EVALUATION OF CROPS POTENTIALS IN THE CONTROL OF SOIL EROSION IN SOUTHERN CROSS RIVER STATE, NIGERIA

Egbai. O. O[1]., Amah, J. E[1]., Okang, A. O[1] & Ajom, S. K[2]
[1,2&3]Department of Environmental Management, University of Calabar, Calabar
[4]Department of Urban and Regional Planning, University of Calabar, Calabar

ABSTRACT
This study evaluated the potentials of various crops in the control of soil erosion in the Southern Cross River State with specific interest in Biase Local Government Area. The purpose was to ascertain the potential of crops in combating erosion perturbation in the tropical rain fed agro ecological region. Four (4) sites were purposively selected for establishment of various crops in distinct blocks on different slope gradients of 6.3%, 6.2%, 5.9% and 5.9% respectively. Each block carried four different crops, each occupying separate plot. Planting at recommended distances was carried out after land clearing and stumping were accomplished. Sediment boxes were established at the foot of each slope. Mean spillways of 2, 8, 16 and 21 were recorded for melon, groundnut, soya bean and maize. Grand mean of 32.6g, 30.9g, 23.6g, and 16.6g of soil loss from crops' plots were recorded for maize, soya bean, groundnut and melon respectively. Result showed that spillways and soil loss (sediment yield) increased significantly in maize, soya bean, groundnut, and melon plots. Melon plots recorded the least amount of soil loss and least number of spillways of 16.6g and 2 spillways across the blocks, followed by groundnut with 23.6g and 8 spillways. The study recommends the use of melon and groundnut where mono-cropping is contemplated rather than maize and soya beans on slope range of 2% - 6.3% in the topical rain fed agro ecological environment.

KEYWORDS: Crops Potentials; Control; Soil; Erosion; Southern Cross River State.

1. INTRODUCTION

Soil erosion represents a range of soil removal processes whether in large or small scale often unnoticeable to the extent that its outcome undermines agricultural production, infrastructural and environmental sustainability. The environment provides the basis for which food production is achieved; in any event of soil erosion, access to environmental assets is usually implicated, undermining food production, and distorting of environmental aesthetics. Iwara et al (2023) enumerated the consequences of soil erosion to include; removal of top soil, and reduction of vegetation cover. The reduction of arable land capacity to sustain food production (FAO, 2025), while Egbai et al (2023) stressed on the loss of essential soil nutrients that support crops' growth and development.

Integrated farm management practices have also been seen to restore soil resilience and health, enhancing sustainable agricultural production and ecosystem services that are crucial for rural livelihoods (Ghimire et al., 2024; Liang et al., 2025). Improved crop rotation which underpine sustainable agricultural practices, have been found to significantly enhance soil protection from erosion while maintaining food security in vulnerable locations (Sharma et al., 2025; Tembo et al., 2025). In addition Bhaduri, Mahato, & Swain, (2025); Javadinejad, Dara, & Jafary, (2022) averred that sustainable agriculture targets soil health and sustainable management systems that ensure global goals of carbon sequestration and ecosystem restoration.

Southern Cross River State is characterized by undulating landscape and sufficient rainfall (Egbai 2016 and Egbai et al 2017), facilitating soil erosion (Li et al 2024) and undermining food production process (Keke et al, 2025). The study area represents a home for luxuriant vegetation although, often undermined by deforestation, a precursor of soil erosion perturbation (Egbai et al 2023). Adaptive solutions to soil erosion, hunger, and flooding are integrated as sustainable crop production strategies in the majority of African environments, including Cross River State, Nigeria (Sher et al., 2025). Crop-based soil conservation measures have become critical practices for sustainable land management in regions where degradation of soil is faced due to profound soil erosion. Crop rotation, cover crops, and agro forestry systems are among the practices that serve significant purposes in improving soil structure, organic content, and reducing erosion risk (Hussain et al., 2025; Al-Musawi, Vona, & Kulmány, 2025).

Mixture of a variety of cover-crop species, use of resilience crop species and increase in awareness of the applicability of agricultural techniques are practices in the tropics and sub-humid zones that have yielded profound results (Scavo et al., 2022; Quintarelli et al., 2022). Pulse-based cropping systems are prime drivers of soil health restoration, resource conservation, and environmental sustainability in rain fed environments (Kumar et al., 2023). Grain legumes in particular are highly desirable in semi-arid and sub-humid agro-ecologies because they can enhance carbon sequestration, nitrogen fixation, and year-round soil cover that reduce erosion (Kuyah et al., 2022). Soya bean and groundnut inter-cropping with cereals or tubers have been known to improve the efficiency of soil resource utilization, augment soil fertility, and improve climate change resilience, making it an essential practice to be used in conserving soil (Akchaya et al., 2025). Diversified cropping and agro-biodiversity conservation, as documented in cases like the Himalayas have shown significant underpinnings (Babu, 2024; Sati, 2024), and in addition, agro-ecological management practice as a viable agricultural system presents soil erosion control possibility (Husain & Sharma, 2022; Manga, Bidogeza, & Afari-Sefa, 2024).

Doubtless, the best soil protection intervention approach in agro ecological setting or at rural scale is that driven by rural people themselves as custodians of their immediate environmental resources, hence, government enforcement mechanisms are often misinterpreted for denial of access to nature; leading to creation of alternatives by the locals to enhance sustainable use of their immediate land resources for cultural and socioeconomic livelihoods. Unfortunately, unguided and inordinate use of environmental resources by the locals is the main reason for soil degradation. This calls for efficient and cost-effective intervention approach adoptable by the locals to avert exacerbated soil loss scenario using available, accessible and cheap erosion control measures. Wang et al (2018), noted that crops offers the best form of vegetation that is subject to considerable human intervention which can influence development of soil erosion. Thus, prevention of exacerbated erosion at rural scale can be guaranteed using available, accessible and cheap erosion control measures (Egbai, 2016; Egbai et al. 2017). Emphasizing the erosion control benefits of crops, Yan et al. (2020) averred that phenology, plant density, leaf area and canopy height of different crops have significant influence on soil erosion control. Relationship between soil erosion and plant cover was noted (Iwara et al 2023), the resilience of crops to soil erosion perturbation and the role of plants part (nature of leafs, root system and stem) have localized effect on resilience or susceptibility to erosion phenomenon (Egbai et al 2023; Egbai et al 2017).

1.1 **Study Area**

The study was conducted in Biase, Cross River State; Biase Local Government Area (LGA) is one of the 18 LGAs situated in the southern part of the state. It lies between longitudes 8°05′E and 8°25′E, and latitudes 5°10′N and 5°30′N sharing boundaries with Akamkpa and Odukpani LGAs to the north, and Yakurr LGA to the west, while extending southwards toward Akwa Ibom State. Villages include; Iwuru, Betem, Ehom, Akpet, Umai among others. The area is characterized by tropical rainforest vegetation, high rainfall, and fertile soils, which is the main reason for sustainable agricultural activities. Farming remains the dominant occupation of the rural people, with crops which include; cassava, yam, maize, rice, groundnut, melon, and cocoa widely cultivated, alongside oil palm plantations and vegetable farming. Annual rainfall is between 2000 and 3500 including a relative humidity of 65% and 95% in the area. Landform is generally gentle slope with varying gradients and elevation of 600m above sea level in some areas (Egbai 2011)

2. MATERIALS AND METHOD

2.1 Experimental site layout and design

Site selection: The selection of site was based on condition like moderate slopes of 6.3%, 6.2%, 5.9% and 5.9% slope gradients. The topography of the area is typical of humid tropics characterized by undulating landscape.

Soil samples were collected from each site with the aid of soil auger for laboratory determination of particle size distribution (sand, silt and clay). This is to give insight into the soil textural characteristics. Thus, four sites were randomly selected and designated as experimental blocks (i-iv) with various slope gradients determined by Global Positioning System (GPS). Each crop's Block was determined with Global Positioning System (GPS). Measuring 20m x 100m; subsequently divided into four (4) plots with each measuring 5m x 25m separated from adjacent plot by 2m. The control block was established on separate location at a close proximity. This helps to prevent interference and ascertain the real differentials in soil volume from the various blocks and plots respectively.

Each block measured 20m x 100m, divided into four (4) plots where crops (maize, groundnut, soya bean and melon were planted), implying that each plot carries one crop type; thus, a plot measured 5m x 25m separated from adjacent plot by 2m. Some of the agronomic practices including clearing of sites were accomplished prior to planting. Planting of crops at recommended distances (Opeke, 2006) was adequately ensured in order to ascertain the contribution, otherwise the potentials of the various crops in relation to soil erosion control. Constructed and fabricated soil loss boxes measuring 90cm x 150cm were placed at the foot of each plot determined by spillways. Each box was placed after rill erosion channels were formed in each of the crops' plot. The number of boxes in each plot was determined by the number of spillways. Spillway which represents erosion channel was presumed to be influenced by ground cover potential of each crop. Eroded soil materials from each plot were emptied into soil loss box placed at the bottom of the slope. Soil materials, trapped at the end of each rainfall event were measured in situ with a weighing balance.

2.2 Design of soil loss box (sediment trap) and data collection process

Data collection started at the commencement of the rains. Soil loss was collected at the end of rainfall event. Meanwhile, crops' potentials were assessed on the bases of their ability to control soil wash. Runoff plots were set up to reflect various crop types. Runoff plots were approximately 25m long and 5m wide. Data were collected on the amount of sediment yield at the end of each storm event. Meanwhile, a total of seventeen storm events were recorded.

Sediment traps of 60cm x 90cm x 60cm were placed at the foot of the slope of each crops' plot. The box was designed in such a way as to allow water pass through it leaving only the soil materials, in other words, the bottom of the box was covered with wire gouge of 2mm. Measurement of soil loss or sediment yield was obtained for every rainfall event. Soil materials were exhumed and emptied into a well labeled polythene bag after draining off the water content and weighed in the balance. The total soil loss during each storm was computed and recorded as the total soil loss from plots. The result was multiplied by two (2x) to take care of soil materials that may be drained with runoff from plot.

3. RESULTS

3.1 Sediment Yield

Across the four blocks, sediment yield varied noticeably among the crop treatments. Maize consistently recorded the highest mean sediment yield, with values ranging from 24.9–36.9 g across the blocks, and achieving the overall peak of 39.4 g in the grand mean. In contrast, Melon produced the lowest sediment yield, with values as low as 10.2 g in Block 2 and a grand mean of 16.6 g, making it the crop with the least sediment contribution. Groundnut and Soya bean showed intermediate yields, with Groundnut ranging from 13.5–31.2 g and Soya bean from 22.6–32.8 g, both remaining significantly lower than Maize but higher than Melon. The differences in superscript letters confirm that these variations among crop types were statistically significant ($p < 0.05$).

3.2 Spillway Characteristics

Spillway measurements also demonstrated clear contrasts among the crops. Maize recorded the highest total spillways (21), total depth (19.1 cm), total width (70 cm), and total length (602 cm), indicating the greatest potential for runoff concentration and channel formation. This was followed by Soya bean, which had 16 spillways with considerable dimensions (11.7 cm depth, 47 cm width, and 570 cm length). Groundnut produced moderate spillway activity (8 spillways), while Melon had the lowest values across all parameters, with only 2 spillways, 1.7 cm depth, 3.1 cm width, and 10 cm length, reflecting minimal runoff pathways.

TABLE1 Textural classes of soil in the study area

Blocks	% sand	% silt	% clay	Texture
1	68	15	17	Sandy loam
2	64	17	19	Sandy loam
3	66	15	10	Sandy loam
4	68	14	16	Sandy loam
Range	64-68	14-17	10-19	
Mean	66.5	15.3	15.5	

Source: Researcher's field work. 2025

TABLE 2: A Total of four sites including control plots were purposively selected as follows

Block	Crop type	Bearing	Latitude	Longitude	Slope	Height	Direction
1	Maize, Melon, Soy a beans &	173^{0}	005^{0} 30^{1} 05^{11}	008^{0} 09^{1} 24^{11} 008^{0} 08^{1} 24^{11}	5.9%	389m	NE
2	Groundnut Soya bean, Maize,	172	005^{0} 28^{1} 16^{11}	008^{0} 08^{1} 04^{11}	6.2%	379m	NE
3	Groundnut & Melon	171	005^{0} 30^{1} 36^{11} 005^{0} 28^{1} 29^{11}	008^{0} 09^{1} 24^{11}	6.3%	390m	NE
4	Groundnut, Maize, Soya bean & Melon Melon, Groundnut, Soya bean &Maize.	137^{0}			5.9%	382m	NE

Source: Researcher's field work, 2025

TABLE 3: Sediment yields from plots in the study area (gram)

Rain	Block 1				Block 2				Block 3				Block 4			
	G/nut	S/bean	Maize	Melon	Maize	Melon	S/bean	G/nut	Melon	Maize	S/bean	G/nut	Maize	G/nut	Melon	S/bean
1	66	72	78	45	28	26	40	36	36	36	35	26	68	55	26	91
2	46	40	49	36	26	23	36	35	35	35	40	27	36	27	26	36
3	35	37	35	35	27	15	37	23	23	35	35	28	23	26	19	29
4	24	26	26	32	23	15	23	13	23	26	19	22	16	24	15	36
5	40	40	50	32	49	3	31	36	5	37	41	40	41	27	15	45
6	28	36	48	10	39	5	27	10	4	32	27	23	45	40	12	36
7	32	23	39	2	36	10	24	12	2	22	24	23	27	33	24	31
8	31	22	24	26	35	2	24	10	5	18	40	41	39	27	10	40
9	35	32	35	39	32	13	27	8	19	15	26	15	37	41	26	65
10	28	19	24	31	24	13	32	8	15	14	23	10	15	22	15	27
11	20	19	20	26	18	13	20	5	2	14	22	24	23	13	14	22
12	2	15	15	13	16	1	22	13	14	15	22	1	16	14	14	15
Slope	6.2%				5.9%				5.9%				6.3%			

Source: Author's fieldwork, 2025

TABLE 4: Summarized result of mean sediment yield from various crop's plots in the study area

Treatment	Maize	Groundnut	Soya bean	Melon
BLOCK 1	36.9[a]	31.2[c]	32.8[b]	25.6[b]
BLOCK 2	29.4[a]	13.5[c]	28.6[b]	10.2[b]
BLOCK 3	24.9[b]	22.6[d]	29.5[a]	14.2[b]
BLOCK 4	32.2[b]	27.0[c]	39.4[a]	16.3[b]
Grand mean	30.9	23.6	32.6	16.6

Source: Author's fieldwork, 2025

Note: Mean values with different superscripts are significantly different ($p<0.05$)

TABLE 5: Mean spillways from various crops cover types

S/NO	Crops	Total spillways	Total depth	Total width	Total length
1.	Melon	2	1.7	3.1	10
2.	Groundnut	8	4.8	28	518
3.	Soya bean	16	11.7	47	570
4.	Maize	21	19.1	70	602

Source: Researcher's field work 2025

4. DISCUSSION

The soils showed similar textural characteristics indicating that they came from the same parent material. The soil is typically sandy loam. The highest value of sand, silt and clay revealed mean values of 66.5, 15.3 and 15.5. With sand fraction ranging between, 64–68; silt, ranged between, 14-17 and clay ranged between, 10-19. Results from different blocks in the study area show uniform textural classes of sand, silt and clay (Gee and Or 2002).

The adoption of appropriate technology to tackle erosion perturbation is usually determined by severity erosion (Chandhury and Jasen, 1999), after intense rainstorm, Udeme and Okoko (2015) suggested a walk around the farm to identify where rill erosion channels have developed. There is no doubt; ground cover density has profound influence on the development of rill erosion channel.

The role of cover crops in erosion control cannot be overestimated giving its nutrient recycling and soil stability benefits (Anikwe and Atumia 2003). Different crop covers have different degrees of soil protection potentials (Egbai *et al.,* 2011 and Egbai 2016). According to the authors, the thicker the crop cover the more the leaves fall and the humus content, implying that the crop density is directly proportional to the thickness of crops' residues. Conversely, the more thick the vegetation cover the lesser the rain drop impact on the soil, limiting the direct impact on the top soil and consequent reduction of soil loss volume. This is applicable in agro-ecological system especially in rain fed regions. Tropical landscapes are largely characterized by undulating land terrains indicating high susceptibility to erosion perturbations.

There is no possibility of separating rural people from farming either for commercial or subsistent purposes hence the need for the adoption of compatible and efficient mechanism in stabilizing soil without interfering with their food production possibility. Different crops have different morphological arrangement and different root systems. These features play important role in the prevention of direct rain drop impact on soil surface and the regulation of rain water infiltration. Spillways connote erosion channels which are determined by land cover type, soil textural characteristics, slope degree and nature of vegetation cover. This implies that how much of erosion path that is produce is dependent on the influence of the aforementioned variables.

The scale of soil degradation is determined by the number of channels (erosion path) otherwise known as spillways, depth, width and the length of the channel. From the result of this study, it is obvious that the various crops have different levels of soil protection from the vagaries of nature. The number of spillways produce in the various plots is a direct consequence of crop type (leaf, root and stem type). These features produce profound ability in controlling erosion perturbation. The quality of fallen leaves by crops is expressed by the quality of soil. It follows, crops' leafs do not only cover the soil thereby protecting it from the impact of rain drop but can as well enrich the soil by adding some important elements that enhance cation exchange capacity of such soils which is key to sustainable soil quality. Singer and Munns (1999) emphasized the effect on nutrient and organic matter removal due to soil erosion. The leaf falls of plant can effectively enhance soil coherence and the more coherence or consistent a soil is, the more invulnerable the soil is to erosion perturbation. The number of spillways, length, depth and width of erosion channels (tables 4&5) explain the extent of erosion. Etukudo (2000) stated that using crop cover to protect soil from the phenomenon of erosion perturbation is a soil management strategy including effort to limit extent of erosion exacerbated by depth, width, length and land slope. Total length of erosion channel was highest in maize and soya bean plots. While the soil protection was demonstrated in melon plots seconded by groundnut plots as indicated in tables 4 and 5.

In table 4 the average monthly measurement of spillways, depth, width and length of erosion channels reduced proportionately across the blocks/plots on the bases of crop cover dynamics. Melon and groundnut plots showed drastic reduction in the number of spillways from 5 to 0 and 6 to 2 spillways. The melon plot proved more effective as they exert profound effect on top soil stability similarly, channel depth, width and length reduce significantly in groundnut plot. in table 4 the number of spillway channels was total depth = 33cm width = 10cm and length 370cm was generally reduced in plots with sufficient ground cover potential. Second on the scale was groundnut plot with 8 spillways, 4.8cm of total depth and a total width of 28cm. While soya bean became third on the scale with 10 spillways, 6.7cm depth, 31cm width and total length of 472cm second to melon plot. The maize plot showed inability to protect the soil from erosion perturbation. Result proved that a total of 21 spillways, 19.1cm depth, 70cm width and 602cm length of erosion channel were recorded in maize plot. Indicating that plot with maximum ground cover protects soil better than those with scanty or minimal ground cover. At the beginning of the rains in April where rains are generally known to begin in the tropics, the various plots witnessed general increase in the number of spillway formation. This may not be unconnected with the fact that various crops are yet to established sufficient roots, and leaves which are critical features in crops' ability to withstand erosion perturbation. As the leafs protect the soil from the vertical impact of rain drop on soil surface, the root system protects the soil from effects associated horizontal movement of water velocity. Movement of water (run off) is connected with root system.

5. CONCLUSION

The phenomenon of soil erosion starts unnoticeably in all soil surfaces once exposed to rain drop impact. Agricultural lands are inherently utilized for purposes of food production and sustainable economic livelihoods. Consequently, unguided use undermines its production capacity. At the rural scale, increased production is usually bedeviled by lack of modern agricultural technology, use of crude implements, poor adoption of agricultural innovation and climate change hence, the inevitability of practices that undermine soil quality and efficacy.

Soil erosion is exacerbated by unprotected land surfaces exposing them to vagaries of weather element which pose detrimental effects on their productivity potential and enhance susceptibility. Removal of vegetation cover at various scales is usually attributed to human activity and has continued to account for a huge loss of soil materials at every rainfall events. Coping with the menace of soil loss with an affordable and cost-effective means is desirable especially at rural scale where farming is predominant.

This study revealed that crops possess features that significantly reduce erosion perturbation while guaranteeing food production. Certain crops' features; leaves, roots and stems are critical in the protection of soil against impact of rain drop and soil erosion by reducing the number of spillways, channel depth and channel expansion. Melon and groundnut plots demonstrated potential in erosion control. On the other hand, maize plots across the blocks showed profound susceptibility to erosion perturbation. Implying that at slopes of 2% to 6.3% planting maize as mono crop is not sustainable and does not guarantee soil protection as they lead to preponderance of spillways, increased length, depth and width of channels across the blocks and plots respectively

.

REFERENCES

Akchaya, K., Parasuraman, P., Pandian, K., Vijayakumar, S., Thirukumaran, K., Mustaffa, M. R. A. F., ... & Choudhary, A. K. (2025). Boosting resource use efficiency, soil fertility, food security, ecosystem services, and climate resilience with legume intercropping: a review. *Frontiers in Sustainable Food Systems*, *9*, 1527256.

Al-Musawi, Z. K., Vona, V., & Kulmány, I. M. (2025). Utilizing Different Crop Rotation Systems for Agricultural and Environmental Sustainability: A Review. *Agronomy*, *15*(8), 1966.

Anikwu, M.A.N, & Atumia, J. (2003). Characterizing the suitability of some indigenous soil improving legumes in a humid tropical environment using shoot and root attributes. Tropicultura 21, 4, 179-185

Babu, P. K. (2024). Traditional Agri/Horticultural Crops, Farming Practices and Conservation in the Himalayan Region. In *The Resilience of Traditional Knowledge Systems for a Sustainable Future: A Focus on Agriculture and Food Practices in the Himalayas* (pp. 59-90). Cham: Springer Nature Switzerland.

Chaundhurry, K. & Jansen, I. K. (1999). Technology for integrated resources planning and management soil resource management and conservation services FAO land and water development.

Edem, I. D. & Okoko, P. (2015). Pedo transfer function of saturated hydraulic conductivity and soil fertility and aggregation international journal of plant and soil science 4(5) 461-474.

Egbai, O. O. (2016). Effect of crop cover on soil susceptibility to erosion in southern Nigeria. Journal of physical science and environmental studies 2(2), 20-28.

Egbai, O. O., Akintoye, O. A., Agbochom, E. E,. and Edet, E. O. (2017). Influence of ground cover on spillways formation in Ikang, Bakassi, Local Government Area, Cross River State. Journal of Physical Science and Environmental Studies. Vol 3, No. 5, pp. 58-62.

Egbai, O. O., Ndik, E. & Uquetan, U. I. (2011) influence of soil textural properties and land use cover type on soil erosion in Betem, south Nigeria. Journal of sustainable development 4(4) 222-229.

Egbai, O. O., Oko,P. E., Brain E. U., Ikpi Arikpo, A. I., Abanyam, V. A., Ozoh, S. I., Ambe, B., and Asor. L. J. (2023). Resilience potentials of indigenous vegetable crops to soil erosion perturbation in the coastal plain soil of Akpabuyo, Nigeria. DOI: 10.1389/ujar.2023.110310.

Gee, U. W & Or, D. (2002). Particle size analysis in: J. H. Dane and G. C. Topp (eds) methods of soil analysis part 4, physical methods, SSSA, incorporated Madison, 255-294.

Ghimire, R., Aryal, D. R., Hanan, N. P., Boufous, S., Burney, O., Idowu, O. J., & Prihodko, L. (2024). Carbon sequestration through sustainable land management practices in arid and semiarid regions: Insights from New Mexico. *Agrosystems, Geosciences & Environment*, *7*(4), e70019

Husain, S., & Sharma, V. (2022). Sustainable crop production in the floodplains of Niger Delta, Nigeria. *Book Chapter Crop production in the floodplain*, 196-219.

Hussain, Z., Bezanjo, M. A., Ahmad, S., Mithal, U., Arshad, M. U., Kamran, M., & Basheer, N. (2025). Agroforestry for Climate Mitigation, Resilient Farming, and Food Security. *Global Research Journal of Natural Science and Technology*.

Iwara, A. I., Abua, M. A., Udonwa, R. E., Esuabana, S. B., Archibong, E. P., Idika, D. O., Bassey, I. E., Antia, A. S., Egbai, O. O., and Eneyo, V. B. (2023). Relationships between Erosion Losses and Vegetation in Fallows of Southern Nigeria. Pp.483-492.

Javadinejad, S., Dara, R., & Jafary, F. (2022). Creating a framework for coordination food security and sustainable management in agriculture lands and crop efficiency. *Safety in Extreme Environments*, *4*(1), 1-11.

Keke, L.; Zhanhang Zou; zhen Wang;; Yi, Zeng; Klaus Hubacek, Posquale Bowelli;Cai, Li,; Wenting Zhang; zangui Deng; Jingyu, Wang, ; Zhihua shI; (2025). Oportunity for mitigating soil loss by water erosion in crop land through crop switching and improvement in China. Geography and sustainability volume 6 issue 4 100262 doi;org/101c/j.geosus 2025

Kumar, S., Gopinath, K. A., Sheoran, S., Meena, R. S., Srinivasarao, C., Bedwal, S., & Praharaj, C. S. (2023). Pulse-based cropping systems for soil health restoration, resources conservation, and nutritional and environmental security in rainfed agroecosystems. *Frontiers in Microbiology*, *13*, 1041124.

Kuyah, S., Muoni, T., Bayala, J., Chopin, P., Dahlin, A. S., Hughes, K., & Öborn, I. (2022). Grain legumes and dryland cereals for enhancing carbon sequestration in semi-arid and sub-humid agro-ecologies of Africa and South Asia.

Li, K. K., Yang, J. Y., Wang, J. Y., Zang, Y., Borrelli, P. Hubacek, K, Hu. Y. C., Xu, B. D., Fang, N. F., Zeng, C, Zhou, Z. H., Shi, Z. H., (2024). Human altered soil loss dominates nearly half of water erosion in China but surges in agriculture-intensive areas. One earth; 7 (11) 2024, pp2008-2018. 10.1016/joneer 2024.

Liang, X., Yu, S., Ju, Y., Wang, Y., & Yin, D. (2025). Integrated management practices foster soil health, productivity, and agroecosystem resilience. *Agronomy*, *15*(8), 1816.

Manga, L. A. A., Bidogeza, J. C., & Afari-Sefa, V. (2024). Urban effects on the adoption of soil conservation practices in urban and peri-urban vegetable production of Yaoundé, Cameroon. *Scientific African*, *26*, e02342.

Opake, L. K. (2006). Essential of crop farming. Ibadan: spectrum Books.

Quintarelli, V., Radicetti, E., Allevato, E., Stazi, S. R., Haider, G., Abideen, Z., & Mancinelli, R. (2022). Cover crops for sustainable cropping systems: a review. *Agriculture*, *12*(12), 2076.

Ranjithkumar Arumugam, (2025). Assessing the impact of agricultural land reduction on future global food security: challenges and sustainable solution. Food and Agriculture Organization (FAO), Rome, ISSUE 88, Feb 2025.

Sati, V. P. (2024). Crop Diversity and Agro-ecological Zones. In *Farming Systems and Sustainable Agriculture in the Himalaya* (pp. 39-48). Cham: Springer Nature Switzerland.

Scavo, A., Fontanazza, S., Restuccia, A., Pesce, G. R., Abbate, C., & Mauromicale, G. (2022). The role of cover crops in improving soil fertility and plant nutritional status in temperate climates. A review. *Agronomy for Sustainable Development*, *42*(5), 93.

Sharma, S., Sharma, U., Sharma, S., Sharma, S., Likhita, J., Thakur, S., & Sharma, N. (2025). Strategies for Sustainable Land Management Through Climate-Resilient Horticulture: A Systematic Review. *Land Degradation & Development*.

Sher, A., Mazhar, S., Islami, I., Parra Acosta, Y. K., Balc, R., Azadi, H., & Yuan, H. (2025). Land Use Practices: Sustainability Impacts on Smallholder Farmers. *Land*, *14*(8), 1632.

Singer, M. J. & Munns, D. N. (19990. Soil an introduction. New Jersey: Practice Hall.

Tembo, A., Muyabe, O., Musenge, D. C., Mhango, J., & Nkomanga, G. C. (2025). Impact of sustainable agricultural practices on farm productivity, yield, and climate resilience among smallholder farmers in Zambia. *Journal of Agriculture, Aquaculture, and Animal Science*, *2*(1), 30-38.

Wang, S. S., Sun, B. Y., Liu, C. D; Li, Z. B. and Ma, B. (2018). Runoff and soil ersion on shop cropland: a review. J. R esour. Ecol 9(5) 2018, pp 461-470

Yang, H; Wang, l., Wang, T. W., Wang, Z., and Shi, Z. H (2020). A synthesized approached for estimating the C- factor of RUSLE for a mixed – landscape watershed, Southern China; Agric. Ecosyst. Environ301(2020) Article 107009