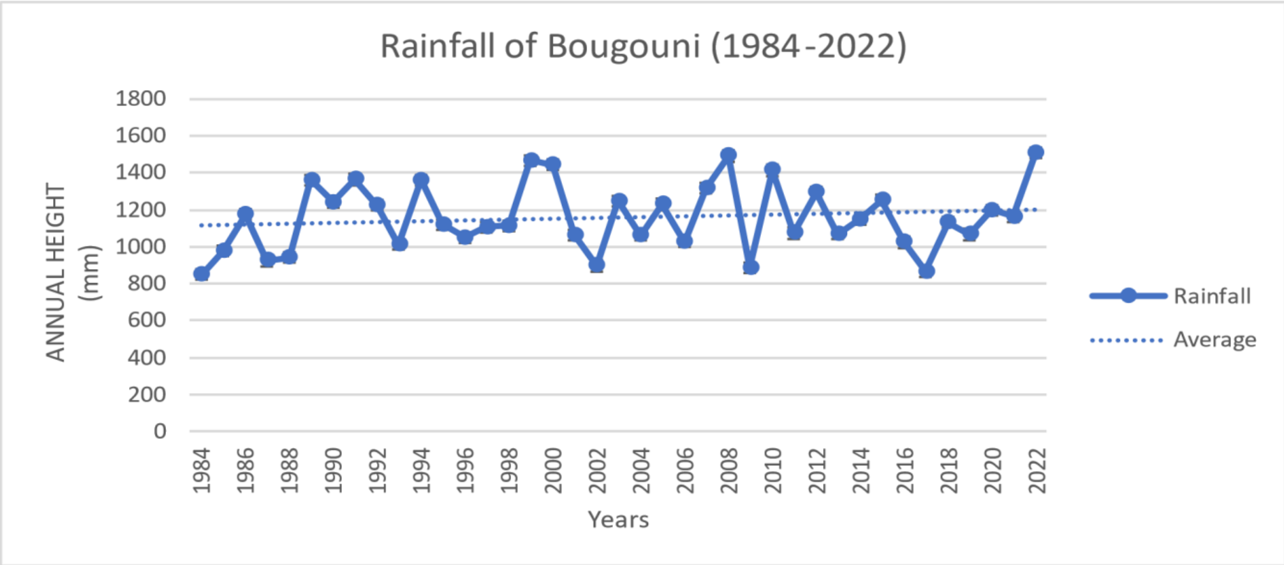

Figure 3: Evolution of rainfall from 1984 to 2022 (Adama, 2023)

3.3. Agricultural situation in Bougouni region:

Cotton is the main industrial and cash crop in the region. The main food crops are: Sorghum, Millet and Maize. Secondary activities such as logging (non-timber forest products and wood), market gardening, trade, gold panning and crafts are practiced there. According to the data in Tables 2 and 3, there is a trend towards increasing yields of sorghum and millet production over the years, attesting to the positive impacts of management and ecological conditions that are still relatively undisturbed. The tables on cereal production show a marked increase in average production over three marketing years. This increase is mainly driven by maize production, which accounts for more than half of cereal production.

Table 1: Evolution of sorghum production in the region.

Designations	Sorghum				
	2013/2014	**2014/2015**	**2015/2016**	**2016/2017**	**2017/2018**
Supervised holdings	28800	29000	29500	30000	31000
Herbicide area (ha)	71000	74000	76000	77500	80000
Production (tons)	65000	70000	74000	77000	94000
Yield (kg/ha)	915	946	974	994	1175

Source: Coordination CMDT/Bougouni (2019)

Table 2: Evolution of millet production in the region.

Designations	Millet				
	2013/2014	**2014/2015**	**2015/2016**	**2016/2017**	**2017/2018**
Supervised holdings	18900	19800	20500	21000	21400
Herbicide area (ha)	36300	38400	38900	39600	42000
Production (tons)	30900	34100	35400	36500	49000
Yield (kg/ha)	851	888	910	922	1167

Source: Coordination CMDT/Bougouni (2019)

Table 3: Evolution of maize production in the region.

Designations	Maize				
	2013/2014	**2014/2015**	**2015/2016**	**2016/2017**	**2017/2018**
Supervised holdings	34059	35000	36000	36600	37200
Area. sown (ha)	93500	101000	103000	105000	107000
Area with Organic Manure (ha)	32200	33000	35000	38000	40000
Area with cereal complex	93500	101000	103000	105000	107000
Area with urea (ha)	93500	101000	103000	105000	107000
Herbicide area (ha)	45000	50000	60000	75000	76000
Production (tons)	210300	244000	252000	262000	350000
Yield (kg/ha)	2249	2416	2447	2495	3271

Source: Coordination CMDT/Bougouni (2019)

Cotton, which has been plagued by difficulties in recent years for reasons linked to the fall in world prices, is on the road to recovery, especially since 20 to 45% of regional agricultural land is devoted to it. More than 70% of national cotton production is carried out by the regions of Bougouni, Koutiala and Sikasso. The statistics for the Bougouni region, presented in Table 4, reveal the revival of cotton production and thus the extension of the area devoted to cotton.

Table 4: Evolution of cotton production in the Bougouni region

Designations	**Cotton**				
	2013/2014	**2014/2015**	**2015/2016**	**2016/2017**	**2017/2018**
Supervised holdings	33558	37225	35821	38664	39000
Large farm donation	958	1190	13025	21480	2000
Areas sown (ha)	92413	107500	115101	142942	125000
Average area farmed (ha)	2,75	2,89	3,21	3,70	3,21
Areas with organic manure	40332	57685	53050	63529	65000
Areas with cotton complex 150kg/ha	90488	95135	93193	116282	95000
Areas with complex cotton 200kg/ha	1926	12365	21908	2660	30000
Areas with urea 50kg/ha	92413	107500	115101	142942	125000
Areas with 4 treatments	91595	107500	114550	114550	125000
Areas with 5 treatments and more	70510	68000	93694	93694	64000
Superficies avec herbicide ha	42540	46600	71763	88421	100000
Production (tons)	86630	114000	112979	134301	165 244
Yield (kg/ha)	937	1060	982	940	1020

Source: Coordination CMDT/Bougouni (2019)

Logging: According to the Cantonment des Eaux et Forets de Bougouni, the region includes 5 classified forests for an area of 127,040 ha. These forests, which are potential reservoirs of biodiversity, are now threatened by anthropogenic actions: shifting cultivation, bush fires, overgrazing, excessive cutting of green wood, gold panning, etc.

They are now the object of illegal occupation by farmers, gold miners and breeders, losing de facto the status that subjects them to a special regime of conservation and protection.

3.4. The average percentage of the different speculations grown in Mafèlè:

Figure 5 shows that in the village of Mafele, the following speculations are cultivated:

Conventional cotton, organic cotton, maize, rice, groundnuts, cowpeas and funio.

Among its speculations, conventional cotton is the best cultivated with the largest area (41%) followed by maize with (30%) then comes groundnuts (10%), rice comes in 4th position with an average of (8%) followed by organic cotton, funio and cowpea which have respectively 6%, 3% and 2% in terms of average area. This analysis confirms their conventional cotton production of the year 2021 which was the year when Mafele was the first producer of conventional cotton in the area because conventional cotton was the most cultivated crop with the largest area.

3.5. The agroforestry system encountered in Mafèlè

Although the three agroforestry systems (agri-silvicultural system, silvo-pastoral system and the agri-sylvo-pastoral system) are practiced in Mafele, the dominant system is the agri-sylvicultural system. Figure 3 shows that in the village of Mafèlè, shea is the most abundant species in the fields with an average of 59%. Then we have the mango tree and the cashew tree which have respectively 15% and 14%. Moringa and baobab each have an average of 5% and finally nere at 3% as an average value. Mango, cashew and moringa have recently been planted by farmers in the fields, they are young

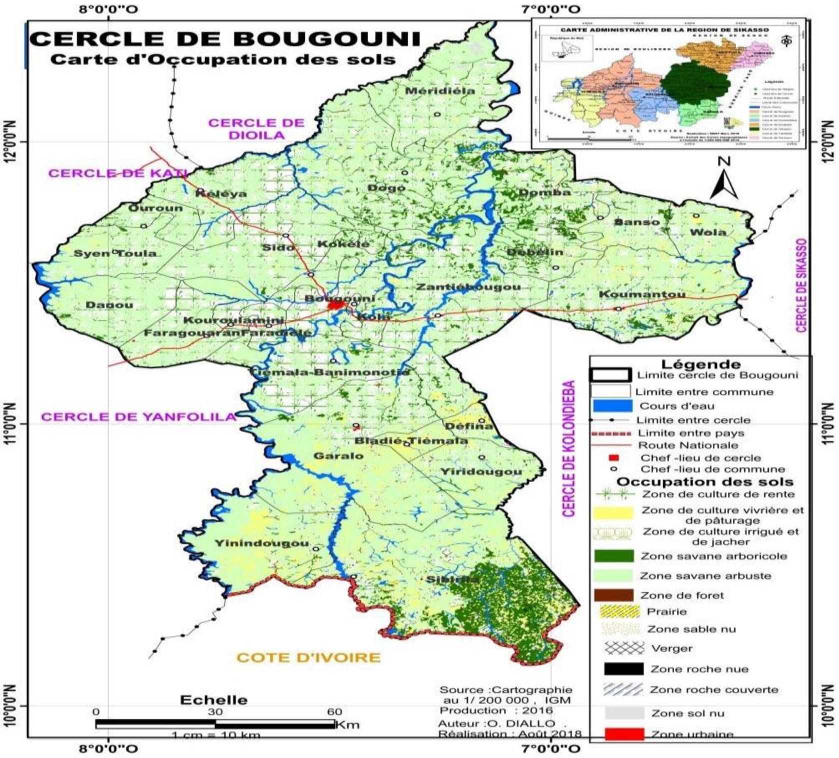

Figure 4. Land cover map in the Bougouni region (IGM, 2016).

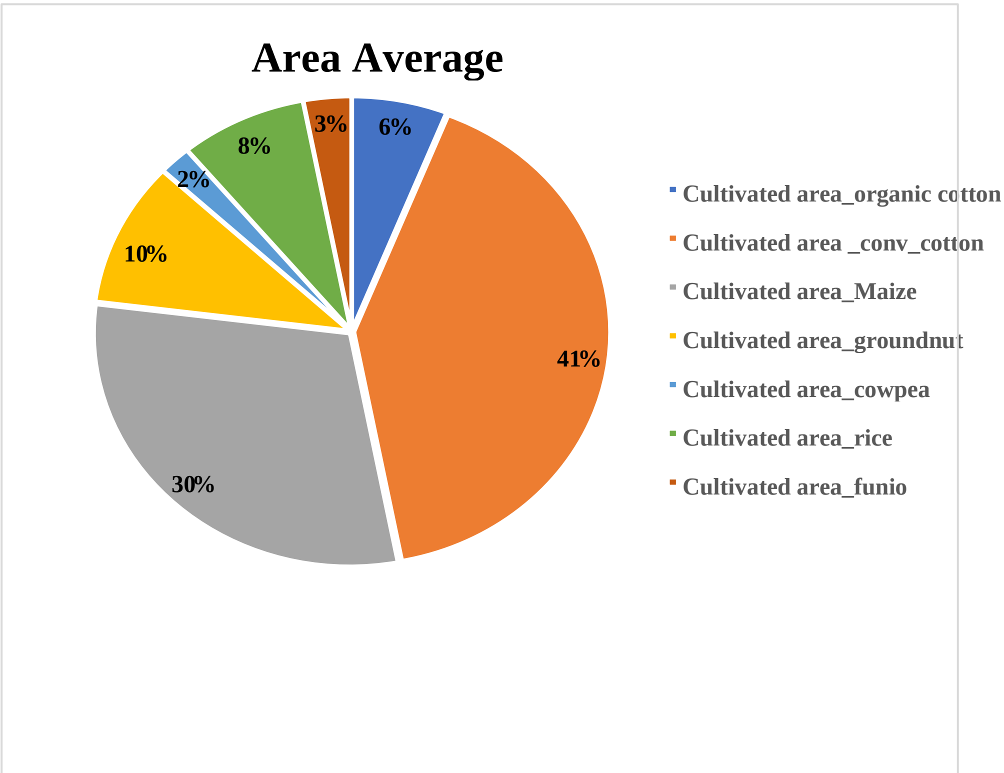

Figure 5: The average area per crop speculation in Mafele (Adama; 2022)

plants that have not yet entered the fruiting phase in the fields i visited. Shea, nere and baobabs are naturally regenerated and are deliberately left in the fields by the farmer himself.

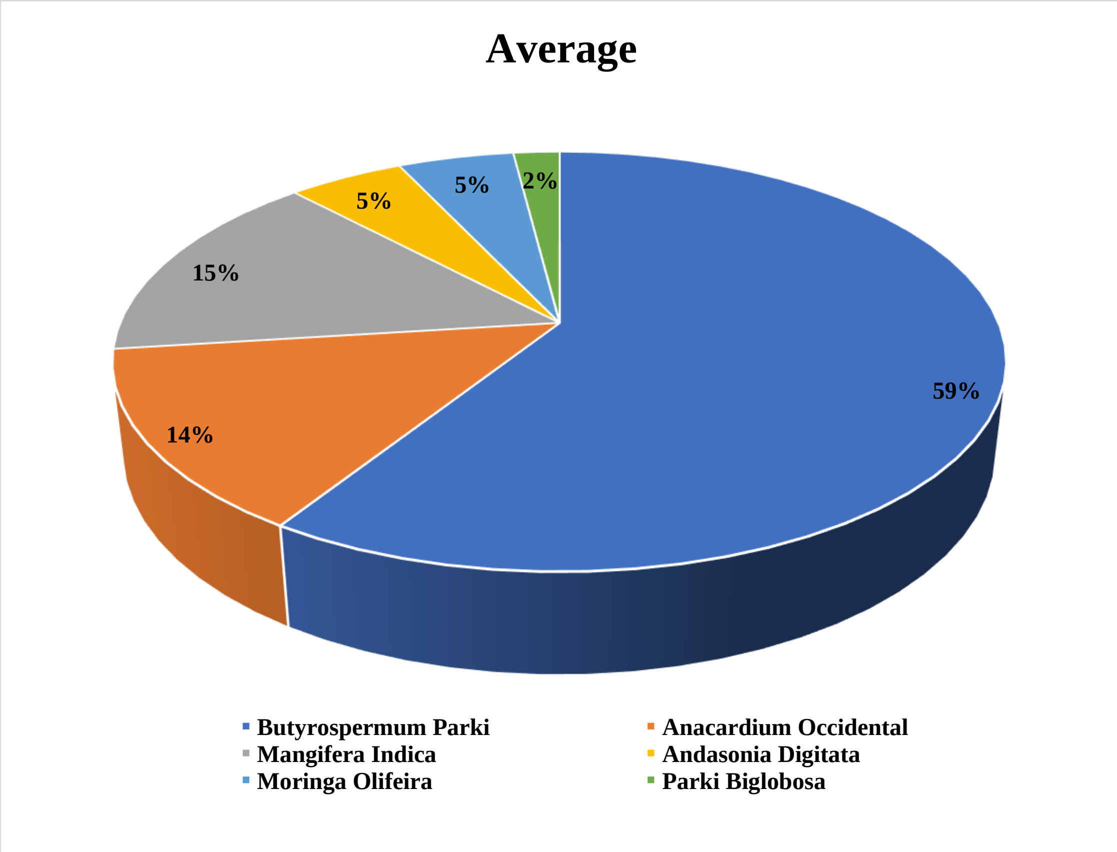

Figure 6: Tree species dominating in Mafele (Adama;2022)

Table 5: Some plant species encountered in Mafele (Adama; 2022)

Gender	Species	Vernacular name (Bambara)
Vitellaria	*Paradoxa*	*Chii*
Parkia	*biglobosa*	*Néré*
Adasonia	*Digitata*	*Zira*
Moringa	*Oleifera*	*Bassiyirini*
Anacardium	*occidental*	*Sômô*
Ziziphus	*mauritiana*	*N'tômônô*
Mangifera	*Indica*	*Mangoro*
Balanites	*aegyptiaka*	*Zèkènè*
Prosopis	*Africana*	*Guélé*
Pterocarpus	*erinaceus*	*Guenou*
Afzelia	*Africana*	*Lingué*
Lannea	*Acida*	*Bembe*

Tamarindus	*Indica*	*N'tomi*
Afromosia	*Laxiflora*	*Kolo kolo*
Piliostigma	*reticulatum*	*Niamani*
Senna	*Siamea*	*Mali yirini*
Lophira	*lanceolata*	*Mana*
Jatropha	*Curcas*	*Bagani*
Isoberlinia	*Doka*	*Chô*
Entenda	*abysinica*	*Jimbi-jamba*
Danelia	*Oliveri*	*Sanan*
Cola	*cordifolia*	*N'tabanôgô*
Cussonia	*arborea(djalonensis)*	*Bolokourouni*
Bombax	*costatum*	*Boumbou*
Burkea	*Africana*	*Siri*

3.6.Farmers' perception of agroforestry practice in Mafele.

The analysis of the figure on the peasant perception for the practice of agroforestry shows that 100% of respondents agree that the practice of agroforestry reduces wind speed, reduces soil loss through erosion, increases soil moisture. Indeed, 60-85% think that the practice of agroforestry makes it possible to increase crop yields, increase farmers' incomes, increase the production of wood and forest products, reduce the contribution of manure in the field. However, 30-50% believe that the practice of agroforestry reduces sedimentation flooding downstream, reduces deforestation and also that the practice of agroforestry provides other benefits. However, 15% do not agree that the practice of agroforestry reduces the input of manure into the field and 2% do not agree that the practice of agroforestry increases farmers' incomes. Regarding whether the practice of agroforestry allows the increase of wood production and forest product, increase crop yield, reduction of deforestation, reduction of sedimentation floods downstream or even if the practice of agroforestry can provide other benefits, 20-60% do not know the answer to these questions.

Based on these results, we can conclude that agroforestry is well perceived by producers in the village of Mafele, commune of Farangouaran in the Bougouni region.

3.7.Sustainable Land Management (SLM) techniques in Mafele

The analysis of these figures shows that: Starting on the basis of 100 respondents, sustainable land management techniques such as crop rotation, agroforestry based on the cultivation of *Moringa oleifera Gliricidia sepium* and *Acacia albida*, manure spreading are practiced by 95%; The technique cultivation of legumes is practiced by 84% while fallow is practiced by 72%; The technique of field crop residue management is practiced by 47%. However, the zaï technique and the technique of improving plants (angole weight, mucuna, aeschynomene, stylosanthesis) are not practical in the village of Mafele.

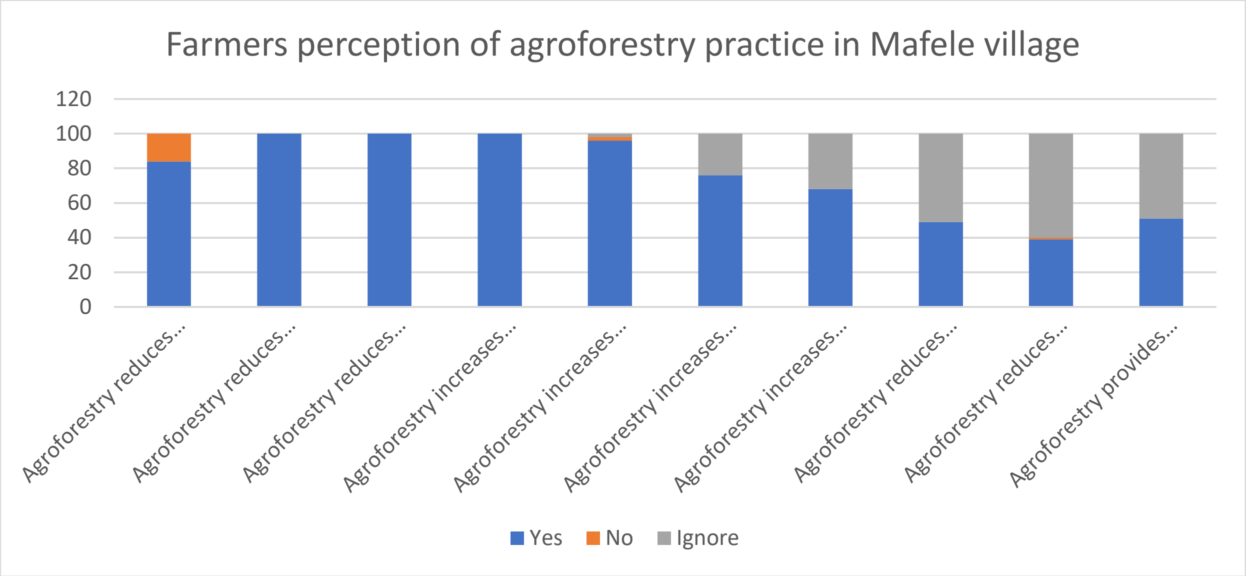

Figure 7: Farmers' perception of agroforestry practice in Mafele (Adama; 2022)

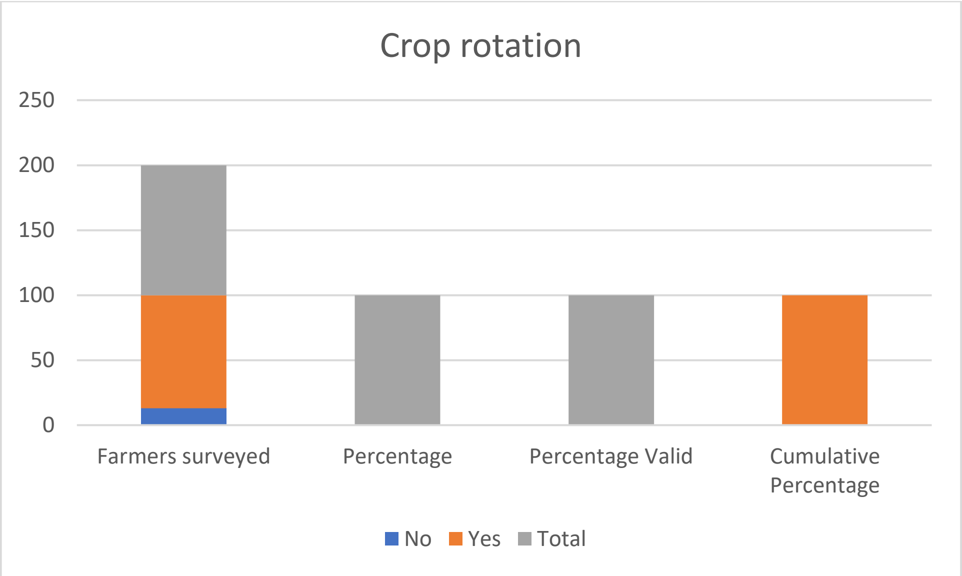

Figure 8: Crop rotation frequencies in Mafele (Adama; 2022)

3.8. Limitations and suggestions to the challenges facing adoption of agroforestry technology in this region.

According to our study lack of capital was among the limitations preventing farmers from fully adopting agroforestry practices, lack of technical skills, lack of quality seeds, lack of manpower, and market inaccessibility.

We suggested that giving subsidies to farmers can play a vital role in agroforestry adoption, we suggested that species for agroforestry should made available, availability of tree nursery establishment, community participation may help overcome the challenges affecting agroforestry adoption to help farmers feel part of the decision-making process regarding agroforestry policies and programs. Also, capacity building through training and field demonstrations is important to increase the adoption rate of agroforestry technology. Furthermore, making markets for agroforestry products more accessible can improve agroforestry adoption in this region.

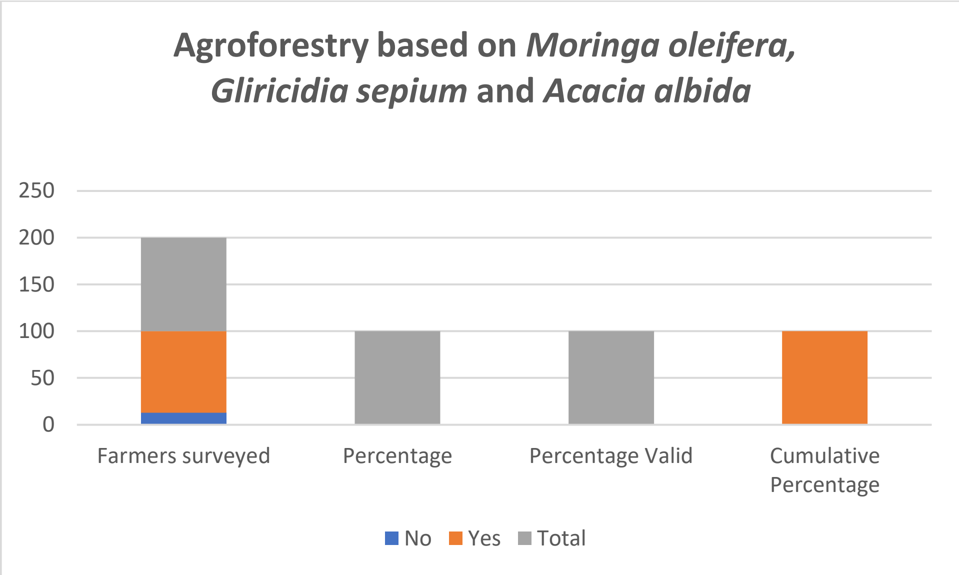

Figure 9: (SLM2) Agroforestry based on *Moringa oleifera*, *Gliricidia sepium* and *Acacia albida* frequencies (Adama; 2022)

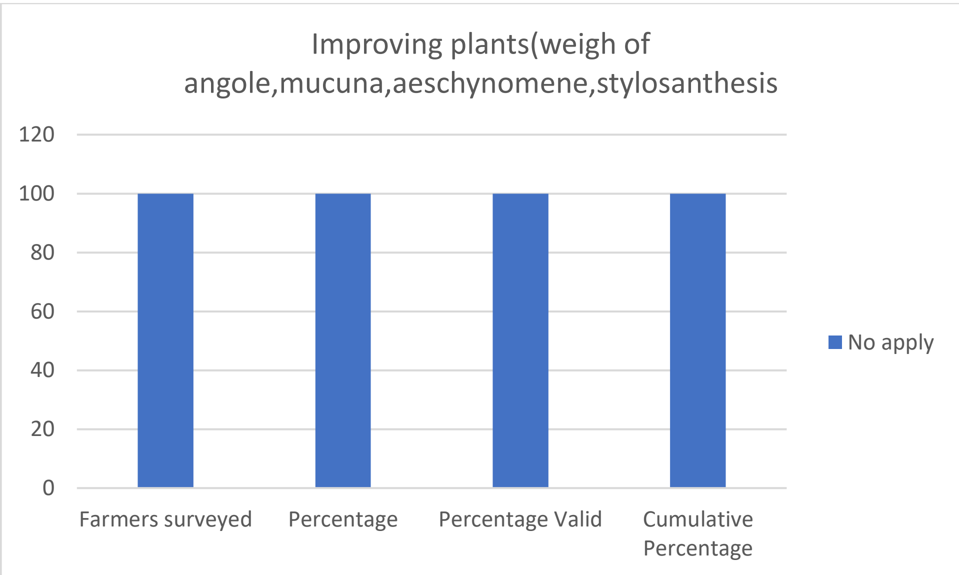

Figure 10: (SLM3) Improving plants (weight of Angole, Mucuna, Aeschynomene, Stylosanthesis) frequencies (Adama; 2022)

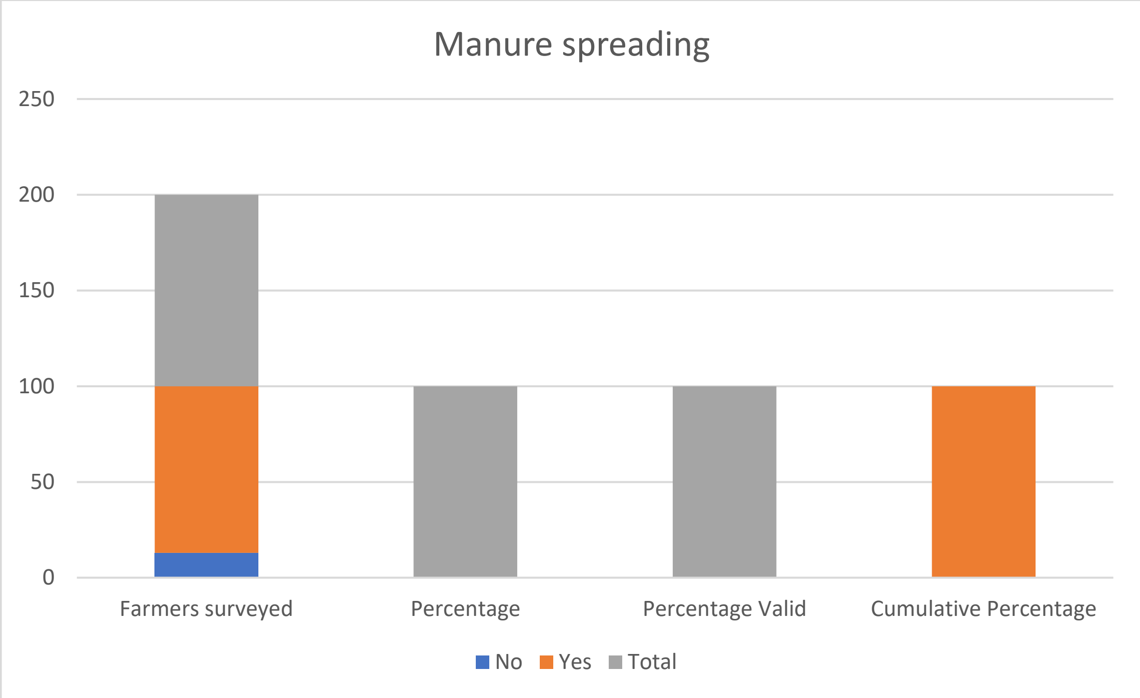

Figure 11: (SLM4) Manure Spreading frequencies (Adama; 2022)

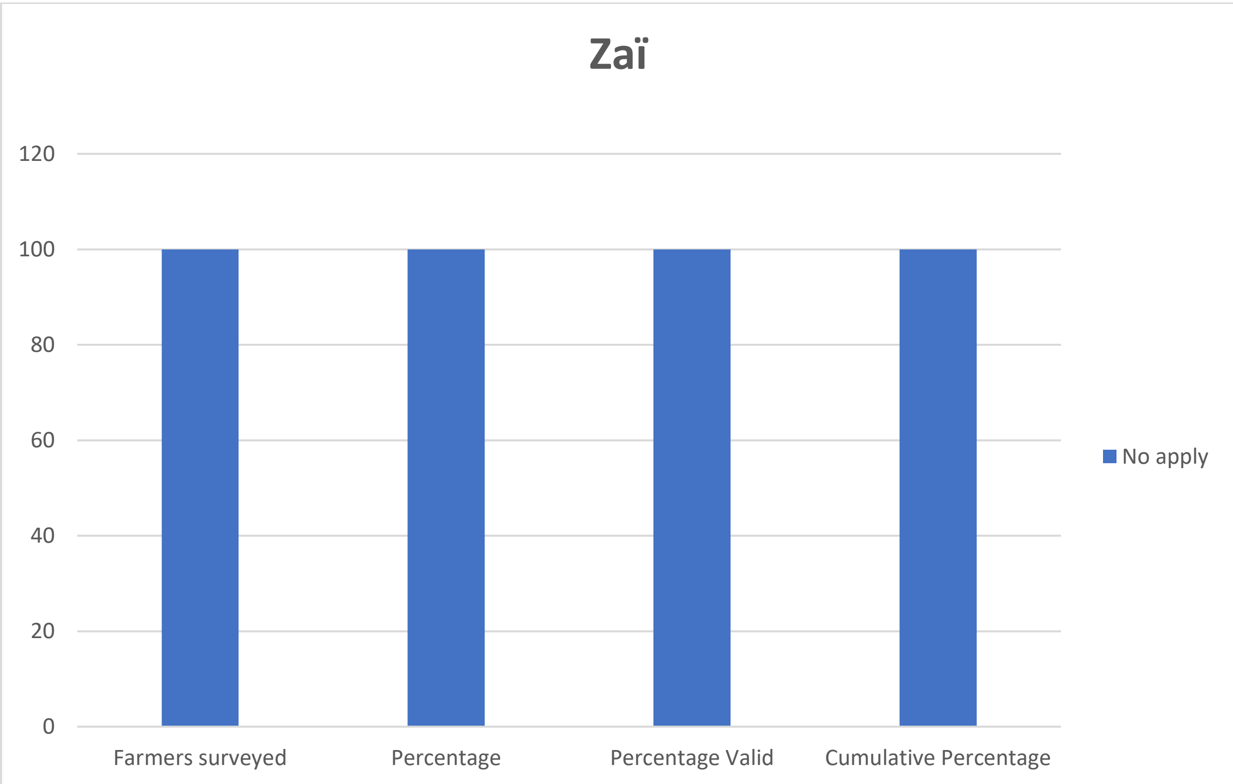

Figure 12: (SLM5) Zaï frequencies (Adama; 2022)

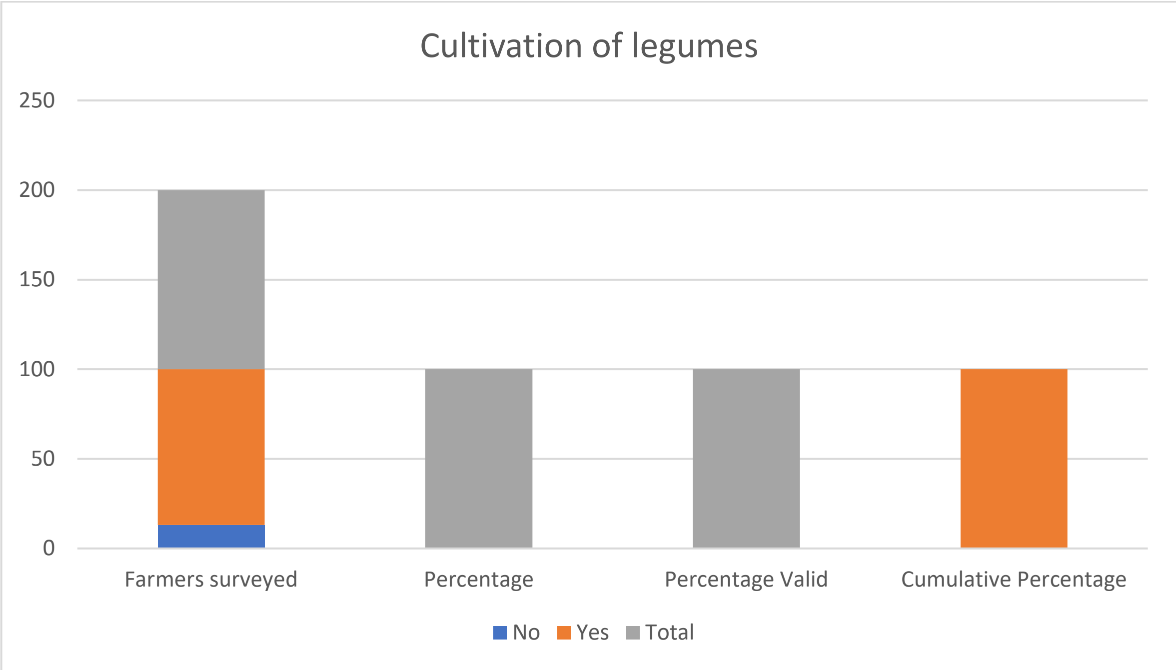

Figure 13: Cultivation of Legumes frequencies (Adama; 2022)

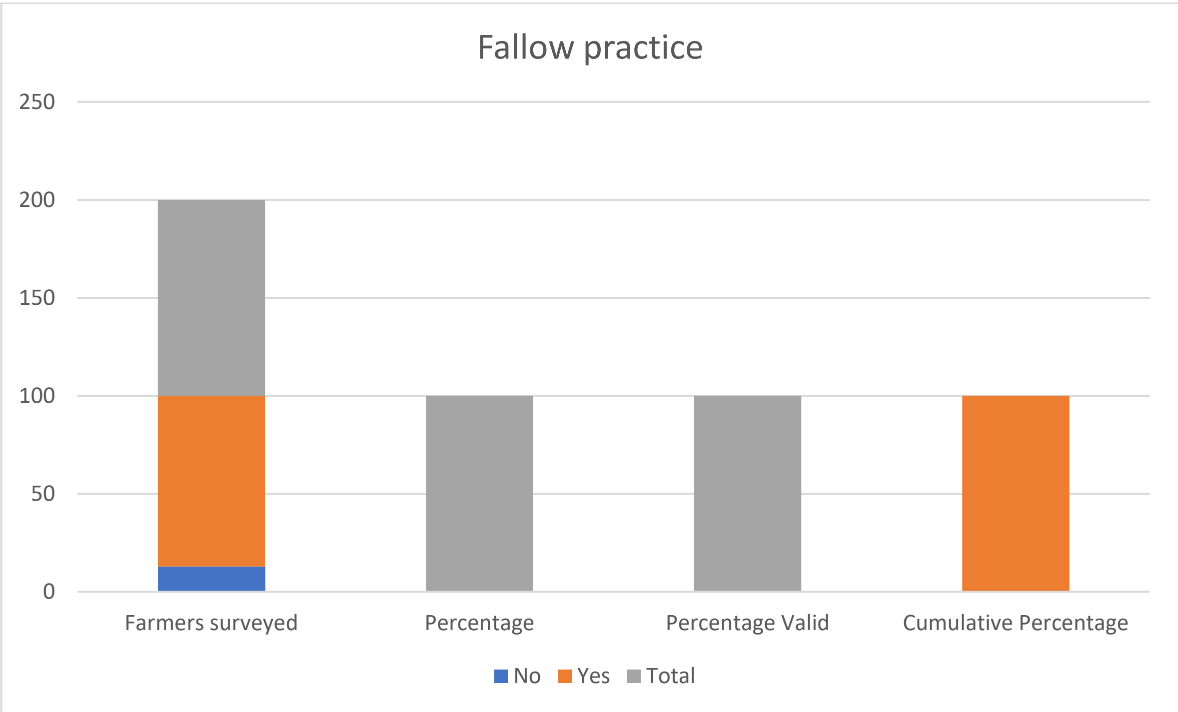

Figure 14: (SLM7) Fallow practice frequencies (Adama; 2022)

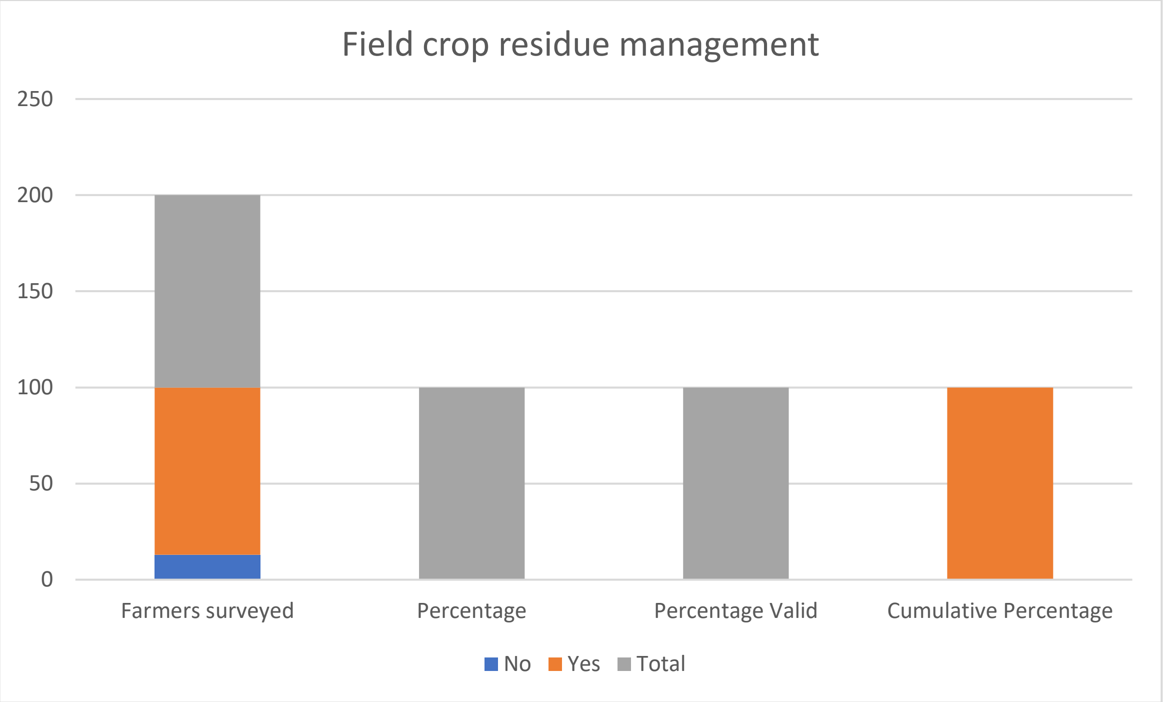

Figure 15: Field crop residue management frequencies (Adama; 2022)

4. Conclusion:

In the light of this survey conducted in Bougouni and Mafele; The results obtained showed that: Climate change is real in Mali. The climate of Bougouni region is tropical dry, called "South Sudanian", with a rainfall greater than 1100 mm / year. The climate of the Bougouni region has been characterized since the 71s by a great interannual variability of rainfall. Over the period 1984 and 2017 Rainfall deficits were recorded with 800 mm in 1984 and 850 mm in 2017 (Adama, 2022). This situation is linked to climate change, which is a major handicap for development. After a certain deficit in 1972 and 1973, rainfall improved until 1982. A sharp decline occurred during the 80s, to recover afterwards in the years of 2000. This considerable decrease in rainfall, predicted by the climate scenario, has had negative repercussions on the biophysical environment, agricultural production and food security. This decrease in rainfall has led to a weakening of ecosystems and a reduction in vegetation cover. It showed also agroforestry systems encountered in Mafele all generate income for farmers. The association of trees with crops is a source of diversification of production and a guarantee of food security for populations.

The activity of marketing arboreal products is lucrative; But their impact on farmers' living conditions can be further improved if they pay more care in their maintenance.

From the results of our surveys, it appears that the diversity of trees on the plots is more common than that of a single species. Cost-effectiveness calculations at the level of different types of agroforestry systems revealed that, compared to monocultures, agroforestry systems generate a higher net income. The same remarks were made by [22]. This author stresses that agroforestry systems, because of the many possible associations, are the source of diversification of agricultural activities, production and therefore income.

Contrary to the vision of improving land fertility that is often given to agroforestry, the main reasons that motivate Mafele farmers to practice agroforestry is that trees provide insurance and security for the family in the future and contribute, in addition to crops, to improving their income. The same situation was observed in Benin in the study of agroforestry systems based on wild apple trees [23]. Shea, mango, cashew, parkia, tamarind have other functions such as improving soil fertility, protecting soils against water and wind erosion and protecting crops against strong winds. Indeed, trees cause changes in the physical (improvement of structure, porosity and permeability), chemical (reduction of acidity, salinity and strength) and biological (increase in microbial and enzymatic activities, improvement of mineralization and nitrogen fixation and increase in invertebrate populations) of agricultural soils [12,13]. More precisely, trees provide, through their litter, an essential amount of organic matter that ensures soil fertility [13]. To a lesser extent, leaf cover also provides some soil protection against wind and water erosion [14].

The results also showed that there are several fruit trees (wild and domestic) in the area. These fruit trees are subject to several constraints that discourage farmers from maintaining them.

The diversity of woody and non-woody species is wider in the fields (11 to 25 species). With regard to the dynamics of agroforestry parks, it has been noted that shea and parkia are abundant in Mafele because of their economic, food and medicinal importance and compliance with Mafele's texts prohibiting the cutting of these species.

Bougouni’s remaining natural forest is under intense pressure due to increasing rural population growth and subsistence farming. Through the Ministry of Agriculture, the government has introduced agroforestry practices in forest dependent communities in order to promote sustainable agriculture and forestry as well as to improve the livelihood of local people. This new technology has, however, not been widely adopted, with many farmers still practicing conventional subsistence farming which is continuing to cause land degradation in some areas. This research surveyed 100 household heads to find out the environmental benefits of the introduced agroforestry technology and to identify the obstacles standing in the way of adoption. The respondents acknowledged that the income of farmers who have adopted agroforestry practices is increasing since its introduction in their field. Also, respondents said that the introduction of agroforestry has essentially been beneficial to the environment regarding soil fertility improvement, reduction of deforestation, and soil and water conservation. However, the respondents recognized that the adoption of agroforestry practices is facing some challenges in this area. They attributed these challenges primarily to lack of skills and technical know-how, capital, and quality seeds. The respondents perceived that these challenges can be surmounted by the provision of subsidies to farmers, regular training and informal education to help farmers build their skills and capacities, establishment of tree nurseries to improve the production of quality seeds, and to involve farmers in decision-making with regard to agroforestry policies and programs. The Malian government should show commitment by providing adequate funding and by subsidizing agricultural inputs for farmers to encourage them to adopt this new technology. The government should also partner with the private sector and NGOs to establish tree nurseries for quality seeds and agroforestry species to help farmers maximize their output in the Bougouni region and other parts of the country. Further, the Ministry of Agriculture should encourage community participation by involving all stakeholders in the design and implementation of the agroforestry program. Additionally, the Ministry of Agriculture and local agencies should intensify capacity-building training programs to equip farmers to effectively adopt this new technology to achieve its intended purpose in the country.

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