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Agriculture Sustainability Assessment: A Case Study of Malakal State in South Sudan

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Abstract: ***Agriculture Sustainability Assessment is frequently hampered by data availability. Sustainability Agriculture is farming in sustainable ways, which means meeting society's present food and textile needs' without compromising the ability for current or future generations to meet their needs it can be based on an understanding of ecosystem service. Several issues at international, national, and farm levels affect agricultural sustainability .the issues include social, environmental, and economic. Often they are addressed separately from each other. This study considers this line of thinking and suggests an agriculture sustainability framework for assessing Agriculture Sustainability Index (ASI) at Upper Nile State (Malakal) level. The proposed methodology and framework are explained in a case study of Upper Nile State Malakal in South Sudan .the assessment of (ASI) at the state level uses a newly proposed framework composed of the three main pillars of sustainability i.e. social, environmental and economic. Social pillar has a single category. Environmental pillar is subdivided into agriculture biodiversity, agriculture management practices, Agri- environmental quality, and exposure of agriculture land to natural disasters and soil quality. The economic pillar is further divided into economic indicators and productivity. The study also suggests fifty-seven indicators and under the selected categories. The study utilizes the allocation of weight to indicators and categories. Experts' opinion is sought through questionnaire and assessed using Analytical Hierarchy Process (AHP).The indicator values are normalized using a proposed 5-point categorical scale. The ASI was assessed using the additive method by aggregating parameters weighted normalized values. The study proposes a new rating scale for ASI with color codes for easy interpretation. For Upper Nile State Malakal, ASI is assessed as 54.46 which is rated as moderate (yellow).***

Keywords: Agriculture Sustainability Assessment

1. Introduction

Agriculture production is considered as a major human activity and is the primary source of income and provides the main livelihood for the world's poorest people in developing countries. Climate change and associate environmental change are the major sustainability challenges for humanity in this 21st century (Sarkar et al. 2020).Agriculture as an activity is carried out primarily to produce food, fibers, fuel, and other commodities through the controlled use of mainly terrestrial plants and animals. Since the agriculture revolution approximately 10,000years ago, growing crops and livestock farming have been the major causes of loss and degradation of natural resources(Tamufor et al. 2017). There is an increasingemphasis on more sustainable techniques in developing countries and monitoring of agriculture sustainability has become important for targeted policy support by extension agencies(Goswami et al. 2017). The policymaker is looking for single composite indices for assessing agriculture sustainability which will help to make decisions in the field of human development and environmental sciences. Thus, a research challenge facing agriculture development is to determine the key indicators for measuring the impacts of agriculture policy reform and practices on agriculture sustainability(ul Haq and Boz 2020)y. Agriculture sustainability index is an important tool but it must be scientifically valid as it quantifies multiple dimensions of agriculture sustainability and is instrumental in monitoring agriculture production, environment, society nexus and support in informed policy decision making (Lampridi et al. 2019) .urge agriculture researchers to recognize the importance of sustainability in agriculture system; devise of measuring the sustainability, and examine empirically the sustainability of some well –defined cropping or farming systems and develop methods to measure it. The developed system will help in coming with a practical system for measuring sustainability in the cropping and livestock keeping on humanity depends for subsistence. In South Sudan, the Agriculture sector-wide Approach (ASWAP) is a strategic policy paper a mined at encouraged accelerated agriculture growing to achieve 6 percent annual growth rate as indicated in South Sudan growing and Development Strategy (SSGDS)and comprehensive Africa Agriculture Development program(Lokosang et al. 2011). Presented a proposal for measuring the economic sustainability of agricultural holding in Poland based on agriculture census data these authors used the indicators of economic sustainability and productivity labor profitability farms market activity and sources of household income and maintenance(Dos Santos and Ahmad 2020). There is, however, no universal tool developed for assessing the sustainability index at either farm level, regional level, or project national level .this study is designed to suggest a framework and demonstrate a method for assessing agriculture sustainability. A set of representative indicators is suggested. A method to do scoring and rating is then demonstrated. Malakal state as a case study area.

1.1 Description of Study Area

South Sudan has a tropical savanna climate. Within the tropical climate, there is still room for higher temperatures, officially known as the Republic of South Sudan is a landlocked country in East-Central Africa. The country gained its independence from the Republic of the Sudan in9 July 2011, making it the newest country with widespread recognition. Its capital and largest city are Juba. South Sudan is bordered by Sudan to the north(1,937 km), Ethiopia to the east(883 km), Kenya to the southeast(232 km), Uganda to the south(435 km), the Democratic Republic of the Congo to the southwest(628 km) and the Central African

Republic to the west (682 km)(Read 2018) cvb.currency is South Sudanese pound (SSP). Total Area of South Sudan is 619,745km2 sq. (239,285 mi) and Sudd wetland is 57,000 km2 during the dry season and 130,000 km2 during the rainy season, the average annual rainfall is around 750-1000mm/year, The mean annual temperature is 25°C with a minimum of 18°C and can rise above 38 to 40°C during the dry season, potential evaporation decreases from a maximum of 2400mm/year in the north to 1400mm/year in the south, The country divides into four regions, which are; East, West, South, Northern and North-East Regions with (UNS), Malakal is in the northern part. South Sudan's population is14, 228,267millio, Juba is the capital city of South Sudan. As shown in figure 3. South Sudan lies between latitudes 3° and 13°N, and longitudes 24° and 36°E. Precipitation hovers around 800/1,100 millimeters (31/40 inches) per year, with a minimum in winter, when it rarely rains, and a maximum in summer, usually in August. Mountains in the Far East on the border with Ethiopia, which reach 1,700/2,000 meters (5,600/6,500 feet), the only mountain, range of some importance, are the Imatong Mountains, culminating with Mount Kinyeti, 3,187 meters (10,456 feet) in the south, near the border with Uganda(Simon et al. 2020).

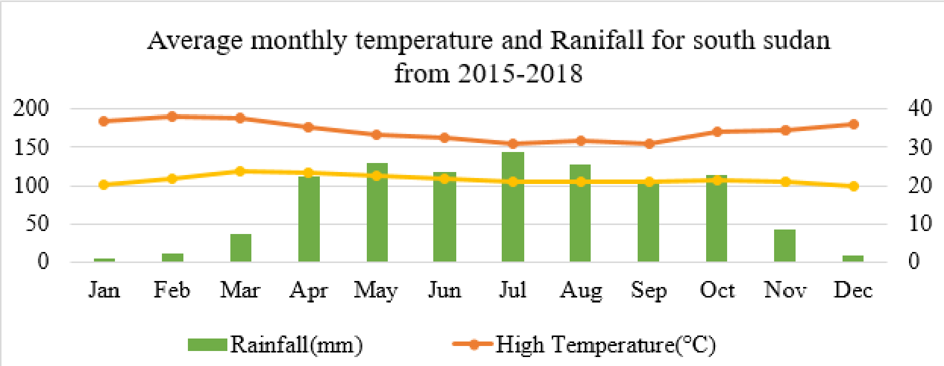

Figure 1: Average Monthly Temperature and Rainfall

Malakal, Upper Nile State is located in South Sudan's north-eastern region. It has a total area of 77,823 sq. (30,048 mi).It is situated about 500 km north of Juba, the capital city of South Sudan. HDI is 0.234 (2019). Upper Nile State (UNSM) has borders with the Republic of Sudan in the north about 650 km (400mi) south of Khartoum, the capital of Sudan, and with the Federal Democratic Republic of Ethiopia in the east (883 km) (Pluckrose and Pluckrose 2018).It is located 9.53 N latitude and longitude31.66 E and it is situated at elevation 400 meters above sea level. It is the second-largest city after the national capital Juba, Malakal average temperature of 31.1 °C, April is the hottest month of the year. At 26.1 °C on average, July is the coldest month of the year. The rainfall here averages 770mm, The White Nile, which runs from south to north in South Sudan, connects Malakal with juba and runs north toKhartoum and then to Egypt. The Nile River forms "Sudd", which is a vast swamp in South Sudan Lying between Juba and Malakal Town with an area of around 57,000km sq. during the dry season and 130,000 km sq. during the rainy season(Pluckrose and Pluckrose 2018).As shown in Figure 1:Upper Nile state (Malakal) development indicators stay insignificantly moo low for education, health, sanitation, and access to clean drinking water. The state is composed of 13 counties which incorporate Akoka, Bailet, Fashoda, Longochuk, Maban, Maiwut, Makal, Manyo, Melut, Luakpiny/Nasser, Panyikang, Renk and Ulang. The state's dominant tribe is Shilluk but too has inhabitants from the Nuer and Dinka tribes, the Bari-speaking bunches as well as Arabs. It has a surface area of 737 sq. km and a total population in Malakal (2018) 160,765. It is composed of five payams: Lelo, Central, and the Northern, Eastern, and Southern payams(Simon et al. 2020).As shown in figure 2.

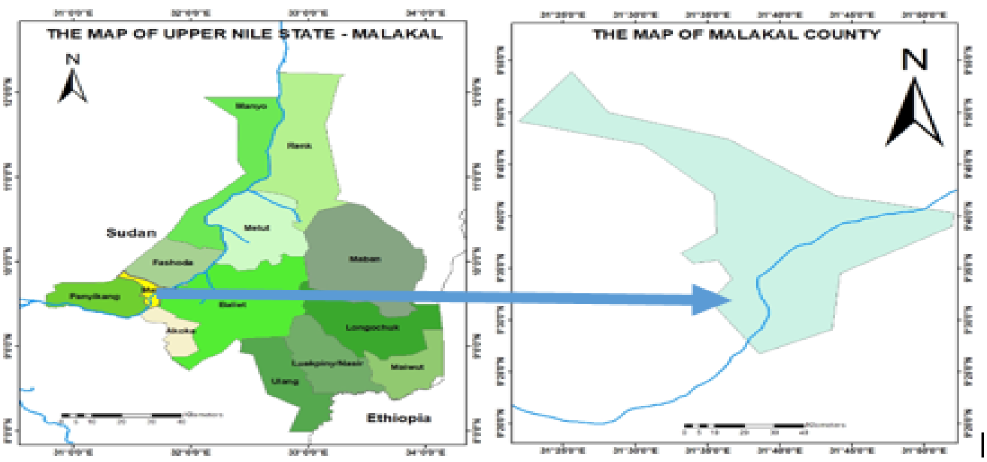

Figure 2: Study Area location (Malakal state)

The Nile River flows from south to north through eastern Africa. It begins in the rivers that flow into Lake Victoria (located in modern-day Uganda, Tanzania, and Kenya), .The Nile covers eleven countries, namely, Tanzania, Uganda, Rwanda, Burundi, the Democratic Republic of the Congo, Kenya, Ethiopia, Eritrea, South Sudan, Republic of the Sudan and Egypt. A land area of 3,200,000 km². Its three main tributaries are the White Nile, Noun tributary of the Nile River flowing from the highland rivers of Burundi to Lake Victoria. the Blue Nile, Noun tributary of the Nile River flowing from Lake Tana in Ethiopia and meeting the White Nile at Khartoum, Sudan, to form the Nile River. And the Atbara Noun tributary flowing from Lake Tana in Ethiopia and pass Eritrea and meeting the Nile River at Atbara. The Nile River flows over 6,600 kilometers (4,100 miles) is the longest river on earth, with the Amazon (6,400 km) and Yangtze (6,300 km) coming second and third. Until emptying into the Mediterranean Sea(LUAL 2012).

2. Methodology

This study aims at suggesting a sustainability framework and then use it in assessing the sustainability of the agricultural system. The framework is used in a case study of Upper Nile State Malakal of South Sudan, a semi-arid zone, by analyzing social, economic, and environmental indicators the influence agriculture system in the area. This study is supported by the analysis of primary secondary data from the study area. The study is divided into four main steps as indicated in Figure 3. Step I includes the following activities: identification of issues in agricultural production, categorization of parameters, setting proposed framework, development, and listing of proposed indicators. The outcome of step I is based on a literature review of previous work on the topic, study area and experts opinion through consultation and interviews. The main output of step 1, in this study, is the development of an initial agricultural sustainability framework with proposed categories and indicators and methods to be used in assessing agricultural sustainability in the study area. Step 2 involved data collection through a questionnaire survey and literature review. Besides, this step involved the handling/processing of primary and secondary data. The outcome of Step 2 is processed observed values for indicators. Step 3 involves further processing of data values by way of normalization, calculation of weight, and weighting of values. The result of step 3 is the normalized weighted indicator values. Lastly, Step 4 involves data processing, summarizing, and results inthe presentation. Specifically, step 4 involves the aggregation of different indicators into sub-index and then the final aggregation of sub-indexes into ASI. Different steps and methods for this study are described in detail in the subsequent sections of this chapter.

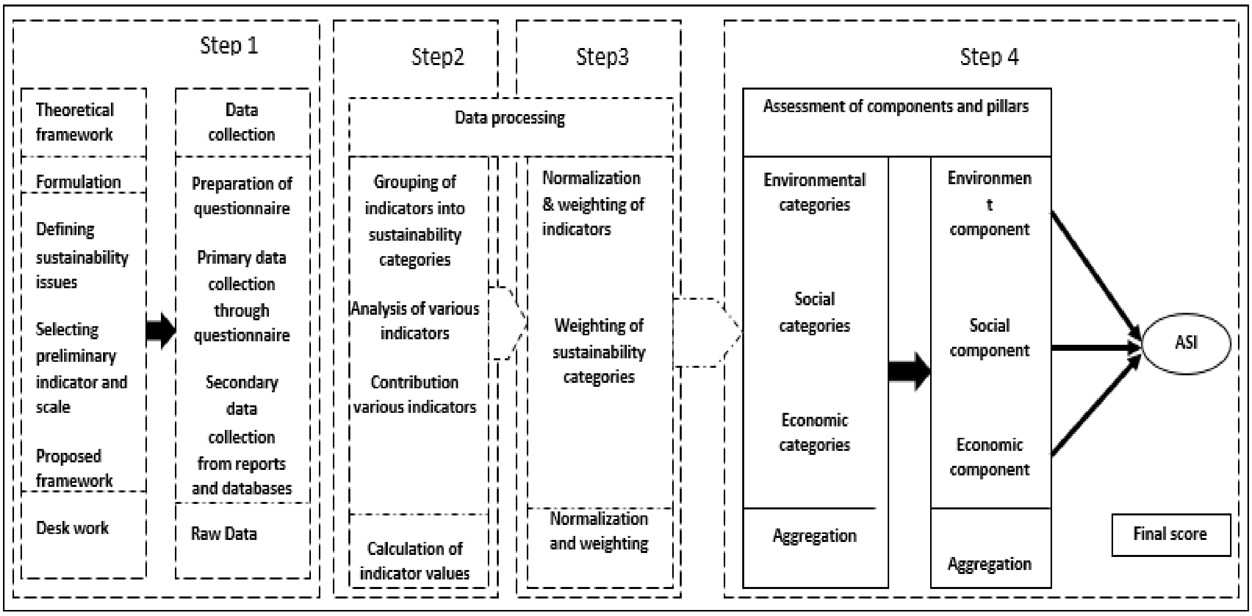

Figure 3: Steps used in the Study Area

2.1 Aggregation

The standard linear additive aggregation method (OECD, 2008) is used in the study, Equation I, to aggregate the weighted category values into sub-indexes, is, and the weighted Agricultural Sustainability Index, ASI with a value ranging from 0 to 100. Linear additive aggregation is a widely used method for the summation of weighted and normalized individual indicators (OECD, 2008). The linear additive aggregation method requires that the indicators are mutually independent. Furthermore, this method allows the contribution of each indicator separately towards the final assessment as they are added together to get a total value. The set back of this method is that the source of error and error itself is not easily traced and hence the composite index cannot be rectified when an error is found.

$$I_s = ASI_w = \sum_{i}^{n} W_i X_i$$

Where X_i = normalized indicator; w_i = weight attached to x_i; $(0 \leq w \geq 100)$ and n = number of variables.

The author proposes and develops a modified 5-point rating scale with traffic lights color codes from FAO for determining the level of final agricultural sustainability index ranging from 0 to 100 for easy interpretation of the results by all stakeholders(Patnaik et al. 2017).as presented in Table1.

Table 1: Scale for defining levels of ASI

Scale for the Agricultural Sustainability					
Rating	Unacceptable	Limited	Moderate	Good	Best
Percentage Score	0-20	20-40	40-60	60-80	80-100
Color Code	Red	Orange	Yellow	Light Green	Green

Statistical correlation of various variables' was tested using excel 2016 P=0.01 to check the interrelationships of the variables. Stepwise multivariate regression analysis was used to determine the most influential categories in agricultural sustainability in the study as used by (Roy et al. 2014).The selected agricultural categories were treated as independent y/ variables while the ASI was the dependent variable in regression modeling.

3. Results and Discussion

According to the literature review, the author found 8 main issues that affect agricultural sustainability from various sustainability pillars in the study area. These include agricultural biodiversity, agricultural management practices, agri-environmental quality, and exposure of agricultural land to disasters, soil quality, economic factors, productivity, and social factors. This study proposed these issues as categories for assessing agricultural sustainability in Upper Nile State (Malakal). It also suggested fifty-seven specific indicators from all categories to assess sustainability. The study incorporated stakeholder participation in the selection and weighting of parameters. The observed (calculated) values of the indicators, which were normalized, weighted, and then aggregated into an index are presented in Table 2 - Table 3. A framework for assessing agricultural sustainability is suggested in this study. Figure 4.Showsa list of indicators, agricultural sustainability categories, and the three sustainability pillars in the suggested agricultural sustainability framework. This study is based on the assessment of agricultural sustainability using a composite index on the current conditions and practices and then produce achievable goals towards its sustainability.

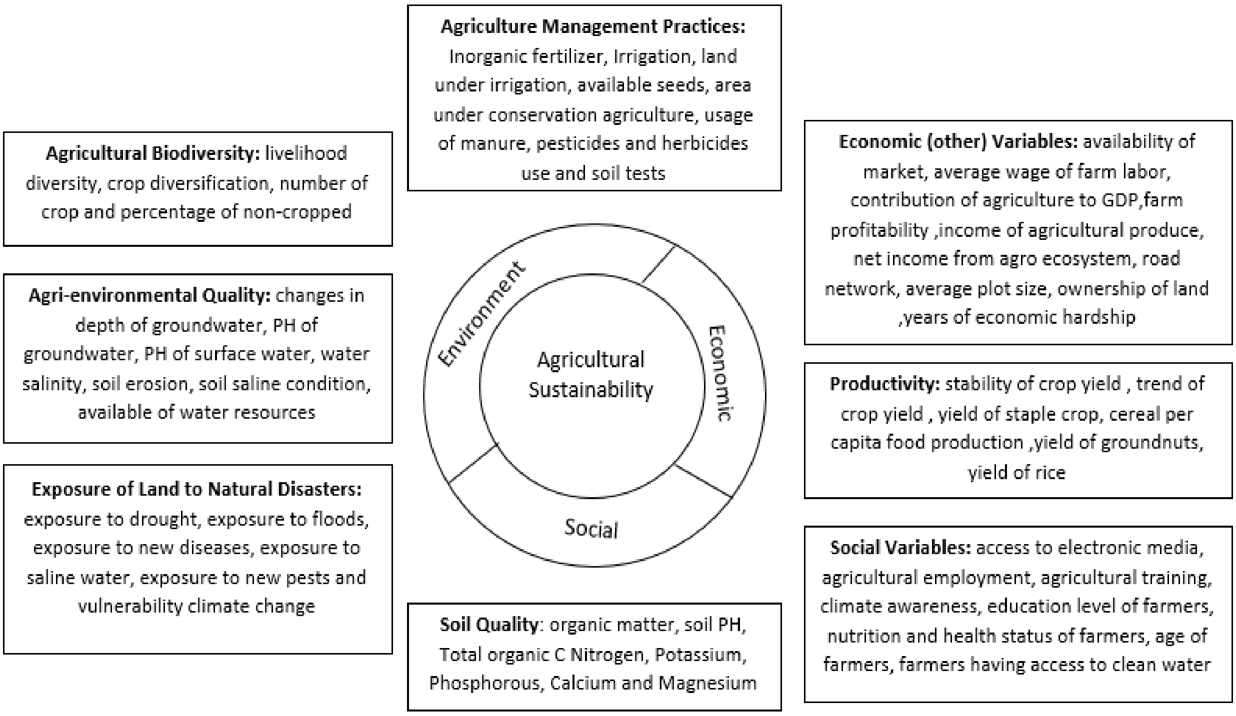

Figure 4: A framework for agricultural sustainability assessment

Table 2: Observed, threshold and normalized indicator values for agriculture biodiversity category

Category	Indicator	Threshold Value/Ideal State	Observed Value	Normalized Value	Weighted Normalized Value
Agricultural Biodiversity	Livelihood Diversity (Number)	5[a]	1.73	36.90	8.78
	Crop Diversification (Index)	1	0.39	61.74	16.84
	% of non- Cropped Area(%	30[a]	24.00	79.81	19.40
	Use of alternative crops(Number)	4[a]	2.01	51.81	12.75
	Sub Index:AB	100		57.78	6.51

Table 3: Observed threshold and normalized indicator values for factors category

Category	Indicator	Threshold Value/ Ideal	Observed value	Normalized Value	Weighted Normalized Value
Social	Access to mass or electronic media (newspaper, radio and television).	100[j]	42.60	44.63	5.32
	Agricultural employment/rural labour	80.30[d]	48.40	61.42	7.91
	Agriculture training	100[j]	73.76	74.23	10.01
	Climate change awareness	100[j]	54.63	56.06	7.68
	Education level of farmers/literacy level	100[j]	56.54	57.87	7.53
	Nutritional and health status of family members	100[j]	77.00	77.31	9.50
	Age of farmers	35[e]	42.1	98.43	10.75
	Percent of farmers who have access to clean water	100[j]	82.15	82.20	9.70
	Sub Index :social			68.40	7.49

4. Conclusion

From this study, a framework for assessing agricultural sustainability index is proposed. The index is based on eight suggested sustainability categories - Agricultural biodiversity, agricultural management practices, agri-environmental conditions, economic factors, exposure of agricultural land to natural disasters, productivity, social factors, and soil quality. The study uses fifty-seven indicators under the categories. The method for assessing ASI normalizes the parameter values using a 5-level categorical scale before giving them weightage calculated using the AHP. The weighted normalized values are added to give an index. The study utilized primary and secondary data. The results from the case study show that Upper Nile State (Malakal) has a moderate agricultural sustainability level. It performed poorly in agricultural management practices, which is also the most important category with the highest weight. It has fewer issues in the exposure of agricultural land to natural disasters. The proposed methodology and framework for agricultural sustainability assessment in this study introduces a new way of understanding and measuring agricultural sustainability of a cropping system. It involves incorporating stakeholder's views in the selection of parameters and weighting of the same in an area. It also combines all the three pillars of sustainability in the assessment of the different activities done by man and the state of the natural system that supports agricultural activities to ensure agricultural sustainability and a good number of livelihoods of farmers and the general population. The proposed methodology and framework for this study can be adopted as a tool for the design and implementation of monitoring programs for agricultural crop production, development of policies and practices in the agricultural sector at the state level. To improve agricultural sustainability in Upper Nile State (Malakal), there is a need to formulate a sustainable agricultural policy that will guide the running of agricultural activities in the State. The policy formulation process should take into consideration the local conditions and all the three main sustainability pillars of environmental, social, and economic. Additionally, the policy should emphasize strict adherence of guidelines mainly agricultural practices, which are very important among the 8 agricultural sustainability categories in the study area but unfortunately performed poorly. The indicators that have to be improved under this category include the inefficient water use, use of inorganic fertilizer without checking the required and recommended nutrients lacking in the soil. Much emphasis is to be placed on the promotion of area-specific inputs like he high-value crops that will increase crop yield and income. Equally, important emphasis should be placed on other aspects of agricultural management practices that include reducing the intensity of inputs that reduce sustainability and reduce production costs. Such practices include inorganic fertilizer, pesticides, and irrigation water.

4.1 Recommendations to Improve Agricultural

The study suggests resource-conserving technologies and practices that will improve agricultural sustainability by using natural capital within the agricultural system itself. Although most of the recommended technologies and practices are currently being used by farmers in the study area. The statistics from this study indicate that they are on the lower side to call them sustainable. The adaptation and spread of these technologies and practices may be slow because the processes involved have costs attached. Hence, farmers are not willing to adopt or abandon old practices such as the use of pesticides, herbicides, and fertilizers and hope to maintain production and profit. For the changes to be effective there is a need for investment in training and time on farmers. This involves showing them practical results of the new conserving technologies by way of experimenting together with them. The natural resources conserving technologies include; 1) Integrated Pest Management (IPM). 2) Conservation tillage. 3) Agroforestry. 4) Water harvesting. 5) Livestock integration. 6) Practicing efficient irrigation technologies. 7) use of high yielding and resistant crop varieties. It must be noted that the adoption of sustainable agriculture is hindered by a lack of knowledge and management skills on the part of implementers, which include farmers and extension workers

4.1.1 Integrated Pest Management (IPM)

IPM system uses the philosophy that allows the use of pesticides or chemical control for pests as a last resort after other options have proved a failure. The use of IPM as a recommendation will help in lowering the cost of production at the same time saving the environment from contamination by chemicals.

4.1.2 Conservation Tillage

Conservation tillage, which is also known as no-till, reduces the amount of tillage and encourages soil conservation and moisture storage that can be utilized by crops efficiently.

4.1.3 Agroforestry

Agroforestry involves the planting of trees in a crop field that will help in conserving or protecting the soil from direct raindrop impact, also reduce the speed of surface runoff and the decaying leaves from them supply soil nutrients. Other methods under this intervention are incorporating hedgerows that reduce soil erosion by reducing the impact of wind on the soil surface.

4.1.4 Water Harvesting

Water harvesting is the accumulation and storage of rainwater for use at the same place later through damming or promotion of groundwater recharge. The harvested water is used during the dry season or in dry areas. The other forms of water harvesting are pit planting that encourages water retention by allowing it to infiltrate into the soil.

4.1.5 Livestock Integration

Livestock integration into farming helps the farmers to have more livelihood options and save them in case crop enterprise fails at any particular time. The integration may include both small and big livestock at family and community levels while encouraging zero gratings. The livestock may include the following: dairy cattle, pig, and poultry.

4.1.6 Practicing Efficient Irrigation

Agricultural productivity in the wake of increasing population and climate change effects can be boosted with modern and efficient irrigation technologies. This intervention will result in increasing the agricultural output per unit of irrigation water and land.

4.1.7 Use of High Yielding and Resistant Crop Varieties

Subsistence farmers should be encouraged to plant high yielding and resistant crops and varieties. For example, they should plant crops that resist the effects of climate change such as cassava and potatoes. The farmers should also use high yielding and resistant crop varieties that will support them in food security and income. This approach is impeded by expensive technology, lack of training, and the inability of local communities to mobilize finances (Marcis et al. 2019).

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