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The Effect Of Cropping Systems On Component Crop Productivity And Land Resource Use Efficiency

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Abstract
Adoption of intercropping has the potential to make efficient use of scarce land resource in densely populated AEZs of western Kenya and provide both livestock feed and human food while ensuring climate resilience. Most studies have focused on one intercrop while in this study, we tested Maize-Desmodium intercrop with vegetables on system productivity and land equivalent ratio (LER). Field experiment was conducted during short rains of 2023 and long rains of 2024 in Maseno to determine the effect of integrating kales and African nightshade into Maize-Desmodium intercrop on productivity of component crops and LER. Treatments consisted of sole Maize, Desmodium, Kales and Nightshade and their intercropping components of Maize-Desmodium, Maize-Desmodium-kales, Maize-Desmodium-Nightshade, Kales-Desmodium and Nightshade-Desmodium, arranged in RCBD with three replications. Data was collected on plant yields and used to determine land equivalent ratio (LER) and analysed using R software and significant means separated using LSD0.05 Maize yields in all cropping systems were not statistically significant in both seasons although Maize-Desmodium- kales had a slightly higher yields than other cropping systems on both season. Nightshade and Kales had no significant effect on dry matter biomass yield. Sole Desmodium (2.84t/ha) and Kale-Desmodium (2.34t/ha) had a significantly higher dry matter yield during the short rains but during the long rains, sole Desmodium (2.69t/ha) had a significantly higher dry matter. The LER for Maize-Desmodium-nightshade (2.8 and 1.96) and Maize-Desmodium-kales (2.45 and 1.88) was significantly higher indicating positive complimentary interaction between the crops Intercropping Desmodium with maize and kales or nightshade increases maize yields. Additionally, intercropping of Desmodium with maize, kales or nightshade significantly improves the land use efficiency.
Keywords: *Intercropping, Productivity, LER, climate resilience*

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I. Introduction

The availability of land for agriculture has become limited due to growing population and utilization of non-agricultural activities (Jiang et al. 2013). For instance, intercropping allows for a more efficient use of land resources where different crops are grown on the same space (Stomph et al. 2020). This ensures that, the available resources are used more effectively, minimizing waste and improving overall productivity (Paudel, 2016). According to Altieri et al. (2015), intercropping unlike monoculture, enhance yield stability of the component crops. Different crops have different root structures and growth habits, which can help to prevent soil erosion and improve soil health (Fahad et al. 2022). Furthermore, the continuous cover provided by multiple crops can reduce water evaporation, helping to conserve water (Wang et al. 2021). Intercropping maize-*desmodium* cropping system has been instrumental in increasing maize yield (Ndayisaba et al., 2020). Beyond productivity gains, intercropping contributes significantly to ecosystem, including improving soil structure, biodiversity conservation, pest and disease suppression, and climate adaptation through microclimate regulation(Mir et al., 2022; Ray et al., 2025), it also offers socio economic benefits, such as income diversification and crop failure mitigation for smallholder farmers. In addition, desmodium, plays a crucial role in this system. It has the unique ability to fix atmospheric nitrogen, thereby enriching the soil with this essential nutrient, it increases the soil organic matter, significantly improving carbon sequestration and the uptake of phosphorus through synergistic interaction of N (Bamboriya et al, 2022; Ndiritu, 2022). Hence offers an effective alternative to the use of inorganic fertilizers, which can be expensive. By covering the ground, desmodium helps in conservation of soil moisture, reduces soil erosion and suppresses the growth of Striga weeds (Osieyo, 2022). Intercropping maize with various vegetables, like tomato, onions, kale, nightshade, cowpea and spinach, can also be productive. These combinations allow for a more efficient use of space and resources, while also providing a diverse diet for local communities (Henze et al. 2020). Despite these advantages, the successful implementation of intercropping requires careful planning and management, including informed crop selection, spatial arrangement, period of sowing and nutrient management to balance to balance to balance competition and facilitation among component species. This paper explores the ecological, agronomic and socioeconomic dimensions of intercropping systems synthesizing current research on their mechanisms, benefits and limitation. By examining diverse intercropping strategies and their impact on productivity, land use and sustainability.

II. Materials And Methods

Experimental site description

The experiment was carried out in Maseno university farm, Kisumu County which lies at Latitude**:** N00.00304 and Longitude**:** E034.59989 and is approximately 1526 asl. Maseno receives a mean rainfall of 1500-1700mm annually with bimodal rain distribution of short rains(August-December) and long rains(March-July). The minimum mean temperature ranges between 10-18^{0}C and the maximum mean temperature ranges between 25-30^{0}C.The soil types are well drained, deep reddish to brown clay-loamy Ferralsol with slightly acidic (Sikuku., 2010).

Experimental design and layout

The experiment comprised 9 treatments replicated 3 times totalling to 27 experimental units. All treatments were arranged in Randomized Complete Block Design(RCBD). Each experimental unit was measuring 4.5x4.5m (20.25m^2).

Treatments

Treatments consisted of Maize+*Desmodium* , African nightshhade+*Desmodium*, Kales+*Desmodium*, Maize+Kales+*Desmodium*, Maize+African Nightshade+*Desmodium*, Sole kales, Sole maize, Sole African Nightshade, Sole *Desmodium*. Intercropping of maize and vegetables was superimposed on already established *Desmodium,* where each row of maize and vegetables alternates with *Desmodium.*

Weather data

The daily rainfall and hourly ambient temperature and humidity within the cropping system of the nine treatments was measured using the rainfall and temperature and relative humidity data loggers stationed at the farm.

Crop establishment and management

The experiment was conducted for two seasons of short rains of 2023 and long rains of 2024. Land was prepared during the dry season to control weeds and improve soil structure with a nursery bed prepared for vegetables seedlings three weeks before transplanting. Due to acidic soil on the site, lime was applied at a recommended rate at 2t/ha through broadcasting and hand harrowed properly with a fork hoe. *Desmodium spp* was trimmed before planting Maize and vegetables at a spacing of 75cm between rows and 30cm within rows. Planting holes were created using a hand hoe. Since phosphorus was adequate from our soil analysis only CAN fertilizer (40kg N/Ha) was applied in two stages at planting and at 5th leaf stage of maize to ensure adequate nitrogen supply. *S*tand count on maize and vegetables was taken two weeks after planting. Weeding was done at two and six weeks after crops establishment. Maize was sprayed with Pyrethrin pesticide to control fall army worm infestation while vegetables was sprayed with Dudutrin to control leaf miners, aphids and diamond black moth.

Data collection

Maize yield and bomass

Plant yield on maize crop was determined at physiological maturity. Two middle rows was harvested in each maize associated treatment and the ear number, field ear weight and moisture content determined. Maize grain yield per hectare was calculated using the following formulae;

$$\text{Grain yield (t/ha)} = \left[\frac{\text{FW(kg/plot)}\times 10\times(100-\text{MC})\times 0.8)}{(100-\text{adjusted MC})\times\text{Plot Area}}\right]$$

Whereby;
FW= Field ear weight in kg MC= Field moisture content
Adjusted MC= moisture content adjusted to 13% Shelling coefficient=0.8
Harvested area= 6.75m^2

The above ground biomass was computed by sampling 4 plants obtained from 6.75m^2 harvesting area. After weighing the 4 plants, shoots, leaves and cobs was chopped into small pieces and placed in khaki bags. These were taken to the laboratory and oven dried at 70^{0}C for 24hrs before taking dry weight.

Vegetable Dry Matter Determination

Two middle rows of each vegetable was harvested 3 times during each season at an interval of 2 weeks starting at 3 weeks after planting. After taking fresh weight, a sample was taken for dry matter determination by oven drying at 70^0C for 24hrs. Dry weight was taken which was used to calculate dry matter weight per unit area. At the end of each season, two middle rows of *Desmodium spp* in each plot was harvested, fresh weigh and sun dried for 4 days for total dry matter biomass determination.

Land Equivalent Ratio

Data collected on maize, vegetables and *Desmodium* yields was used to determine the yield advantage of intercropping kales and African Nightshade into the maize-*Desmodium* cropping system over the sole cropping system described by (Mead & Willey, 1980).

$$LER = La + Lb + Lc = \frac{Ya}{Sa} + \frac{Yb}{Sb} + \frac{Yc}{Sc}$$

Where La, Lb, and Lc are the LERs for the individual crops (maize, *desmodium*, kales or african nightshade). Ya, Yb, and Yc are the yields of individual crops in intercropping, while Sa, Sb, and Sc are the yields of the sole crops.

Data analysis

The data collected was compiled and tabulated for statistical analysis using Microsoft excel. The data was subjected to analysis of variance (ANOVA) and significant means separated using least significance difference (LSD0.05) using R software (version 4.2.2) to determine significance differences between the treatments for LER, maize grain yield and dry matter yields of maize, vegetables and *Desmodium*.

III. Results

Weather

Short raining season recorded a total of 941.8mm rainfall between September and December 2023 and the long rains recorded a total of 749.2mm rainfall between March to August 2024. The average mean monthly temperature during the short rains were 25.6ºC and 23.1ºC during the long rains season. The month of May received the highest amount of rainfall while the month of December received the lowest amount of rainfall during the short rain season (Fig. 1). During the long rains, May and July receive the highest and lowest amount of rainfall respectively. The monthly average temperature during the short rains were lowest in November (20.3ºC) and highest in December (25.3ºC) while in long rains, monthly average temperature was recorded lowest in March (21.5ºC) and highest in July(24.6ºC).

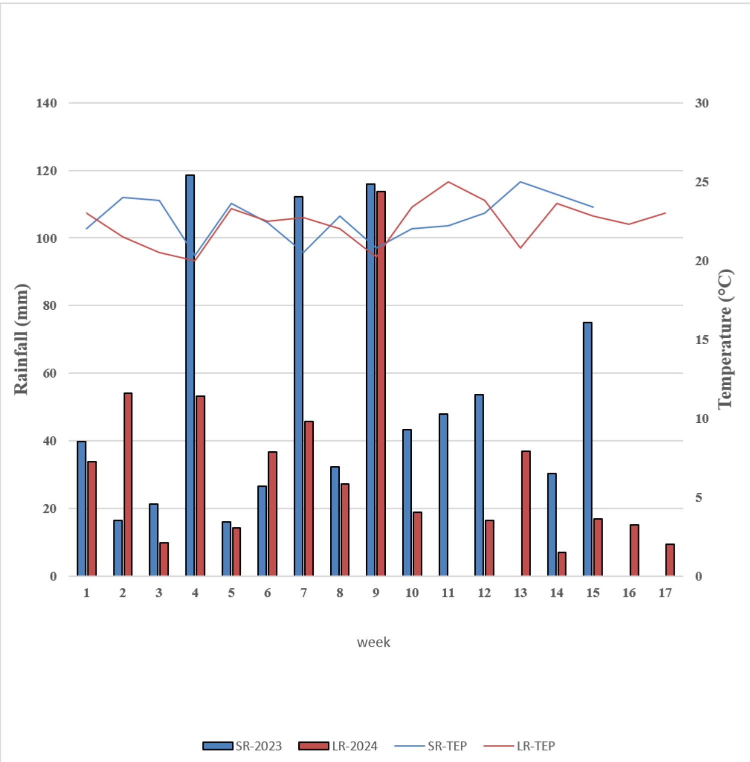

Fig 1; Maseno rainfall and temperature during copping season.

Plant Yields and dry matter weight

Maize yields (t/ha)

The maize yields(t/ha) on maize-*desmodium*-kale, maize-*desmodium*, maize-*desmodium*-nightshade and sole maize was not significantly different from each other on both seasons. However, Maize yields(t/ha) from SR-2023 had the highest mean maize yields (1.57t/ha) compared to the LR-2024 (1.41t/ha)

Table 1: Maize yields (t/ha).

YIELDS (t/ha)		
Cropping system	**SR-2023**	**LR-2024**
Maize- *desmodium*- kale	1.68	1.63
Maize-*desmodium*	1.53	1.36
Maize-*desmodium*-nightshade	1.55	1.31
Sole maize	1.53	1.35
MEAN	**1.57**	**1.41**
LSD	**NS**	**NS**
CV%	**17.60**	**24.46**

LSD-Least Significance Difference, CV- Coefficient of variance, significance difference at *p<0.05,* t/ha-ton/hectare, SR-Short rains, LR-Long rains

Dry matter weight of Kale

The were no statistical significant differences observed on kale dry matter weight (t/ha) of Maize-*desmodium*- kale, Kale-*desmodium,* and sole kale on both seasons. The SR 2023 had a higher kale dry matter weight mean (0.82t/ha) compared with the LR-2024 (0.23t/ha)

Table 2: Kale dry matter weight (t/ha).

Dry matter weight (t/ha)		
Cropping system	**SR-2023**	**LR-2024**
Maize- *desmodium*- kale	0.83	0.26
Kale-*desmodium*	0.82	0.23
Sole kale	0.82	0.21
MEAN	**0.82**	**0.23**
LSD	**NS**	**NS**
CV%	**5.78**	**24.65**

LSD-Least Significance Difference, CV- Coefficient of variance, significance difference at *p<0.05,* t/ha-ton/hectare, SR-Short rains, LR-Long rains

Dry matter weight of nightshade

The were no statistical significant differences observed on Nightshade dry matter weight (t/ha) of Maize-*desmodium*- nightshade, nightshade-*desmodium,* and sole nightshade on both seasons. On seasonal comparison in terms of dry matter weight, SR-2023 had a higher Nightshade dry matter weight mean (1.96t/ha) compared with the LR-2024

Table 3: Nightshade dry matter weight

Dry matter weight (t/ha)		
Cropping system	**SR-2023**	**LR-2024**
Maize-*desmodium*-nightshade	2.38	0.56
Nightshade-*desmodium*	1.81	0.48
Sole nightshade	1.68	0.61
MEAN	**1.96**	**0.55**
LSD	**NS**	**NS**
CV%	**21.68**	**29.49**

LSD-Least Significance Difference, CV- Coefficient of variance, significance difference at *p<0.05,* t/ha-ton/hectare, SR-Short rains, LR-Long rains

Dry matter weight of desmodium

On *desmodium* dry matter weight (t/ha), Sole *desmodium* (2.84t/ha and 2.69t/ha) were significantly different from Maize-*desmodium*-kale, Maize-*desmodium,* Maize-*desmodium*-nightshade, and Nightshade-*desmodium* on both seasons, except Kale-*desmodium* (2.34t/ha) during the SR-2023 which was not significantly different from Sole *desmodium.* SR-2023 had the highest *desmodium* dry matter (t/ha) than the LR-2024.

Table 4: *Desmodium* dry matter weight

Dry matter weight (t/ha)		
Cropping system	**SR-2023**	**LR-2024**
Maize-*desmodium*- kale	1.64c	1.55b
Kale-*desmodium*	2.34ab	1.17b
Maize-*desmodium*	2.19bc	1.76b
Maize-desmodium-nightshade	2.02bc	1.92b
Nightshade-*desmodium*	1.73bc	1.92b
Sole *desmodium*	2.84a	2.69a
MEAN	**2.12**	**1.84**
LSD	**0.639**	**1.95**
CV%	**16.52**	**29.9**

**Means followed by the same letters between treatments are not significantly different from each other.*
LSD-Least Significance Difference, CV- Coefficient of variance, significance difference at *p<0.05,* t/ha-ton/hectare, SR-Short rains, LR-Long rains

Land Equivalent Ratio

The total land equivalent ratio (LER) of all the five cropping systems were greater than one (>1). This shows that, the cropping system had a yield advantage over the sole crops (table 16). The total LER of Maize-*desmodium*-nightshade were significantly different from Maize-*desmodium*, Kale-*desmodium*, and Nightshade-*desmodium* except Maize-*desmodium*-kale which was not significantly different from Maize-*desmodium*-nightshade on both seasons.

Table 5: Total Land Equivalent Ratio of the cropping system.

LER		
CROPPING SYSTEM	**SR2023**	**LR2024**
Maize- desmodium-nightshade	2.80a	1.96a
Maize-desmodium- kales	2.45ab	1.88ab
Nightshade-desmodium	1.46b	1.21c
Kales-desmodium	1.46b	1.48bc
Maize-desmodium	1.42b	1.39c
MEAN	**1.918**	**1.58**
LSD	**1.07**	**0.47**
CV%	**29.64**	**15.76**

**Means followed by the same letters between treatments are not significantly different from each other.*
LSD-Least Significance Difference, CV- Coefficient of variance, significance difference at *p<0.05,* t/ha-ton/hectare, SR-Short rains, LR-Long rains.

IV. Discussions

Cropping system had no significant effect on yields of maize crop and dry matter of vegetables, this might be attributed to the compatibility of the plant combination of the cropping system in terms of a balance in uptake of nutrients, water and light, it could have also been contributed by the favorable microclimatic condition created within the cropping system. Singh *et al*. (2012) demonstrated that the microclimate created by combining short and tall crops limits solar radiation, which decreases evapotranspiration and ultimately boosts the productivity of the intercrops. The cropping system likely promoted resource complementarity and ecological balance, leading to a stable dry matter yields across treatments. This contradicts results found by (Iderawumi et al., 2012)whose research demonstrated that intercropping increased dry matter yield compared to sole crops, due to better use of light and soil moisture. *Desmodium* recorded significantly higher dry matter yield on Sole *desmodium* and kale-*desmodium* compared with *desmodium* from other cropping system. Kifuko *et al*. (2012) found that *desmodium* when intercropped with maize has little effect on maize yield, but affects *desmodium* biomass production. This implies that sole *desmodium* which is shorter requires maximum sunlight to perform well. Sole desmodium had fully access to soil nutrients, water and sunlight, a pure stand of desmodium allow maximum canopy expansion and photosynthetic efficiency unlike when intercropped with taller species which could limit its ability to capture sunlight thereby reducing dry matter production. Kale-*desmodium* intercrop could be attributed to resource balance and compatibility of the cropping system due to their short height, capturing a balance of sunlight interception.

The total LER of all the five intercropping system were greater than 1 indicating that intercropping systems had a better yield advantage over the sole crops. Takim (2012) also found similar results that intercropping were higher in intercrops, indicating an optimum exploitation of resources. Maize-*desmodium*-

nightshade had significantly higher LER in both seasons respectively. This could be attributed to a positive interaction enhancing compatibility of the cropping system. Three-crop intercropping increases LER because it maximizes complementary use of light, water, and nutrients, minimizes intra-specific competition, enhances yield stability. Temporal niche differentiation enhances difference growth harvest periods of intercrops, promoting optimal resource partitioning enhancing improve yields, resulting in greater land use efficiency and overall productivity.

V. Conclusion

Maize yields and vegetables dry matter were not significantly affected by the cropping system, the compatibility of plant combinations ensures efficient resource use and minimize competition. Desmodium exhibited optimal dry matter weight accumulation when grown alone or with shorter crops rather than when intercropped. Maize-desmodium-nightshade had a higher land equivalent ratio, underscoring the benefit of microclimate condition created in multi-cropping and a positive interaction among the three crops. Therefore, farmers may be able to diversify with vegetables in maize-desmodium systems to maximize land resource use.

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Conflict of interests

The authors declare no conflict of interest

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