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Agricultural Land Management: Capturing Synergies among Climate Change Adaptation, Greenhouse Gas Mitigation, and Agricultural Productivity

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In the coming decades, the international community will face the challenges of reining in global climate change, ensuring food security for a growing population, and promoting sustainable development. Meeting these multiple challenges requires changes in the agricultural sector. Farmer-driven adaptation in Kenya and elsewhere in East Africa must include sustainable agricultural management practices. Many of these management practices also directly contribute to reducing greenhouse gas (GHG) emissions and increasing agricultural productivity and net revenues. This note is based on a report on the synergies and tradeoffs of agricultural management strategies used by farmers in seven districts in Kenya, spanning the country's arid, semi-arid, temperate, and humid agroecological zones (AEZs). The note identifies win–win–win strategies among agricultural adaptation, mitigation, and profitability based on analyses using household survey data and crop and livestock simulation modeling.

Agricultural Land and Livestock Management Practices and Adaptation Strategies in the Study Sites

According to the survey data, the most common land management practices used by farmers include the application of inorganic fertilizer (45 percent), the use of compost or manure (40 percent), intercropping (39 percent), the use of soil bunds (18 percent), crop residue management (12 percent), and the use of grass strips (11 percent). Farmers in the arid zone use the least number of practices, while farmers in the semi-arid, temperate, and humid zones employ a wider range of management strategies.

Many mixed crop–livestock farmers have started to adopt improved livestock feeding practices, particularly for milk cattle. The dairy systems in the temperate zone are generally commercially-oriented, with stall-fed high-grade dairy animals, high-energy-density diets (through the use of concentrates), and the use of napier grass as a cut-and-carry fodder. On the other hand, rangeland-based systems in the arid zone rely on extensive production, where supplementation, mostly in the dry season, is based on crop residues and the opportunistic use of feed resources like roadside weeds.

Farmers have also begun to shift agricultural management strategies due to perceived climate change. Common adaptations in the surveyed sites include changing crop variety (33 percent); changing planting dates (20 percent); and changing crop type (18 percent); planting trees (9 percent); decreasing the number of livestock (7 percent); diversifying, changing, or supplementing livestock feeds (7 percent); changing fertilizer application (7 percent); and using soil and water conservation (SWC) (5 percent).

Perceptions of the Link between Agriculture and Climate Change

Agricultural management strategies have implications for climate change mitigation, yet few farmers and pastoralists fully understand the links between agriculture and climate change. Sixty-seven percent of farmers surveyed stated that they believe agricultural practices contribute to climate change.

Table 1. Net revenues from carbon sequestration and maize production, alternative management practices, in Kenya

		Package 1		Package 2		Package 3		Package 4	
		RES50		RES50, FERT, & MNR		RES50, FERT, MNR, SWC, & ROT		FRT, MNR, RES50, SWC, ROT, & IRG	
AEZ	Soil	Revenue from carbon (US$/ha)	Net revenue from yield (US$/ha)	Revenue from carbon (US$/ha)	Net revenue from yield (US$/ha)	Revenue from carbon (US$/ha)	Net revenue from yield (US$/ha)	Revenue from carbon (US$/ha)	Net revenue from yield (US$/ha)
Arid	Clay	1	-16	9	-195	15	7	24	1151
Arid	Sand	1	35	2	-221	10	241	8	892
Semi-arid	Loam	2	177	22	910	22	1072	21	1023
Semi-arid	Sand	2	116	8	231	6	309	5	162
Semi-arid	Clay	2	210	19	1626	19	1920	17	1947
Temperate	Loam	2	12	24	816	23	910	22	736
Humid	Loam	0	116	13	1431	12	1513	11	1061

*assumes a carbon price of US$10 per tCO2e

**price per kg of maize is US$0.375

Note: RES50=50% residues on field; FERT=40 kg N/ha; MNR=3 ton/ha/year; SWC=soil water availability before planting is 30% of field capacity and small amount (2 mm/ha/10-day) of soil moisture is additionally available in the root zone throughout the growing season; ROT=rotation with dry beans every 4th year; IRG=meet full crop water demand. Results are for an open pollinated variety.

Most of these farmers reported that afforestation and agroforestry would help mitigate climate change; only a few mentioned other agricultural management strategies. Though farmers clearly perceive a link between deforestation and climate change, their survey responses reveal that farmers in rural Kenya know very little about the link between sustainable management practices and climate change mitigation.

Implications of Alternative Agricultural Management Strategies for Productivity and Profitability and Greenhouse Gas Mitigation

Potential Benefits of Cropland Management Strategies

Soil carbon stocks and maize yields were simulated over a 40-year period for combinations of key crop management practices identified in the survey under a wet and a dry climate change scenario. The results show that many of the management practices already used by farmers in the study area have positive effects for soil carbon sequestration, crop yields, and net profits. Table 1 shows the profitability of selected "packages" of management practices.

The results highlight nutrient management (i.e., combinations of inorganic fertilizer, mulching, and manure) as a particularly promising strategy. This strategy increases soil carbon sequestration and boosts yields, thereby increasing farm revenues and providing a buffer against the negative impacts of climate change. The yield improvement benefits far outweigh the costs of purchasing and applying fertilizer and manure. However, inorganic fertilizer application alone does not increase soil carbon sequestration across all soil types and AEZs. Instead, inorganic fertilizer needs to be combined with other soil fertility management practices, such as manure, mulch, crop residues, or a combination of these in order to achieve maximum benefits.

Leaving crop residues on the field has a high potential to increase yields, net profits, and soil carbon sequestration. Applying residues is also associated with lower labor costs as it reduces the time needed for weeding and removing residues from the field. Combining crop residues with fertilizer and manure significantly increases the benefits.

However, in the rangeland-based systems, where farmers use residues as a feed supplement during the dry season, they may not always choose to leave residues in the field because the cost of purchasing feed replacement reduces net profits in these areas. Generally, the optimal allocation of residues—balancing benefits from crop and livestock production—depends on the chosen combination of management practices, as well as the agro-climatic and soil conditions. In more than half of the scenarios examined, farmers profited more from leaving only 50 percent of crop residues in the field. In the remaining scenarios, it was more profitable to leave 75 percent of residues in the field and purchase replacement feed (napier grass).

Other results differ significantly by AEZ. In the arid site, the maximization of soil carbon and agricultural profits requires irrigation and SWC. Humid sites generally have ample water but limited nitrogen. As a result, SWC structures have limited benefits and irrigation lowers average yield (and net profits) across various combinations of management practices, possibly due to increased nitrogen leaching from the soil. In the semi-arid sites, where water supply is somewhat limited, SWC practices and irrigation increase overall yield levels and net profits. However, integrated soil nutrient management maximizes soil carbon sequestration. Similarly, in the temperate sites, SWC and irrigation improve yields, but not as significantly as nutrient inputs; and soil carbon sequestration is highest with soil nutrient management.

While farmers mentioned changing crop variety as a key adaptation strategy and other studies have touted the benefits of this practice, the crop simulation results show that the hybrid maize variety did not generally improve soil carbon sequestration, even with nutrient management practices. Determining whether hybrid varieties specifically calibrated to local conditions are more effective at increasing soil carbon requires further research.

Table 2. Net revenues from improved feeding practices compared to baseline revenues in Kenya (dairy cattle)

	Baseline Diet		Improved Feeding		
District	Net revenues (US$)	Net revenues per liter of milk (US$)	Scenario[a]	Net revenues (US$)	Net revenues per liter of milk(US$)
			Prosopis		
			1.5 kg	104.1	0.23
Garissa	92.1	0.33	3 kg	118.8	0.18
			Desmodium		
			1 kg	172.3	**0.26**
Gem	62.2	0.11	2 kg	169.2	**0.23**
			Napier grass		
			2 kg	150.8	**0.16**
Mbeere	31.3	0.04	3 kg	146.2	**0.15**
			Hay		
			1 kg	279.9	**0.19**
Njoro	175.8	0.14	2 kg	357	**0.19**
			Desmodium		
			1 kg	547.4	**0.24**
Mukurwe-ini	383	0.18	2 kg	511	**0.23**
			Hay		
			2 kg	348.8	**0.16**
Othaya	311.1	0.15	4 kg	233.2	0.11
			Napier grass		
			2 kg	239.1	**0.24**
Siaya	109.6	0.16	3 kg	169.2	**0.23**

[a]This column presents the scenarios used in the analysis (type and amount of improved feed replacing baseline diets)

The rotation of maize and beans, a key management practice used in much of Kenya, has only limited benefits compared to more explicit nitrogen input measures, such as the application of inorganic fertilizer or manure or both. While soil fertility improves, the low biomass contributed by beans does not make a significant contribution to soil carbon stocks, making the difference in yields minimal.

Potential Benefits of Improved Livestock Feeding Practices

A governmental push toward market-oriented production is driving production systems in the study areas toward increased use of improved livestock feeding practices. These practices can help farmers adapt to and, at the same time, mitigate climate change's adverse impacts. Modeling results show significant opportunity exists to produce milk at lower methane emissions per liter in the seven districts under study through improved feeding practices. Large differences exist between the regions under study, with the greatest potential improvements evident in the arid pastoralist zone.

On average, the tested supplementation strategies increased milk production by 36 percent, while also increasing total manure and overall methane production by 6 and 4 percent respectively. Despite a slight overall increase in methane production, methane production per liter of milk produced decreased by 20 percent, on average. In cases where overall emissions increase, households would have to also engage in destocking to receive benefits from carbon markets. A number of agencies and NGOs operating in Kenya advocate maintaining a smaller number of better-quality, more productive animals, and many households are already adopting this strategy in response to climate change.

Improved feeding practices also increase net profits from the sale of milk in most cases (Table 2) and enable households to apply additional residues to cropland, increasing productivity and income from crop production. One exception is in the arid site where farmers graze livestock and do not generally purchase feed; the cost of purchasing improved feeds reduces net profits per liter of milk. These households, therefore, will require additional incentives to adopt improved feeding practices.

Conclusions and Policy Implications

The results indicate that farmers in Kenya do not fully recognize the interlinkages among agricultural productivity, adaptation, and mitigation. While farmers recognize the connection between tree planting and climate change, they are less aware of the benefits of other agricultural management strategies for mitigation, net profits, and climate change adaptation. Governments, NGOs, and extension agents will need to address this significant knowledge gap in Kenya and elsewhere in the developing world.

Summary results, presented in Table 3, show that many agricultural practices provide synergies among adaptation, mitigation, and crop and livestock profitability. Their benefits, however, vary significantly across the study sites, suggesting that particular strategies should be carefully selected to suit the location and farm. As the results showed, SWC structures used to increase soil moisture are not appropriate in areas where soil moisture does not constrain production.

Both simulated modeling and survey results highlight the importance of soil nutrient management—in particular, combinations of inorganic fertilizer, mulch, and manure—for enhancing crop yield, soil carbon stocks, and income from agricultural production. Few farmers know of the multiple benefits of soil nutrient inputs, and in fact, some believe inorganic fertilizers contribute to global warming. This is true in cases where farmers over-apply fertilizers, which occurs, for example, in parts of Asia. However, because fertilizer use in much of Sub-Saharan Africa remains below optimal levels, increased application improves soil carbon sequestration.

Similarly, there is a belief that improved livestock feeding practices would be negative for Kenya's carbon footprint. However, methane production per liter of milk produced actually decreases with improved feeding practices. When combined with destocking, overall emissions decline without sacrificing food production or food security. Moreover, improved feeding practices can increase crop productivity and profits by freeing up residues for application to farm land.

Adopting new and appropriate farm practices or technologies requires knowledge and experience. Farmers' successful adoption of these measures will thus require greater access to information and advice through extension services, inputs, and additional financial resources, particularly in the case of more costly investments such as irrigation. Policymakers can facilitate adoption of the most promising practices and technologies in several ways. Expanding access to credit can encourage the adoption of more costly practices and technologies that offer multiple adaptation, mitigation, and productivity benefits. Promoting agricultural intensification to avoid the expansion of cultivated area—through investments in agriculture such as the provision of inputs, capacity development, and additional research and development—would further facilitate the adoption of synergistic practices.

Furthermore, though some carbon markets (such as the Clean Development Mechanism) exclude many agricultural mitigation activities, some markets do provide financial incentives to smallholder farmers for soil carbon sequestration. These opportunities—as well as other financing options, such as adaptation and mitigation funds, and credit mechanisms—should be further explored while international climate negotiators intensify efforts to create additional incentives for agricultural mitigation.

Table 3. Synergies among adaptation benefits, mitigation potential, and crop productivity and profitability in Kenya

Management practices	Adaptation benefits[a]	Mitigation potential[b]	Productivity/Profitability
Cropland management			
Improved crop varieties and/or types	positive	mixed	unclear
Changing planting dates	positive	unclear	unclear
Improved crop/fallow rotation/rotation with legumes	positive	mixed	mixed
Appropriate fertilizer/manure use	positive	positive	positive
Incorporation of crop residues	positive	positive	positive [c]
Water management			
Irrigation/water harvesting	positive	mixed	positive
SWC	positive	mixed	mixed [d]
Livestock/grazing land management			
Improved livestock feeding	positive	positive	positive
Destocking	positive	positive	positive

[a] As reported by farmers
[b] As calculated with DSSAT and livestock mitigation models
[c] Tradeoff with livestock feed in certain areas
[d] Positive impacts in areas where soil moisture is a constraint, depends on combination of technologies

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