Agroforestry Practices and Potential of On-Farm Trees and shrubs for Food Security & Climate Change Resilience in Rajaf County-South Sudan

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ABSTRACT

Incorporating trees and shrubs in food crop systems can help to address food insecurity issues and reduce vulnerability of agricultural systems to climate change. The purpose of this study was to investigate the current agroforestry practices and their relevance to enhancing food security and climate change resilience among rural communities in Rajaf County. Household surveys using structured and semi-structured questionnaires, Key informant interviews and Focused Group Discussions were used. Data analyses were done in descriptive statistics that include comparing their frequencies and percentages while others were presented in charts and graphic forms. Results indicated that most households practised agrisilvicultural and agrisilvopastoral agroforestry systems with scattered trees on farms, boundary plantings, homegardens, and woodlots as their on-farm arrangements. While goats and chickens were most reported domestic animals; sorghum, beans, groundnuts, cassava, maize, and simsim were the main reported food crops. The most preferred tree species were *Mangifera indica, Azadirachta indica, Balanites aegyptiaca, Mahogany spp* and *Acacia spp*, for distinguished utilization. Planting more evergreen trees in woodlots were their main practices for resilience to climate change due to its capacity to hold more components resulting into more diversified alternative sources. Although agroforestry practices require intensive labour, there is always a secured next component in case of failure of one component. Therefore, farmers should be encouraged to practice agroforestry that results to food availability and accessibility inorder to become food-secure households.

Keywords: Agroforestry practices, Food security, Climate change strategy, Trees and shrubs.

INTRODUCTION

Agroforestry (AF) is a term that many authors have attempted to define in various ways with complex meanings. From its interdisciplinary view-point as a science and practice, agroforestry has been harmonized into various different descriptions by many authors. Seemingly, one of its recently accepted and widely used definitions is one derived by International Council for Research in Agroforestry (ICRAF) which delineates agroforestry as a "joint or collective word that refer to any land use systems and practices, where deliberately woody components or perennials (trees, shrubs, bamboos, vines etc.) are incorporated with non-woody components (agricultural crops and/or animals (pastures)) either arranged spatially or temporally on the same piece of farmland in which interactions between these woody and non-woody components must be ecological and economical in practice (Ong *et al.*, 2015). Louise *et al.(*2009) further noted that, agroforestry system describes the deliberate growing of two or more plant species in spatial and temporal arrangement which may include raising of livestock and at least a plant component preferably a woody perennial tree or shrub.

Agroforestry is therefore, recognized by most international donor communities and development practitioners as one of the complex and labour intensive land use system that is increasingly adapted as the appropriate farming systems, technologies and management options with great potential to address food insecurity as well as the provision of ecological services to most rural small-holder farmers in developing countries. For this reason, its practices have currently drawn the minds of many developing nations as a central point of entry for sustainable development (Callo-Concha and Denich, 2014; Mbow *et al.*, 2014).

According to Ong *et al.* (2015), a typical agroforestry system usually composed of basically two or multiple functions or products and benefits within the same ecosystem with its normal growth cycle approximately estimated to last beyond one year. Any structural and functional complexity that accrues to its system(s) greatly encompasses complex socio-economic functions as opposed to traditional mono-cropping system. Muschler (2014) also noted that a variety of goals and objectives entails a typical agroforestry system that represents integration between agriculture and forestry, and incorporate a mixed land use system which allows symbiotic, economic and ecological interactions between the woody and non-woody components to increase, sustain, and diversify the total land output. Despite of these, many agroforestry practices still exist as traditional farming systems which have not been subjected to scientific scrutiny nor evaluation (Kumar *et al*, 2015; Wood and Burley, 1991). This implied that no proper study has been carried out on the role of agroforestry to food security and climate change resilience in many areas of South Sudan including Rajaf County. Despite some efforts

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being undertaken by UNFAO, World Vision and others to increase and improve agroforestry practices in South Sudan (Natamba *et al,* 2018; Wel, 2012), widespread of such agroforestry practices still remain low throughout South Sudan and Rajaf County in particular. Although incorporation of trees and shrubs in food crop systems can help address food security issues and reduce vulnerability of agricultural systems (FAO, 2010), questions still remain as to whether households with varying degrees of food security would choose to retain or cultivate specific tree species for a particular purpose (Sabastian *et al.,* 2014). Such questions needed a holistic approach as agroforestry land use management is very necessary for increasing carbon stock and socio-economic development of rural communities among others. This was so, because a research geared towards eliciting knowledge on the role of agroforestry in food security and climate change resilience is very necessary as far as making proper future policies and strategies on the use of agroforestry practices to enhance food security and communities' resilience to climate change.

Indeed, many studies conducted by FAO do not offer a clear isolation between different landscapes of forests and agriculture concurrently with trees (FAO, 2013). Agroforestry is also viewed as a mixture of historical irregularity rather than indication of inappropriateness between perennial plants and annual plants within a farming system (de Foresta *et al.,* 2013). Although a number of approaches have been proposed for defining a typology of agroforestry practices and systems (Zschocke, 2011), inclusion of multiple characteristics is still necessary for grasping all major distinctive attributes of agroforestry systems (Mbow *et al*.,2014).

MATERIALS AND METHODS.

Study area

The study was conducted in four payams (Gumbo, Kolye West, Kolye East and Tokiman Islands) sites of Rajaf County of Jubek State-South Sudan. Rajaf County is located along the eastern and western banks of River Nile, southeast of Juba city at latitude range between 4° and 6°North and longitude of 27° and 32° East. It covers a total area of 3,204 km^2 and hosts a total population of about 15,604 people (Sudan Population and Housing Census, 2008). The area is covered by open woodland and grassland in the rich moist tropical highland environment. The main trees and shrub species include *Mahogany spp, Acacia seyal, Acacia mellifera, Balanties aegyptiaca, Acacia senegal, Hyphaene thebaica, Borassus aethiopum, Mangifera indica, Tarmarindus indica,* and *Azadiractha indica (*Suleiman, 2007).

Humidity usually exceeds 80% during the rainy season, and drops to below 50% in the dry season (Mbwiga, 2016; Shilabu, 2008). Maximum temperatures in the area range between 30ºC - 33ºC all year round with a minimum of 18ºC in the wet season (Donat *et al.,* 2014; Mohamed *et al.,* 2006).

Due to its proximity to the bank of River Nile, its fertile soil grades and potentials make it favourable for agriculture and growth of agroforestry species and natural forests stands.

Research design, sample size and sampling procedures

This study was based on descriptive household (HHs) surveys and on-farm observation. The household surveys involved conducting interviews with household heads, key informants interviews (KIIs) and focused group discussions (Shilabu, 2008).

Four payams of Rajaf County were purposefully selected for the study. From each selected payam, three villages called Bomas were selected randomly and at least 25 households from each were visited for interviews. This made up at least 75 randomly selected household respondents from each Payam and an overall of 332 respondents within Rajaf County were sampled. A list of Bomas that contained a total of 2432 households retrieved from payam registry was used for random selection and 5 % of the total households found in the registry were selected (Humphreys and Ahern, 2017; Bartlett, *et al*., 2001). Members of the focused group discussions were got from two distinct groups (men and women) of varied age category (Wel, 2012). This was done with consultation and approval of concerned payam administrations and local leaders.

Data collection

Prior to data collection, pre-testing of field questionnaires was done inorder to evaluate its strength or weakness, for clarity checks and to improve its reliability and necessary adjustments incorporated (Kwiyega, 2015; Shilabu, 2008). During the survey, household heads or any of the willing representatives present was interviewed. Direct translation other than audio transcription was done since all interviews were conducted in local language and colloquial Arabic. The final responses were then recorded in English. The survey focused on types of AF practices/systems including indigenous knowledge for managing various agroforestry practices, farmers' potentials of on-farm tree planting and agroforestry activities and their contribution to food security and alleviation of climate change.

Data analysis

The household survey data in the filled questionnaires were analysed in descriptive statistic using Minitab v.14. and SPSS v.23 (Bryman & Cramer, 2009) that include frequency distribution and percentages. The data were presented in tables, charts and graphic forms to compare and explain the contributions of various agroforestry practices and systems and farmers' indigenous management knowledge among the payams (Kabwe *et al*., 2009).

RESULTS

Agroforestry system and practices for enhancing food security in Rajaf County

Most respondents (62.7%) reported agrisilvicultural system as most preferred agroforestry system. Only 34.3% and 1.8% of the households' respondents preferred agrisilvopastoral and silvopastoral systems respectively (Table 1). Over 97% of the households respondents preferred to have scattered trees in farms as their major AF practices. Other agroforestry practices reported were home gardens, boundary planting or retaining of trees along borders, woodlots, alley cropping and shifting cultivation preferred by 92.5%, 83.1%, 47.6%, 37.3% and 16.9% of the respondents respectively (Figure 1).

Table 1: Agroforestry systems in Rajaf County

Agroforestry systems	Frequency (N)	Percentage (%)
Trees+Crops only (Agrisilvicultural)	208	62.7
Trees +Crops+Animals (Agrisilvopastoral)	114	34.3
Trees +Animals only (Silvopastoral)	006	01.8
Other agroforestry systems	004	01.2
Total	332	100.0

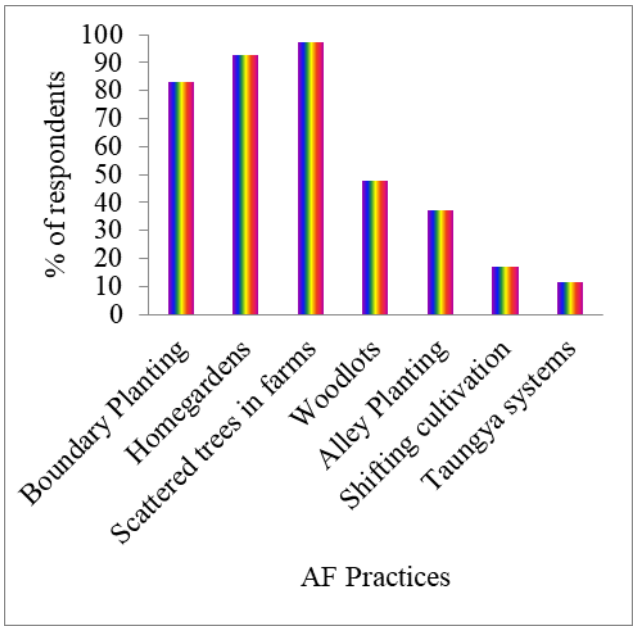

Figure 1: The agroforestry practices viable in all farms at Rajaf County

Reasons for practicing agroforestry in Rajaf County

The major reasons for practising agroforestry in Rajaf County were continuous food supply, ready markets, accessible agroforestry inputs, favourable government policy and large farm size reported by 96.4%, 91.9%, 87.3%, 50.6% and 42.5% of the respondents respectively (Figure 2).

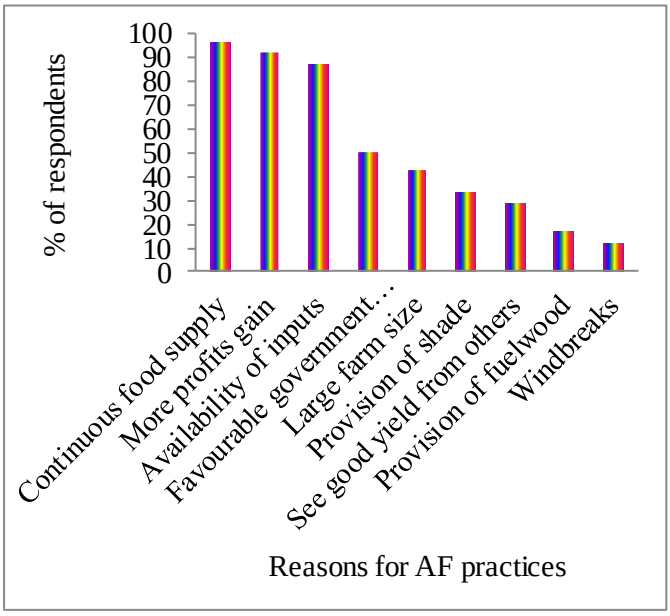

Figure 2: The reasons for practicing agroforestry

Preferred agroforestry niches for native and exotic AF tree/shrubs species for food security in Rajaf County

Agroforestry niches preferred by local farmers in Rajaf County included home compound, home gardens, cropland niches and boundary planting reported by 70.8%, 63.0%, 47.3% and 13.9% of the respondents respectively (Table 2).

Table 2: Preferred Agroforestry Niches in Rajaf County (N=332)

AF Niches	Responses (N)	%
Home compound land	235	70.8
Home garden land	209	63.0
Cropland niche	157	47.3
Boundary planting	046	13.9
Home grazing land	028	08.4
Woodlots	016	04.8
Windbreaks	004	01.2
Nurse/ shade trees	004	01.2
Fences niche	002	00.6
Roadside niche	001	00.3

Most residents of Rajaf County preferred to grow or retain native tree species such as *Balanites aegyptiaca*, *Tarmarindus indica* and *Acacia spp* reported by 97.3%, 85.2%, and 76.4% of the respondents preferences respectively (Table 3, N=332).

Table: List of the native and exotic AF trees/shrubs spp

Species name	N	%
Mangifera indica L.	329	99.1
Balanites aegyptiaca L.Delli	322	97.3
Azadiractha indica L.	300	90.4
Psidium guajava L.	289	87.0
Tarmarindus indica.L	282	85.2
Citrus spp (limon (L.) Osbeck & sinensis (L.) Osbeck	270	81.3
Acacia spp (sieberiana DC.; *nilotica* (L.) Delile; *senegal* (L.) Willd.; *seyal* var. seyal*)*	253	76.4
Tectona grandis L.f.	226	68.1
Borassus aethiopum Mart.	207	62.5
Carica papaya L.	184	55.4
Vitellaria paradoxa C.F.Gaertn.	164	49.5
Terminalia spp (catappa L. & glaucescens Planch. ex Benth.)	148	44.7
Musa spp (acuminata Colla & Musa × paradisiaca L.)	131	39.5
Senna siamea (Lam.) H.S.Irwin & Barneby	127	38.3
Mahogany spp (Khaya grandifoliola C.DC. & senegalensis (Desv.) A.Juss.	126	38.1
Kigelia africana (Lam.) Benth.	079	23.9
Eucalyptus spp(camaldulensis Dehnh.; grandis W.Hill	031	09.3
Ziziphus abyssinica Hochst. ex A.Rich.	015	04.5
Persea americana Mill.	013	03.9

About 99% of the household heads preferred *Mangifera indica* as their main exotic tree species to grow in their agroforestry farms. Others preferred *Azadiractus indica, Psidium guajava, citrus spp, Tectona grandis, and Carica papaya* that accounted for 90.4%, 87.0%, 81.3%, 68.1%, and 55.4% as reported by respondents respectively (Table 3).

The economic values or uses of agroforestry trees/shrubs species in Rajaf County

According to the opinion of the respondents, major economic values of trees in their agroforestry practices included trees that provide food (99.7%), income generations (86.1%), fuelwood (78.9%), shade (75.9%), building poles and timber (70.2%), fodder for domestic animals (59.3%) (Table 4).

Tree products category preferred by the respondents to grow on-farms in Rajaf county

Farmers said that they would grow trees inorder to get the following products: fruits, timber/poles, fuelwood, ornamentals, and livestock fodder reported by 100%, 97.6%, 96.7%, 95.2%, and 81.0% of the respondents respectively (Table 5).

Table 4: The economic values or uses of agroforestry trees in Rajaf County (N=332)

Uses of Agroforestry trees[a]	Frequency (N)	%
Food(raw or cooked)	331	99.7
Incomes generation	286	86.1
Fuelwood	262	78.9
Shade	252	75.9
Construction/building(timbers/ poles)	233	70.2
Fodder	197	59.3
Fruits for beverages &Juice making	187	56.3
Provision of employments	151	45.5
Modify climates	137	41.3
Manure/Soil replenishment/fertility	129	38.9
Wildlife habitats	125	37.7
Gums and fibre production	116	34.9
Oils and Detergents	110	33.1
Acts as windbreaks/Shelterbelts	103	31.0
Decorations around homes & recreations	103	31.0
Cottage industries (Walking sticks, statues, etc)	78	23.5
Boundary demarcation	67	20.2
Medicines(herbs & can be processed)	27	8.1
Soil erosion control	27	8.1
Cultural rights	27	8.1

Agrisilvicultural system (crops vs trees) and reasons for component integration

Over 97.0% respondents reported that they mixed trees and crops in their farms. All growers of sorghum as main seasonal crop included trees in their cropland. However, beans, groundnuts and sesame were reported grown with trees by 90.4%, 87.3% and 60.2% of respondents respectively. Other agricultural crops grown with trees included cassava, maize, green vegetables and sweet potatoes reported by 84.9%, 66.9%, 58.4% and 41.0% of respondents respectively (Table 6).

Table 5: Tree products preferred by HH respondents to grow on-farms for FS (N=332)

Tree product category	Frequency (N)	Percentage of cases
Food/fruits trees	330	99.4
Timber and Poles	324	97.6
Fuelwood trees	321	96.7
Ornamental trees	316	95.2
Livestock fodder	269	81.0

Table 6: Food crops grown alongside trees by the

respondents on farms (N=332)

Food crops grown[a]	Frequency (N)	%
Sorghum/dura	332	100.0
Beans	300	90.4
Groundnuts	290	87.3
Cassava	282	84.9
Maize	222	66.9
Sesame	200	60.2
Green vegetables	194	58.4
Sweet potatoes	136	41.0
Pumpkins	100	30.1
Rice	086	25.9
Sugarcane	052	15.7
Yams	041	12.3
Watermelon	027	08.1
Millet	011	03.3

Table 7: Reasons why crops are grown together with trees on farms (N=332)

why mixed trees with crops[a]	Frequency (N)	%
Shade/drought tolerant	232	84.1
Contributes to food needs	209	75.7
Grows and matures faster	191	69.2
Soil fertility	190	68.8
High Yields	186	67.4
Easy to manage	165	59.8
Mixed sources of fodder	157	56.9
Control weeds and soil erosion	150	54.3
Resistant to pests and diseases	138	50.0
Provides mixed /many uses	127	46.0

Reasons given for growing these crops included shade/drought tolerance, contribution to food needs, faster growth/early maturity, soil fertility improvement, high yielding and ease of management reported by 84.1%, 75.7%, 69.2%, 68.8%, 67.4%, and 56.9% of the respondents respectively (Table 7). Other reasons given for growing trees with crops were that trees provide mixed fodder for animals, control weeds and erosion, and act as windbreaks and have many uses.

Livestock and Poultry and their Management in Rajaf County

a) Types of livestock and poultry kept by households for food security

In Rajaf County, livestock and poultry kept for household food security included goats, cattle, sheep, chicken and ducks reported by 37.2%, 12.8%, 12.2%, 25.0% and 7.6% of the respondents respectively (Figure 3).

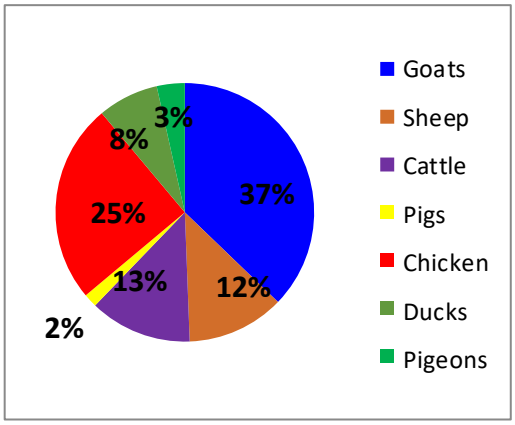

Figure 3: Livestock or poultry kept by farmers in Rajaf County

b) Management of livestock and poultry in Rajaf

The main livestock and poultry management strategies employed by farmers in Rajaf county included free range grazing systems, tethering animals, rotational grazing and build animal hut reported by 95.8%, 74.9%, 58.8%, and 48.9% of the household respondents respectively. Other management practices such as keeping manageable herd size, zero grazing, paddocking systems, dip litter system, deworming, and vaccinating were of minor importance (Figure 4).

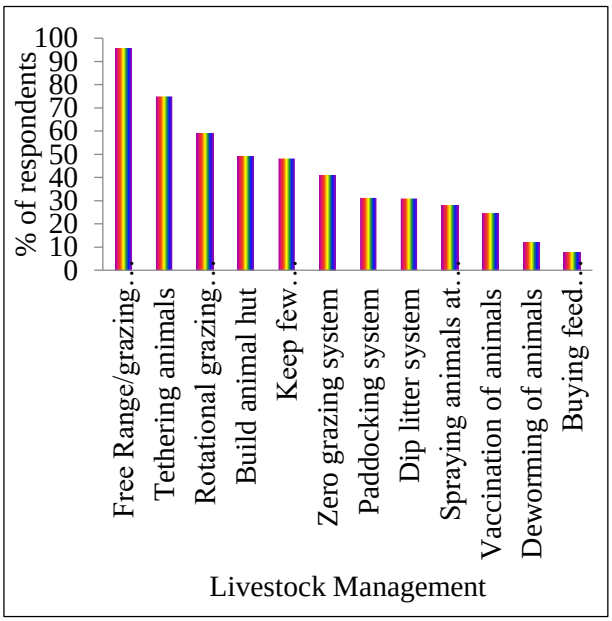

Figure 4: Livestock and poultry management Strategies

Agroforestry practices for enhancing resilience to climate change

The major AF practices for enhancing resilience to climate change included woodlot plantation, scattered trees on-farms, boundary planting of trees, homegardens, shelterbelts/windbreaks, alley cropping, rangelands or parklands, taungya systems and shifting cultivation reported by 77.9%, 72.8%, 69.2%, 68.5%, 61.6%, 58.7%

49.3%, 46.7% and 40.6% of the households respondents respectively (Figure 5).

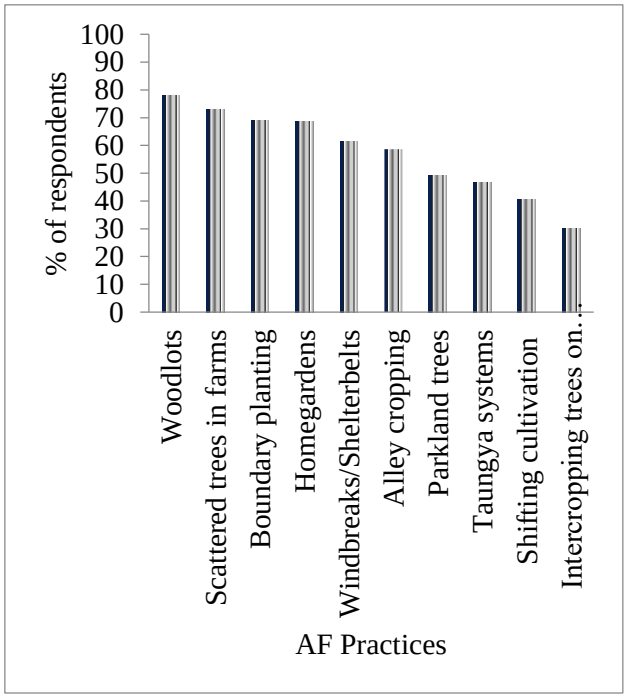

Figure 5: Main AF practices resilience to climate change in Rajaf County

Agroforestry tree species identified by farmers and reasons for their preference to mitigate climate change

Trees/shrubs that were being retained/ grown by farmers for enhancing farmers' resilience to climate change included *Mangifera indica, Tectona grandis, Azadirachta indica, Mahogany spp (Khaya spp), Eucalyptus spp, Balanites aegyptiaca, Vitellaria paradoxum, Terminalia spp, Acacia spp,* and P*ine spp* reported by 98.5%, 93.1%,89.5%, 78.6%, 78.3%, 68.1%, 60.5%, 60.5%, 45.5%, and 39.8% of respondents respectively (Figure 6). Reasons advanced by the respondents regarding their choice to grow/retain the various trees/shrubs on-farms included trees that act as sources of food, strong trees that can withstand drought, posses ability to modify climate, fast growing species and can regenerate quickly, conserve soil and water, act as windbreaks, and their multipurpose (MPTS) nature reported by 93.4%, 85.2%, 75.0%, 70.5%, 66.3% and 56.0% of the respondents respectively (Table 8).

Respondents' reported strategies to enhancing resilience to climate change in Rajaf County

Strategies reported by the respondents for enhancing resilience to climate change included planting more trees on farm, avoiding cutting down trees, avoiding burning of bushes, practicing reforestation and afforestation programmes, planting/retaining different species of trees on-farms, planting trees as shelterbelts/windbreaks, planting evergreen trees, and encouraging investments of AF activities as reported by 93.7%, 88.3%, 81.6%, 63.3%, 60.2%, 60.2%, 54.2%, and 47.6% of the respondents respectively (Figure 7).

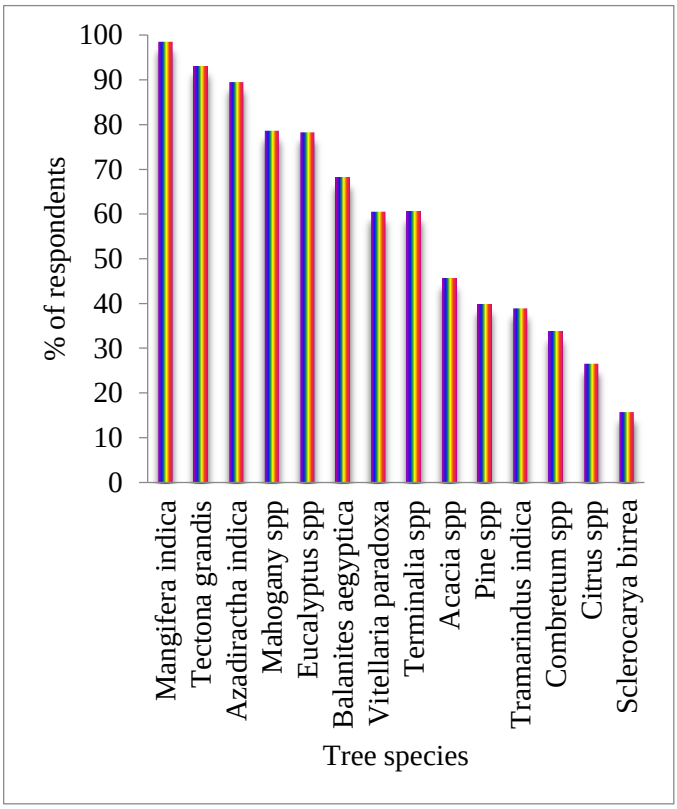

Figure 6: Trees/shrubs species preferred by HHs to grow to enhance resilience to CC

Table 8: Reasons for respondents' choice of those tree species to mitigate climate change

Reasons for farmers' choice for tree spp[a]	Frequency (N)	%
Sources of food & Inputs	310	93.4
Very strong and can withstand drought	283	85.2
Attract rainfall	249	75.0
Fast growing and regenerates quickly	234	70.5
Can conserve soil and water	220	66.3
They are MPTS	186	56.0
Their seeds are readily available	165	49.7
Reduce high temperature & provides clean air	157	47.3
Do not shed off leaves fast	154	46.4
Resist pest and diseases	141	42.5
Have good crown cover	129	38.9
Acts as windbreaks/ shelterbelts	115	34.6
Do not occupy large portion of land	106	31.9
They Modify microclimates	071	21.4

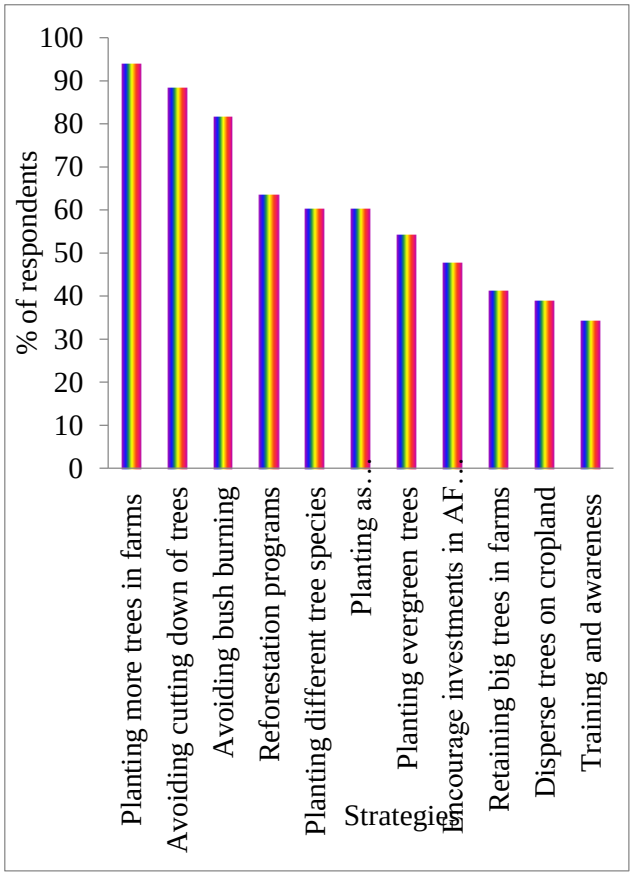

Figure 7: Reported strategies for enhancing resilience to climate change in Rajaf County.

DISCUSSION

Agroforestry systems and practices for enhancing food security

Over 62% of the farmers in Rajaf County practised agrisilvicultural system and few practised silvopastoral and other forms of agroforestry systems (Table 1).The indication of higher adoption of agrisilvicultural systems could be attributed to the fact that agricultural crop production is the major socio-economic activity of the local communities in the County. These farmers who cultivate mainly food crops and cash crops all year round seem to adopt agrisilvicultural agroforestry. The results conform to the findings reported by Chija (2013) and Mgeni (2008) for Kasulu, Kigoma Mufindi and Iringa districts of Tanzania where food and cash crop are grown in agrisilvicultural systems.

Profoundly, the most preferred agroforestry practices for the County were scattered trees in farms. This was with the view that abundant trees in farms shade crops and act as hosts to pests and diseases hence reducing yields of crops (Fasi *et al.*, 2016). However, as indicated in figure 1, homegardens, boundary planting, and woodlots are also common practices in most farms. Continuous supply of food, profit gains from the sale of AF products, sufficient fuelwood supply, adequate supply of AF inputs and favourable government policy were the reasons given by farmers for such practices (Figure 2). This agrees with findings of Chija (2013).

The agroforestry niches, native and exotic tree/shrub species, and their reasons for preference in Rajaf county

Over 70% households preferred AF niches in home compounds. Homegardens and cropland were also preferred on one hand (Table 2). On the other hand, boundary planting or retaining of trees along the farm borders was to protect farms from pests, avoid destruction by cattle, and to solve farm boundary disputes among neighbours. These could be planted as live fences, nurse trees in alleys and multipurpose trees on farm. This implies that most farmers prefer agroforestry practices that can guarantee continuous production of food such as homegardens with relatively uninterrupted regimes of food supply throughout the year (Morhart *et al.*, 2015; Chija, 2013; Zeleke, 2009)**.**

Although a small number of household heads complained of not been provided with agroforestry inputs, the traditional systems and practices were able to provide farmers with skills of farming, raise incomes for themselves, get access to employment opportunities and to become self-reliant households. Owing to the significant increase in the economic crisis and massive internal displacement of people due to the escalated conflicts in South Sudan, a high demand for food supply may be required to support this population (Wel, 2012).

Our results show that over 40% residents retained *Balanites aegyptiaca* a native tree species. *Tarmarindus indica*, *Acacia spp*, *Borassus aethiopum*, *Vitellaria paradoxa and Kigelia africana* (Table 3) were also found to have been retained on farms for distinct uses. These species of trees were retained on farms because they may provide one or more of the following: good quality timber products, cooking oil, shade/shelter, fruits, fuelwood, manure, modifies microclimate, herbs and for cultural practices (Table 4).

Tree and shrub species such as *Zizphus abyssinica*, *Grawiya spp*, *Anonna spp*, *Sclerocarya birrea*, and others were not recognized to have usefulness in agroforestry. Their contribution is little to food security in the area and are always ignored, removed or cut down. *Mangifera indica*, *Azadirachta indica*, *Guajava spp*, and *citrus spp* were reported as the main exotic tree species grown in their agroforestry farms (Table 3). They provide fruits to the society and improve their nutritional status and also generate income (Table 3).

Similar results were reported by Dowiya *et al.* (2009), Zeleke (2009) and Buyinza *et al.* (2008), who found that similar exotic species of trees were preferred by farmers in their areas because they are edible, nutritious and have additional important services to the communities. This is also in conformity with Gorsevski *et al*, (2012) who did a selected analysis of vegetation types of South Sudan in

areas having various tree species available on farms retained for distinguished functions.

Agrisilvicultural system (crops vs trees)

The analysis show about 97.0% HHs practise agrisilvicultural system with over 80% who have been growing the same crops with trees for the last 10 years. The stable cereal crop, sorghum, is their main seasonal crop grown by every household (Table 6). Growing legumes was also found viable in the area as farmers spatially or temporally mix them with woody perennials on farms as intercrops or in alleys. The high interest of farmers for agrisilvicultural practices could be attributed to short term returns from agricultural annual crop production. The high rate of livestock destocking had left many families without domestic animals to rear and so HHs had to swift to crop production.

These annual crops included sorghum, maize, cassava, beans, simsim and groundnuts as the major food crops usually grown on larger scale and harvested mainly for household family consumption (Table 6). Therefore, the diversity of crop species and trees on–farms ensures multiple functions of food needs, shade, faster growth of crops, fodder supply and soil fertility improvement (Table 7) and adds to nutritional value for both man and livestock although it is a deliberate effort of each HH (Asefa, 2017). The result in the table 7 above also agrees with findings of Morse *et al.,* (2017); Miller (2008); Van der ploeg (2014) who reported that diversity of vegetables grown are very rich in mineral supply and therefore, is expected to provide adequate nutrition for the household.

Livestock and poultry kept by households and their management for food security in Rajaf County

The study shows variation in the preference of livestock reared by households between the payams. Most farmers prefer to keep goats and chicken (Figure 3). This is because they are easy to manage and do not pose threats to agricultural crops. They are easy to handle, grow fast, provide sufficient dietary food value and can solve immediate family needs. The results agree with the findings of Rigolot *et al*., (2017) who reported that most HH families owned domesticated animals (goats, sheep, cattle and chicken in particular) as the way to meet their dietary needs and reduce family expenditures. The small number of other types of livestock such as sheep and cattle per family in Rajaf County is due to persistent insecurity from the current political unrest, cattle raiding and epidemic animal diseases contributed to the destocking. This led to shortage in livestock and livestock products, which by current rates of supplies do not satisfy the current demand of the expanding towns. This argument is in line with Maitima *et al.* (2010) and Ngigi (2008), who stated that despite the high potential of home grown South Sudanese livestock to providing enough animal-based products, large volume of livestock and livestock products are currently being imported from the neighboring countries of East Africa to meet the increasing demand in capital Juba and other major towns in the new nation.

Livestock and poultry are managed and fed primarily as free range /grazing systems but others kept within home vicinity and indoors and some on rotational basis (Figure 4). Livestock browse and feed on natural vegetation including grasses and post-harvested crop residues, leaves of trees probably as cut-and- carry and left-over foods ready for disposal because HHs lack incentives for special feeds.

The livestock are treated by use of herbs, vaccination and through deworming (Figure 4). The results agree favourably with the findings of Arabi (2007), who reiterated that most domesticated animals are given shelter at night and are left as free range during the day in a fenced area to feed on weed seeds, vegetation, and plant residues. However, during cultivation season, animals are kept and fed indoors or tethered under trees for shelter and to avoid threat to crops (Rigolot *et al*., 2017). Livestock have, however, traditionally not been kept fenced during the day in South Sudan.

Agroforestry practices and their choice for enhancing resilience to climate change

The results show that households considered woodlots plantations as the major AF practice for resilience to climate change. Others believed fast-growing and easy-to-manage species as scattered trees in farms, boundary planting, home gardens, and planting shelterbelt and windbreaks can alleviate climate change (Figure 5). However, shifting cultivation and intercropping were not given much consideration as they are based on a variety of management approaches with potentially positive implications for climate change mitigation.

These practices range from obvious interest for fruit production, animal husbandry, shade trees, thinning, coppicing, and trees for fuel wood, windbreaks and soil erosion control and many more. The current findings are also in conformity with Mbow *et al.* (2014) who argued that the interest in investigating agroforestry in the face of a changing climate comes from the potentials of agroforestry practices to produce assets for local farmers, combined with opportunities for climate change mitigation and its potential to promote sustainable production that enhances agro-ecosystems species diversity and resilience.

Agroforestry tree species identified by farmers and their choice to mitigate climate change

Despite being native or exotic to the area, most HHs chose various varieties of *Mangifera indica* as the most preferred tree species probably due to its climatic adaptability, fruits provision, shelter provision and medicinal use. *Tectona grandis, Azadirachta indica, Mahogany spp (Khaya spp),* and *Eucalyptus spp* were also preferred by the communities in the study area (Figure 6).

Additionally, they are preferred for fruits, fuelwood, and windbreaks as they protect crops and houses from damages by heavy winds notwithstanding its contributions to soil and water conservation.

Tree species such as *citrus spp, Combretum spp, Sclerocarya birrea* and others were not recognized as important for climate mitigation (Figure 6). This is because they have narrow crowns, not evergreen and do not establish easily under given environmental conditions. These findings are in line with that of Lulandala (2009), who reported that trees selected must not only be preferred and accepted by the communities using them but also to be able to establish and grown under given environmental conditions for their diversified uses/services.

The respondents' reported strategies for enhancing resilience to climate change

Growing more trees, avoiding deforestation and burning of bushes, planting evergreen trees, practice of reforestation and afforestation programmes; retaining big trees and mixing different tree species in their farms for multiple purposes were considered the main strategies to overcome climate change situations (Figure 7). Another strategy was to maintain trees and tree products for animal fodder and fuel wood as household energy base while they modify climate. This current finding is supported by Bhatt (2013) who reiterated that more than 75% of households would have sufficient fodder and fuel wood from their farmland if they grow more trees for a long time. This would in turn provide lots of environmental clues and become resilience to climate variability.

The economic values/uses/services of AF tree or shrub species in Rajaf County

The research results have evidently confirmed that whether native or exotic spp, many uses of AF tree species are attributed to food, shade at homes and for animals, sources of fuelwood, environmental protection, soil and water conservation, and livestock fodder (Table 4).

The livestock fodder could be from a free rangeland or domestic management unit provided in form of cut-and-carry or fed from free range system. By allowing herbivores to graze within vicinity of trees, they add more organic matter from their droppings and urine as they continue to eat the leaves and grasses underneath trees, thus adding more soil nutrients and energy base in addition to fuelwood from the natural range of forests. The results compared favorably with Chija (2013) findings.

The study also found that for better uptake of nutrients and growth of AF components, leguminous tree species such as *acacia spp* should be planted or retained in farmlands although socioeconomic factors that influence local population is considered. In this case, experienced elderly people knowledgeable about indigenous nitrogen fixing, wild food and medicinal trees should be contacted for promising tree species.

CONCLUSIONS

Majority of households (over 60%) practised agrisilvicultural systems. This practice has put them at high risks of being food-insecure coupled with the high rates of current destocking, with only goats and chicken being the main domestic animals kept in most HHs. With the limited number of livestock kept by most HHs, in circumstances when tree crops failed, HHs would have nothing to sell as supplements to crops yet they would sell products of livestocks. Although presence of livestock in one area increases problems in another area, it also reduces problems in the other as stated by most respondents. Findings from this study would therefore suggest that adoption of fodder bank system is essential strategy to improve and enhance animal and crop production systems in Rajaf communities.

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