SUSTAINABLE FARMLAND MANAGEMENT STRATEGIES IN THE DISTRICT OF KODE (MUNICIPALITY OF ADJOHOUN)

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Résumé

La terre est un élément vital aussi bien pour les populations rurales que citadines. Cette dernière est confrontée à des problèmes d'ordre humain et climatique. Pour palier efficacement à ces difficultés, l'Etat Béninois, les ONG aussi bien nationales qu'internationales et les acteurs du secteur agricole réfléchissent au quotidien pour une production bio, rentable et durable. La notion de stratégies de Gestion Durable des Terres et de l'Eau (GDTE), s'évertue à prendre en compte tous ces paramètres. De ce fait, les stratégies de GDTE adoptées dans l'Arrondissement de Kodé ont été analysées. La démarche méthodologique adoptée pour réaliser cette étude est passée par une recherche documentaire, des enquêtes de terrains effectuées sur 65 personnes à la Ferme Ecole SAIN, le traitement ainsi que l'analyse des résultats. Le choix de la technique d'échantillonnage s'est fait en fonction de la méthode de quota et celle du choix raisonné sur la Ferme Ecole SAIN. Les analyses multicritères et bien d'autres outils de traitements ont été utilisées pour le traitement des données. Les résultats montrent que 60% de la population utilisent le paillage, 30% les couronnes, , 30% l'association des cultures, 70% la rotation des cultures, 20% l'assolement, 20% la jachère améliorée, 10% les diguettes, 5% les haies-vives antiérosives, 90% le choix des cultures à cycles courts, 30% l'agroforesterie, 5% l'utilisation du forage, 40% le Système de Riziculture Intensive (SRI), 3% de l'utilisation des panneaux solaires, 70% l'utilisation de foyer amélioré sont des pratiques de GDTE utilisées à Kodé. La forme particulière de Zaï,

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l'utilisation des biofertilisants et du biogaz et enfin la gestion des surfaces dans la rizière sont uniquement utilisée à la Ferme école SAIN. Cependant, malgré leurs nombreux avantages, ces pratiques sont limitées. Les principales contraintes liées à la réalisation de ces stratégies sont d'ordre financier, humain et technique.

Mots clés : *Arrondissement de Kodé, stratégies d'adaptations, GDTE, changements climatiques*

Abstract

Land is a life-giving resource for both rural and city dwellers. It is threatened by human and climatic hazards. To efficiently overcome these difficulties, the Beninese government, national and international NGOs and agricultural sector players are working on a daily basis to ensure organic, fruitful and sustainable production. The concept of Sustainable Land and Water Management strategies (SLWM) strives to take all these parameters into account. The SLWM strategies adopted in the district of Kodé were therefore analyzed. The methodological approach used to carry out this study involved documentary research, field surveys of 65 people at the SAIN Farm School, the processing and analysis of the results. The sampling technique was chosen on the basis of the quota method and the rational choice method on the SAIN School Farm. Multicriteria analysis and many other processing tools were used to process the data.

The results show that 60% of the population use mulching, 30% use crowns, 30% use crop combinations, 70% use crop rotation, 20% use intercropping, 20% use improved fallow, 10% use bunds, 5% use erosion control hedgerows, 90% use short-cycle crops, 30% use agroforestry, the use of boreholes (5%), the Intensive Rice Cultivation System (SRI) (40%), solar panels (3%) and improved stoves (70%) are some of the WDM practices used at Kodé. The distinctive form of Zaï, the use of biofertilisers and biogas and the management of rice field surfaces are only used at the SAIN Farm School.

Key words: *district of Kodé, adaptation strategies, GDTE, climate change*

I- Introduction

Land is one of the most vital resources in the world's agricultural sector. Moreover, it is the cornerstone of people's livelihoods, especially on the African continent. Soil deterioration is a crucial

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issue in the development of agricultural land in Benin (Assogba, S. C. G, 2017). Soils, thus subjected to strong anthropogenic pressure, in addition to increasingly unfavourable climatic conditions, are getting very prone to degradation and cannot sustainably support the agricultural production systems and modes currently applied. As a result, the agricultural sector's performance is sluggish and heavily influenced by low land productivity (Kohio, E. N, 2017).

Agriculture is a vital economic sector in most of the world's intertropical regions. It underpins the standard of living and living conditions of the majority of their populations (D. Samba, 2022).

Soil deterioration also threatens food security as it contributes to low crop yields, mainly for vegetables, roots and tubers. According to a WFP study (2014), almost 11% of the population was considered to be at risk of food shortage in Benin.

Given the importance of land, the Beninese government has put in place safeguards to ensure its security, hence the involvement of the National Land and Property Agency (ANDF). In the district of Kodé, farmers are exerting tremendous pressure on the land in order to meet the ever-growing consumption needs of the population. Farmers in Kodé are increasingly resorting to inappropriate cultivation practices such as slash-and-burn and the abusive use of chemical inputs in order to meet food requirements (both for the local population and for export). These chemical inputs have a highly damaging effect on the land (as they kill the micro-organisms in the soil that help maintain its appearance and fertility). As a result of these poor farming practices, 42% of agricultural land in Benin has been destroyed (UNDP Benin; 2021). Climate change and land deterioration lead to a considerable drop in agricultural yields and are therefore a major threat to the livelihoods of millions of people (K. Adebiyi et al, 2019). In this situation, meeting the challenges of food security and climate change requires far-reaching changes in production methods. Good Sustainable Land

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Management (SLM) practices, which increase soil carbon content, offer new alternatives (FAO, 2011). These practices promote an integrated management of soil fertility that boosts organic matter levels and soil structure, thereby increasing infiltration and reducing erosion (CILSS, 2012; GIZ, 2012).
Given this situation, suitable solutions are needed so as to ensure the appropriate long-term use of land and, at the same time, increase agricultural production while reducing greenhouse gas emissions. According to the UNCCD, by implementing Sustainable Land Management (SLM) practices, soil and vegetation degradation, poor management of water resources and greenhouse gas emissions can be limited, thereby saving natural resources and increasing agricultural yields.
The aim of this research is to analyze the sustainable land management strategies developed in the district of Kodé to better adapt to the effects of climate change. More specifically, it aims at identifying the different SLM practices developed on the Farm and then studying the developed strategies while highlighting their advantages and limitations.

1- Methods and Materials

1-1 Study area

The district of Kodé is located between 6°42' and 6°47' of north latitude and 2°25' and 2°32' of east longitude (figure 1). It encompasses 6 villages: Kodé Akpo, Gbannan, Hlankpa, Kakanitchoé, Kodé Agué and Gouké. It is bordered to the north by the district of Akpadanou, to the south by the district of Adjohoun, to the east by the Atlantic Department and to the west by the district of Awono.

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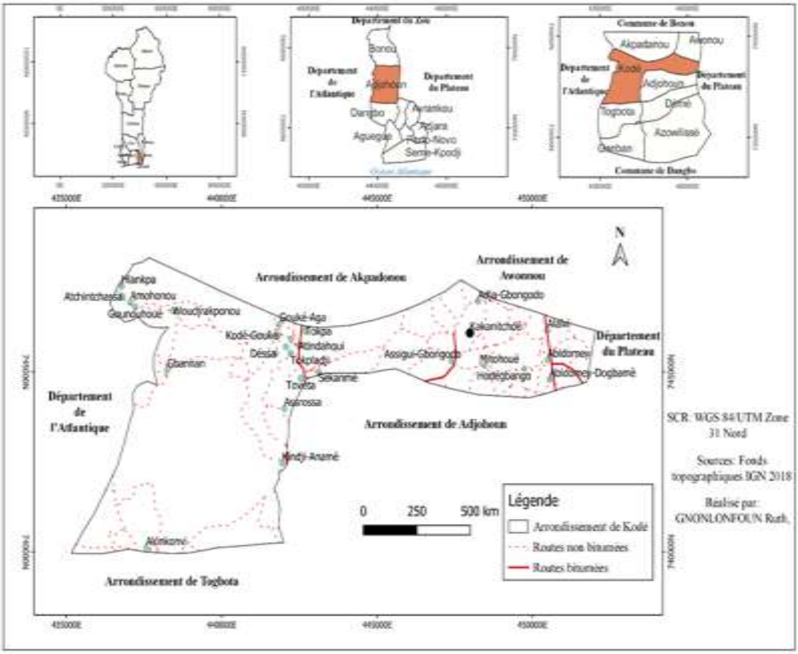

Figure 1 : Geographical location of the study site

The Municipality of Adjohoun, which includes the district of Kodè, is located in Ouémé Valley. Its topography is made up of two geomorphological units: upstream, a shelf at an altitude of between 20 and 200m with significant average undulations and downstream; a flood plain at an altitude of no more than 10m running north-south, east-west. It stretches out on either side of Ouémé river with annual flooding between July and November.

The district of Kodé has a variety of soil types, including: leached tropical ferruginous soils without concretions; modally impoverished ferrallitic soils with low desaturation levels; hydromorphic soils with mineral or low humus content and deep gley; hydromorphic soils with mineral or low humus content and pseudo-gley.

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Kodé has a transitional climate between sub-equatorial and humid tropical of the Sudano-Guinean type. It is characterized by four seasons: a short dry season (in August); a short rainy season (September to October); a long dry season (November to February) and a long rainy season (March to July) (LECEEDE, 2006). The rainfall pattern is generally bimodal in one out of three years. This rainfall pattern can vary with two peaks centred on June and September.

In short, the average climate and soil conditions in the district of Kodé are favorable to agricultural activities. This natural endowment is harnessed by the population which was estimated at 7,178 in 2013 (INSAE 2013).

1-2 Methods

In addition to the natural and human characteristics of the environment, the data and information mainly relate to climatic data for Kodé over the period 1990 - 2019, socio-demographic statistics for the population of Kodé and the various Sustainable Land Management strategies adopted at the SAIN Farm School. These data and information were collected through documentary research and, above all, surveys of senior technicians, students, customers and tourists at SAIN Farm School.

The sampling is presented in Table I.

Table VI: Sampling

Type of respondent	Number of respondents	Women	Men
Agricultural technicians	7	2	5
Students	30	12	18
Customers	15	10	5
Tourists	13	7	6
Total	65	31	34

Source : Field survey

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Questionnaire surveys and direct field observations (using an observation grid); documentary and internet research were the main techniques used to collect information. Descriptive statistical tools (mean, frequency, standard deviation, graphs) were used to process the data and information collected. Maps were created using QGIS software. Word software for data entry.

2- Results

2-1 Sustainable land management strategies adopted in Kodé district

The techniques and strategies used by the people of Kodé to protect, conserve, rehabilitate and manage their hydrological resources will be presented along with their advantages and limitations.

2-1-1 Climate change adaptation strategies

It presents the GDTE strategies adopted by the people of Kodé to increase their resilience to the effects of climate change.

- **Mulching**

The aim of mulching is to protect the soil surface from the destructive effect of rain drops on soil aggregates (splash effect) and to conserve soil moisture by reducing evaporation. It is a technology that can improve the water supply to crops by reducing the impact of drought on the productivity of degraded land. It also allows the recovery of degraded land for agronomic or agroforestry purposes to increase yields and cultivated areas. It involves covering the surface of bare soil with organic material, mainly plants so as to promote moisture retention and soil life activity which increases water infiltration. The mulching technique is very old and widespread in the southern Sahel. Mulching consists of covering the soil with a 2 cm layer of grass equivalent to 3 to 6 t/ha or branches or crop residues (millet or

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sorghum stalks) to stimulate termite activity. The termites break the surface crust of the soil by burrowing under the mulch. This loosens up the soil and increases its porosity, allowing better water infiltration. Mulching should preferably be carried out during the dry season, a few months before sowing, to avoid immobilizing nitrogen by applying materials with a high Carbon/Nitrogen (C/N) ratio.

This technique is used at Kodé to keep the soil moist and to protect it from the sun's rays (in a way that temperatures are rising steadily as the dry seasons extend at Kakanitchoe). Plate 2 shows mulched cucumber and ginger beds.

Plate 2: Mulching ginger and cucumber beds

Shooting: **GNONLONFOUN** R. J, June 2022

Plate 2 shows cucumber beds mulched with acacia leaves (which deteriorates very slowly) and ginger beds mulched with lemongrass leaves produced at SAIN Farm School. Table III presents the advantages and limitations of mulching and an alternative approach.

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Table VII: Advantages, limitations of mulching and suggested solutions

Advantages	Limits	Suggested solutions
- preserves soil moisture by limiting evapotranspiration - protects the soil and its microfauna from the sun's rays - the soil is enriched by the decomposition of straw - limits weed growth - saves water.	When mulch decomposes slowly, there are : - Slowing down water seeping into the ground - Increased runoff leading to soil erosion - Decrease in the amount of water required to recharge groundwater tables - Soil acidity	Use slow-degrading mulches only in areas where water erosion is insignificant

Source : Field survey, June 2022

- **Crown**

This involves making a hole 5 to 15cm deep around the base of a plant or tree (in order to supply it with manure and/or water). Crowns can therefore be used to fertilize food crops and cash crops. For food crops, a hole 7cm in diameter and 5cm deep must be dug at the foot of the plant as shown in photo 1. As Kodé is located in Ouémé Valley, this system is used to limit water run-off and fertilize the plants. At the same time, it combats erosion by encouraging water infiltration. Photos 1 and 2 show crowns made around young maize and oil palm plants respectively.

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Photo 1: Crowns before young maize plants

Shooting: GNONLONFOUN **R. J, June 2022**

Photo 1 shows the crowns created before the young maize plants to provide them with maintenance manure. This boosts the growth of the plants.

Photo 2 : Crown around the palm tree

Shooting: **GNONLONFOUN** R. J, June 2022

Photo 2 shows crowns created around the palm tree to combat water erosion and provide maintenance fertilizer. Table IV shows the advantages and limitations of crowns.

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Table VIII: Advantages, limitations of crowns

Advantages	Limits
- Combats water erosion - Favours water seepage - Makes nutrients available to plants more easily	- Filling of holes after a few months, mainly in the rainy season - Repeatable several times a year

Source : Field survey, June 2022

- **Combining cultures**

It is a production technique adopted on the farm which consists in growing two or more plants playing different roles in order to protect the plantation and the soil against different types of aggression (erosion, uprooting of plants).
Photo 4 shows the combination of groundnuts, cassava and maize made on one of the agricultural plots of the SAIN School Farm.

Photo 3: Combination of peanuts, cassava, corn

Shooting: **GNONLONFOUN** R. J, June 2022

Photo 4 shows the combination of maize, cassava and groundnuts made on one of the agricultural plots of SAIN

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School Farm. Table VI shows the advantages and limitations of crop combination.

Table IX: Advantages and limitations of crop combination

Advantages	Limits
- Favors soil protection - Limits infestations and pests - Fertilizes the soil	- Requires knowledge of the types of crops that can be combined - Excess work

Source : Field survey, June 2022

➢ **Bunds**

Bunds are anti-erosion structures that help control concentrated erosion, slow down water velocity, improve infiltration and promote the sedimentation of soil particles carried away. The purpose of the bunds made of sandy strips reinforced with wood and plant debris is to increase water infiltration into the plot and reduce water erosion. By intercepting and holding runoff, they increase water infiltration into the soil, improve soil moisture and, to a small extent, recharge shallow groundwater. It is said to be a semi-permeable structure. They allow plants to resist pockets of drought caused by climate variability and prevent soil water erosion. Their semi-permeable structure allows them to evacuate excess water from heavy rainfall. The impact on increasing agricultural production is greater with organic amendments than with chemical fertilizers. Training producers with simple methods helps to minimize the costs of implementing the practice. The participatory approach guarantees the sustainability of the developments. The practice is all the more relevant and effective as it takes place at the watershed scale, involving several organized operators. Land tenure issues must therefore be studied before the implementation of bunds. Photo 7 shows the bunds made on the SAIN School Farm.

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Photo 4: Bunds made to limit soil erosion

Shooting: **GNONLONFOUN** C, June 2022

Photo 7 shows the bunds made on the school farm to protect the plants. Table X shows the advantages and limitations of bunds

Table X: Advantages and limitations of bunds

Advantages	Limits
- With a 33 m spacing between the cordons, runoff is reduced at 12%. - Soil losses are reduced at 46%. - The lower the spacing between cords, the higher the average moisture content per plot - Water erosion is channeled	- Significant workforce needed to build Bunds - Difficulties to set up in too sandy areas - Regular follow-up - Importance of having equipment such as wheelbarrow, hoe.

Source : Filed survey, June 2022

➢ **Anti-erosion hedgerows**

Erosion control hedgerows are rows of trees, shrubs or bushes in one or more rows, of one or more species, planted around an agricultural perimeter to protect and restore the soil. They are

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often used in protective agroforestry. Their objectives are to improve water conservation and integrated soil fertility management on farms, reduce bank erosion and improve the density and diversity of plant cover.
On farms, this involves planting shrubs or trees on stone barriers, anti-erosion bunds and half-moons. Gullies and gullies along the banks of watercourses can also be corrected by planting anti-erosion hedges. The main woody species used to create anti-erosion hedges are: Piliostigma reticulatum, Guiera senegalensis, Combretum micranthum, Acacia nilotica, Mimosa pigra, Ziziphus mauritiana, Jatropha curcas, Jatropha gossypifolia. The anti-erosion action of hedgerows can be enhanced by planting perennial herbaceous plants such as Vetiveria nigritana and Andropogon gayanus. Woody plants are planted in single or double rows. It can be linear or staggered. The recommended spacing between plants is 40 cm. Planting should start as soon as the rainy season begins. The hedge should be pruned regularly with hedge shears to give it a compact shape. Pruning ensures that the plants branch out properly and that the stems and branches do not become entangled. The first pruning is recommended after the second year of planting. Photo 8 shows a living hedge created using palm trees.

Photo 5: oil palms' plantation in hedgerows

Shooting : **GNONLONFOUN** R. J, June 2022

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Photo 8 shows an oil palm plantation in the form of a hedgerow. Table XI highlights the advantages and limitations of hedgerows.

Table XI: Advantages and limitations of anti-erosion hedgerows

Advantages	Limits
- Reduce maintenance work on earth bunds; - improve the durability of erosion control structures; - increase the durability of erosion control structures by planting vegetation - reduce water erosion - improve physico-chemical properties through root activity (biological upwelling, biogeochemical cycle)	- Availability of forestry seeds in large quantities - Availability of water nearby; - Creating a habitat for crop predators; - Availability of stump fragments of species to be transplanted; - Planting density must be respected to obtain a sufficiently dense strip, capable of reducing the speed of run-off.

Source : Field survey, June 2022

- **Selecting short-cycle crops or crops that are more resistant to current climatic conditions**

Climate variability is one of the most significant phenomena affecting agriculture. Since Benin's agriculture is essentially rain-fed, climate instability, with its longer dry seasons and higher temperatures, is causing a considerable drop in agricultural yields. To reduce their vulnerability, people are opting to grow short-cycle crops that can withstand or adapt to current climatic conditions. These include crops such as maize, sorghum and millet. Photo 9 shows the variety of corn produced on the school farm.

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Photo 6: Choosing the DMT Corn Variety

Shooting : **GNONLONFOUN** R. J, June 2022

Photo 9 shows the variety of DMT corn produced on the school farm. Table XII shows the advantages and limitations of selecting short-cycle crops.

Table XII: Advantages and limitations of selecting short-cycle crops

Advantages	Limits
- Drought resistance - Profitability of these crops (they are generally highly prized) - Rapid fruit production - High efficiency	- High cost of seeds - Gradual loss of new varieties - Low yield of grain from the first harvest (so you have to buy new seeds each time in order to have a high yield)

Source : Field survey, June 2022

➢ **Agroforestry**

Agroforestry is a set of land management practices in which trees, crops and/or livestock on the same land management unit are deliberately combined according to a particular spatial arrangement or temporal sequence (A. Woodfine). The use of

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trees in combination with crops and livestock is an ancient practice.

Agroforestry is a method of farming that combines tree plantations with crops or pastures. According to the International Centre for Agroforestry Research (ICRAF), agroforestry is "a dynamic, ecologically based natural resource management system that integrates trees into farms and rural landscapes, thereby diversifying and maintaining production and improving social, economic and environmental conditions for all land users".

Agroforestry is therefore a method of using agricultural land that combines trees with crops or livestock to produce products or services that are useful to mankind. The combination (simultaneous or sequential) of trees and agriculture offers considerable advantages, particularly in terms of soil protection In general, agroforestry practices include the improvement of fallow land, taungya (the establishment of a forest plantation at the same time as establishing an annual cycle agricultural crop), vegetable gardens, strip cropping, the use of multi-purpose trees and shrubs on a farm, boundary planting, agricultural woodlots, orchards and arboretums, plantation/crop combinations, woodland and windbreaks, conservation hedges, fodder banks, live fences, trees on pasture and beekeeping with woodlots (A. Woodfine). This helps to combat wind and water erosion and increase yields on the farm. These trees are planted in the vicinity of crops on the Farm in the following ways:

• In cultivated land, in scattered or aligned plantations;
• Along boundary lines, paths or roads or as hedgerows;
• Along soil conservation structures;
• As windbreaks or to limit soil erosion;
• Around dwellings and dormitories, to provide shade or for ornamental purposes;
• To improve fallow land by using nitrogen-fixing species;
• To restore gullied land or stabilize banks.

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Plate 2 shows two forms of agroforestry adopted on SAIN School Farm

Plate 3: Coconut palms planted as a hedge in the maize field at site 2 and coconut palms positioned in the pineapple field to limit wind erosion.
Shooting: **GNONLONFOUN** R. J & **GNONLONFOUN** C, June 2022

Plate 2 shows two forms of agroforestry undertaken on the SAIN Farm School. These are the planting of coconut palms as hedges in the corn field at site 2 and the planting of coconut palms in the pineapple field in order to limit wind erosion. Table XIV shows the advantages and limitations of agroforestry.

Table XIII: Advantages and limitations of agroforestry.

Advantages	Limits
- Protects floors - Tackling water and wind erosion - Boosts agricultural yields - Wood and energy (fuelwood) supply - Provides shade - Helps stabilise riverbanks - Promotes nitrogen fixation through the use of certain species	- Possible interference between certain types of tree and crops - Taking up a large space - Foliage that can prevent other plants (smaller than the tree) from benefiting properly from the sun's rays. - nearby plants are destroyed by windfall - Excess work

Source : Field survey, June 2022

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- **The Use of the borehole**

This water supply system was created to meet the water needs of the residents of the Ferme Ecole, but also to water the plants in the garden. This resource, which is crucial to the survival of living beings, is poorly managed on the Farm. Photo 11 shows one of the boreholes on the Farm.

Photo 7: Drill rig
Shooting: **GNONLONFOUN** R. J, June 2022

Photo 11 shows one of the three solar-powered boreholes implemented on the school farm. Table XV shows the advantages and limitations of using boreholes.

Table XV: Advantages and limits of using drilling

Advantages	Limits
- Availability of water for watering crops so as to meet staff's and tourists' needs. - Useful for several years - Enables to make financial savings	- Installing the device is relatively expensive and requires a great deal of physical effort - Accelerates the depletion of underground water tables

Source : Field survey, June 2022

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It is noteworthy that they also use a particular form of Zaï, crop rotation, crop rotation, improved fallow and area management in the rice field to boost their resistance to the effects of climate change.

3-1-2 Climate change mitigation strategies

This section will briefly describe the various LWM strategies adopted in each of the Farm's areas of activity in order to limit greenhouse gas emissions into the atmosphere.

- **The use of biofertilizers**

The organic matter used to fertilize the soil varies in nature and form. They consist mainly of manure, crop residues, compost, etc. These organic materials undergo a series of transformations that break them down and/or transform them into humus. These transformations are carried out by micro-organisms or worms. It is at the end of this series of transformations that organic matter supplies mineral nitrogen to plants.

The objectives of composting are to ferment organic matter of plant and animal origin for a certain period of time in order to reduce its C/N ratio prior to application to the field, and to purify the organic matter resulting from composting. The aim is to increase the quantity of good quality organic matter for soil improvement and agricultural production, and to improve the physico-chemical and biological properties of the soil so that it can express its productivity. Compost increases the soil's water retention capacity, helping to reduce water stress in crops, which can be exacerbated by climate variability. Compost also increases yields. Finally, it helps to reduce food insecurity, which can be caused by climate change. Organic fertilizer is therefore an important factor in maintaining fertility and improving the efficiency of mineral fertilizers.
As a purely agro-ecological farm (with a very high level of respect for the environment), organic fertilizers derived from the

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composting of certain organic materials (Vermicompost, SAIN Orga, Vermicompost Tea, and Simple Compost) are produced on site from cow dung and worms; this allows them to have internal autonomy. The addition of transformed organic matter (manure) helps to maintain the level of nitrogen mobilized from the soil, and the efficiency of the fertilizer will depend on this level (Issa KABORE, 2014). Organic matter improves the root environment (physically and chemically) and thus offers the plant the opportunity to take better advantage of both the soil's natural fertility and fertilizer inputs. Organic matter, like mineral fertilizers, provides the plant with many nutrients (FAO, 1997). For this reason, the combined application of natural fertilizer and manure would result in greater crop development, particularly of the root system. Organic residues increase soil organic matter content, soil porosity and improve soil structure (I. KABORE, 2014).

Furthermore, the use of these biofertilisers pollutes the environment less and provides the nutrients the plants need for their growth, while preserving the soil's micro fauna and fertility.

It should also be noted that they use only natural inputs such as neem cake and neem oil. Photo 12 shows the biofertilizer production site.

Photo 8: Biofertilizer production site

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Shooting: **GNONLONFOUN** R J, June 2022

Photo 12 shows the biofertilizer production site at the school farm. Table XVI sets out the advantages and limitations of using biofertilisers and suggests a solution.

Table XIV: Advantages, limitations of using biofertilisers and suggested solutions

Advantages	Limits	Suggested solution
- Soil nutrition - Promoting plant development - Helps maintain soil fertility, texture and micro fauna - Environmental protection - Limiting greenhouse gas emissions into the atmosphere	- Often lengthy manufacturing process (30 to 45 days for vermi compost) - Scarcity and high cost of certain raw materials (e.g. earthworms, which cost 12,000 francs per kg)	- Create a worm production unit to limit the financial outlay.

Source : Field survey, June 2022

- **Biogaz**

It is the gas produced by the fermentation of organic matter (pineapple peel, papaya peel, etc.) from the on-site processing unit. It is a combustible gas composed mainly of methane and carbon dioxide. It can be burned at the point of production to produce heat and electricity, or purified to produce bio-methane that can be used as natural gas. Once the gas has been obtained, a liquid organic fertilizer can be used to fertilize the papaya trees near the site.

Gas production process:

Biogas is simply produced through the mechanization process. To do this, we need:

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Stage1: Feedstock supply

Mechanization units must be supplied with high-quality organic matter such as:

- Agricultural or agri-food waste (pineapple or banana peel, ...)
- Crop residues (onions, potatoes, ...)
- Household or restaurant waste
- Sludge from water treatment plants

Etape2: Digestion

Green energy burns the organic waste introduced into the pit, sorts out the raw materials and puts them into a large tank called a "digester". This is boiled and heated for several weeks in a totally oxygen-free shell. At the end of the brewing process, two forms of energy are recovered: digestate, a natural fertilizer that can reduce the use of chemical fertilizers on farms, and biogas.

Etape3: Purification

Before being injected into the network to supply the gas cooker, the impurities in the biogas must be eliminated.

For instance, this gas can be used for :

- Electricity generation,,
- Heating in agricultural greenhouses,
- Fuel for petrol-powered vehicles.

Plate 4 shows the biogas production site at the school farm.

Plate 4: Biogas production site at the SAIN School Farm
Shooting: **GNONLONFOUN** R. J, June 2022

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Plate 3 shows the biogas production site. Table XVII presents the advantages and limitations of installing a biogas production unit.

Table XV: Advantages and limitations of installing a biogas plant

Advantages	Limits
- Obtaining natural gas - Limiting greenhouse gas emissions into the atmosphere - Production of a natural fertiliser - Efficient management of household (organic) waste - Saving money - Long-term use of the device	- Unpleasant odours near the site - Expensive system

Source : Field survey, June 2022

- **Intensive Rice System (IRS)**

Rice production is a major source of methane emissions into the atmosphere (between 50 and 100 million tonnes CH4/year). In all probability, it is the largest anthropogenic source of this powerful greenhouse gas (A. Woodfine). The hot, waterlogged soils of rice paddies provide ideal conditions for methane production and, although some of this gas is generally oxidised by bacteria in the shallow overlying water, the vast majority is released into the atmosphere. It is possible to reduce the amount of methane emitted by rice cultivation by modifying the management of this activity and the selection of rice varieties (A. Woodfine).

The rice intensification system (SRI) was developed in Madagascar between the 1980s and 1990s during a period of drought. Very young plants (15 and 30 days old) were transplanted using a fairly wide spacing method (25-25 cm) in a square (farmers generally use older plants, up to 60 days old) (A.

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Woodfine). Rice does not grow in flooded rice fields, but rather in damp soil with intermittent irrigation. The results exceeded all expectations and, in subsequent years, smallholders have achieved reliable yields of between 7 and 15 tonnes per hectare, cultivating naturally low-fertility soils with very little irrigation and no mineral fertilisers or other agrochemicals. SRI reduces the need for irrigation, which is undoubtedly an advantage for farmers trying to adapt to climate change.

It is therefore a system that enables rice to be produced sustainably while limiting greenhouse gas emissions. It is based on the rational management of plants, soil, water and nutrients, without spreading too much inorganic fertilizer. According to studies, traditional rice production accounts for 10% of greenhouse gas emissions produced by agriculture. It has been shown that SRI is a technique that can effectively increase yields and thus improve food security, with the rural economy also benefiting greatly. The great potential advantage of using improved rice varieties is that they produce much more per surface area, so they can help to reduce the surface area of rice fields without reducing rice production. This rice production technique was tested for the first time in Benin on SAIN farm in 2009. Table XVIII shows the advantages and limitations of IRS.

Table XVI: Advantages and limitations of Intensive Rice System (IRS)

Advantages	Limits
- Rice has strong resistance to pests and diseases - Increased yield - Reduction of the rate of methane emissions into the atmosphere - Food saving of around 87% - Decreased crop irrigation - Water saving	- Relatively large cash intake

Source : Field survey, June 2022

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➢ The use of solar panels

The use of renewable energies aims to reduce the pressure on natural resources. This helps to meet the energy needs of the Farm. The energy generated by these devices is used to operate the groundwater pumping system, light the buildings, and recharge or power the electronic devices of the site's users. Photo 13 shows solar panels installed on the Farm School

Photo 9: Solar Panels

Shooting: **GNONLONFOUN** C, June 2022

Photo 13 shows solar panels used for pumping groundwater. Thus, they operate the drilling rig. Table XVIII shows the advantages and limitations of using solar panels.

Table XVII: Advantages and limitations of using solar panels

Advantages	Limits
- Internal autonomy of the centre - Reduced pressure on natural resources and the environment - Helping to save money	- Dependence on solar energy - Expensive - Low resistance to converting solar energy into electricity.

Source : Field survey, June 2022

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➢ The improved stove

The main objective of using improved cookstoves is to reduce the amount of wood or charcoal used to cook food, thereby helping to reduce demand for wood and charcoal and conserving the forests that sequester carbon, protect land and conserve biodiversity.

The types of improved fireplaces vary according to the following parameters: the material used in making the fire (metal, banco, ceramic, cement, etc.) ; mobility (fixed or movable), dimensions (fireplaces for individual use, dolo fireplaces for large pots, etc.), fuel used (wood, charcoal, gas). Among the improved stoves, the Three Stone Improved (3PA) type has probably been the most popular because of its ease of construction and the materials used. The 3PA improved fireplace is made entirely of banco (straw, cow dung, straw) and is made up of three parts: the body of the fireplace, the slab, the three stones, the combustion chamber and the door that allows the wood to be introduced. The body of the firebox, which is shaped like an inverted cone and has the same volume as the combustion chamber, rests on the slab on which the three stones are fixed. The distance between the wall and the pot is the distance between the pot and the inside wall of the firebox. It acts as a chimney. The distance between the floor and the pot is the distance between the bottom of the pot and the slab (or floor) of the fireplace. The improved stove operates by means of a heat transfer system. Combustion takes place in the combustion chamber, and is maintained by a draught from the door into the space between the wall and the pot. Photo 14 shows some improved stoves. Photo 14 shows 3PA type energy-saving improved stoves.

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Source : internet

Photo 10: Improved stove

Photo 14 shows improved energy-saving stoves type 3PA. Table XX presents the advantages and limitations of the improved stove.

Table XVIII: Advantages and limitations of the improved stove

Advantages	Limits
- Combating desertification and the effects of climate change by saving energy - Improving women's living conditions by making cooking more comfortable and saving working time - Energy savings of around 40% compared with traditional stoves - Improved stoves are easy to build and are also available on the market at affordable prices – Some stoves, such as the 3PA, cannot be moved and have very poor weather resistance	Some stoves, such as the 3PA, cannot be moved and have very poor weather resistance. Very few options exist for improved fireplaces suitable for large-scale use with the comfort of smoke attenuation

Source : Field survey, June 2022

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3- Discussion

The investigations carried out on the SAIN Farm School show that there are a multitude of sustainable land and water management strategies, each as effective as the next. The use of these techniques has a highly positive impact on agricultural yields and soil fertility. The use of biofertilisers, for example, considerably increases yields at the SAIN Farm School Fruits are larger and juicier. These findings are in line with the results of a survey conducted by SAWADOGO, I et al (2016) in Burkina Faso, who found that the use of compost increased yields by 300% at a rate of 10 tonnes/ha and by 45-120% at a rate of 5 tonnes/ha. Likewise, COULIBALY, K et al (2010) have shown that in the event of a one-month delay in sowing, compost can make up for the delay, sometimes even producing better results than plots sown earlier.

As well as having a highly beneficial effect on soil fertility, the use of good SLM practices reduces the rate of greenhouse gases (GHGs) emitted into the atmosphere and at the same time sequesters some of the GHGs already emitted into the atmosphere. This has also been highlighted by Woodfine A. (2009), who claims that the adoption of rehabilitative land-use systems through SLM practices could reduce the rate of atmospheric enrichment of CO2 and other GHGs and increase the rate of carbon sequestration. On a global scale, the potential for COS (Soil Organic Carbon) sequestration through the adoption of SLM practices is 0.9±0.3 Pg C/year, which would offset a quarter to a third of the annual increase in CO2 in the atmosphere due to human activity, estimated at 3.3 Pg C/year ». The use of biogas, for example, makes it possible to reduce the level of greenhouse gases that have to be emitted by decomposing organic matter and/or household waste.

Crop rotation is a technique that sequesters a relatively large quantity of soil carbon. This observation is consistent with Anne Woodfine's findings that restoring crop rotation can increase the

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rate of SOC accumulation at various depths of the soil profile […] it has been shown that increasing the complexity of crop rotation can sequester an average of 20 ± 12 g C/m2/year; in this case, the accumulation of SOC will continue over several years, with a new equilibrium point being reached after 40 to 60 years. To make matters worse, she shows that the difference between the carbon sequestration capacity of a maize monoculture and a legume crop rotation is 20 tonnes C/ha after 35 years.

Despite their advantages, GDTE practices are limited. The main constraints to implementing these strategies are financial, human and technical. Implementing them requires a significant financial contribution, an abundance of labour, the acquisition of tools such as wheelbarrows, and the availability of sufficient quantities of raw materials. Kohio, E. N et al (2017) add to these constraints that the implementation of SLM, land tenure insecurity is a minor threat to the adoption of good SLM practices in the Sudano-Sahelian zone. This contradicts the findings of FAO (2007), which found that land tenure insecurity was a significant barrier to the adoption of good agricultural practices in the Sudano-Sahelian zone of Burkina Faso.

Without these resources, farmers prefer to engage in unconventional and unsuitable farming. To alleviate these problems, the Beninese government is promoting SLM practices through the implementation of the National Action Plan on Sustainable Land Management (PAN-GDT 2018-2027). A number of projects have also been launched, including PAGD-CS (Support Project for the Sustainable Management of Soil Capital), PAPDFGC (Support Project for the Preservation and Development of Gallery Forests and Protection of Digital Base Mapping), PSDSA (Strategic Plan for the Development of the Agricultural Sector), Project for the Strengthening of Economic Knowledge and Capacity for Adaptation to Climate Change in Benin – PRECAB (2014), Integrated Adaptation Programme for the Fight against the Adverse Effects of Climate Change on the Biodiversity of the Environment. Agricultural Production and

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Food Security in Benin (PANA1) 2014, Support Project for the Integrated Management of Water Resources in the Ouémé River and Lake Nokoué Delta "IWRM SfN Ouémé" have been implemented.

The existence of this multitude of projects and programmes shows that financial and technical constraints in particular hinder the dissemination and effective implementation of SLM practices.

It is important to emphasize that the expertise capitalized on by the SAIN Farm School must be disseminated, and their ingenuity, both innovative and straddling new technologies, must be duplicated in all agricultural spheres. More than a school, it is a laboratory of modern agricultural knowledge. As part of its reforms, the Beninese government must draw inspiration from these achievements and implement them wherever necessary to bring about an agricultural revolution.

4- Conclusion

The aim of this study on sustainable land and water management (SLWM) strategies in the context of climate change in Kodé district (in the municipality of Adjohoun) is to contribute to a better understanding of good SLWM practices. The study provides information on the various sustainable land management strategies used in Kodé district. It also aims at identifying the different SLM practices developed on SAIN Farm School, to distinguish between adaptation strategies for mitigating the effects of climate change implemented on the farm, and finally analyze the strategies developed by highlighting their advantages and disadvantages.

The analysis of the results permits to gain a better understanding of the strategies developed on SAIN Farm School in Kodé district. Some strategies such as mulching, crowns, agroforestry, zaï, crop rotation, crop association, the choice of short-cycle

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varieties, land management and the use of boreholes, are being used to reduce their vulnerability to the effects of climate change. Likewise, to limit greenhouse gas emissions, they use biofertilisers, biogas, an intensive rice-growing system and solar panels. Almost all of these practices increase soil fertility while maintaining soil texture and protecting soil microfauna. They therefore have a positive impact on agricultural yields without destroying the environment. These results are obtained from the on-farm survey.

However, because of the significant financial input required to implement these strategies, many farmers still resort to prohibited practices that are so destructive to the environment. To alleviate this problem, the Beninese government is promoting good SLM practices by setting up the National Action Plan on Sustainable Land Management (PAN-GDT 2018-2027) and several projects.

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