A Guide for Soil Health and Fertility for Maize production in Kenya

The Importance of Soil Health

The health of your soil is a fundamental aspect of successful farming. **However, many arable soils in Kenya have degraded and lost fertility over recent decades[1].** This is expected, because many soils were recently transformed from more permanent land uses, which always leads to soil fertility losses[2]. However, this soil fertility loss is largely avoidable with best management practices that replenish soil organic matter and soil nutrient resources[3,4].

Farmyard Manure: A Key to Soil Fertility

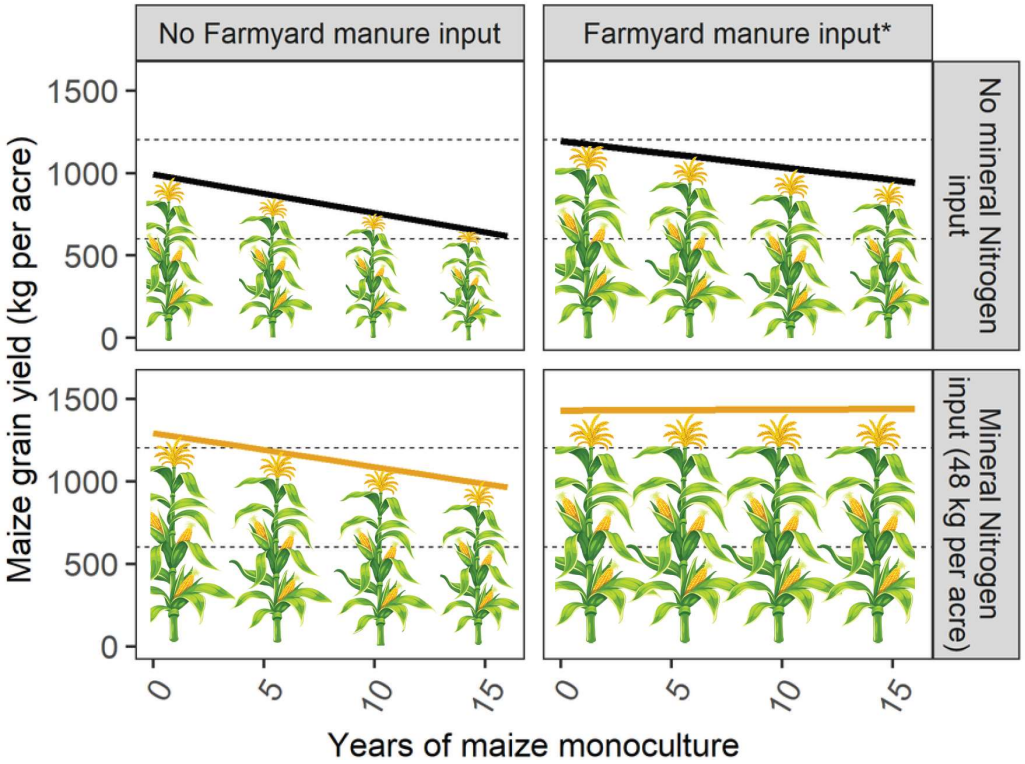
When applying mineral fertilizer, the nutrients contained in it mostly feed your maize. As a result, the overall health of your soil might decrease over time. However, by adding manure or high-quality compost to your fields, you feed your soil with nutrients, increase microbial life, improve soil structure, buffer the pH and thus maintain soil fertility in general. In fact, over a longer time of cultivation, yields from fields where only manure is applied surpass those where only mineral fertilizer is used[5]. This is illustrated in these pictures.

These pictures show maize from different treatments of a long-term experiment, located at Embu, Kenya. The picture on the left shows the treatment that only received mineral fertilizer (48 kg Nitrogen, 24 kg Phosphorus, and 24 kg Potassium per acre and season) while the picture on the right shows the treatment that received only Farmyard Manure, Phosphorus and Potassium. The pictures are taken in January 2021, the 20th year of the experiment.

Combining Manure and Mineral Fertilizer

You should not choose between manure and mineral fertilizer. Using both at the same time is the best option and helps to maintain soil fertility and meet the peak nutrient demand of your crops[4,5]. It is recommended to apply medium amounts of Farmyard Manure. For example, adding about 2 tons of fresh matter per acre per season provides the soil with an equivalent of approximately 150 kg of Carbon, 11 kg of Nitrogen, 2 kg of Phosphorus and 11 kg of Potassium. This should be combined with some mineral fertilizer during the peak demand of nutrients by the maize (for example around 12-24 kg of Nitrogen per acre, depending on your

soils responsiveness and 4-12 kg of Potassium and Phosphorous, each). As you can see from the summarized results of four long-term experiments in Kenya, below, this combination can maintain good yields over decades.



This graph displays the development of mean maize yields for the treatments that received no manure input (Control) and the treatments that received manure input at a rate of about 2-3 tons of fresh matter per acre and season. The results are the summary of four long-term experiments in Kenya. The colors represent treatments with and without the addition of mineral Nitrogen fertilizer. Detailed information on the experimental setup and treatments are freely available in a research article (www.doi.org/10.1016/j.fcr.2022.108788)[5].

How Much Nutrients can Farmyard Manure Supply?

This table shows typical nutrient contents of different types of manure with the typical ranges expressed in the brackets (specifically the median values and 95% confidence intervals from a research article[6]*).*

Manure type	*C (% of dry matter)*	*N (% of dry matter)*	*P (% of dry matter)*	*K (% of dry matter)*	*Typical moisture content (%)*[7]
Cattle	28 (27-30)	1.2 (1.2-1.4)	0.4 (0.4–0.6)	1.2 (1.3–1.6)	70 (60-85)
Goat	27 (26-34)	1.6 (1.4-2.1)	0.3 (0.2 –0.4)	0.8 (0.8–1.1)	70 (60-85)
Swine	42 (27-46)	2.0 (1.7-2.2)	0.9 (0.7–1.5)	1.0 (0.9–1.3)	70 (60-85)
Poultry	37 (27-40)	1.9 (1.5-2.2)	1.3 (0.9–1.6)	0.9 (0.7–1.1)	70 (60-85)

To calculate the amount of nutrients applied with manure, you can use the following formula. With MC being the typical moisture content (in %) and NC being the nutrient content (in %).

$$\text{Nutrients in manure (kg)} = Fresh\ matter\ weight(kg) * \frac{(100 - MC)}{100} * \frac{NC}{100}$$

For example, 2000 kg of fresh matter goat manure with a moisture content of 70% and a Nitrogen content of 1.6% would supply $2000 * \frac{(100-70)}{100} * \frac{1.6}{100} = 2000 * 0.3 * 0.016 =$ **9.6 kg**

of Nitrogen. Because nutrient contents and moisture contents can vary a lot, it is ideal to measure these contents for the manure that you use. Nutrient contents can be measured in a laboratory, while moisture content can be measured by drying the manure at 100°C for 24 hours and measuring how much weight the manure lost.

Understanding the Benefits of Farmyard Manure

Farmyard Manure is beneficial for long-term yield maintenance, because it replenishes soil organic matter and soil nutrients, maintains soil life and buffers soil acidification. **However, it's important to note that only about a third of the contained nutrients are released in the first season**[8]. Therefore, it is advisable to supplement Farmyard Manure by micro-dosing with mineral fertilizer during top-dressing.

The Need for Proper Manure Management

Proper manure management is crucial to prevent nutrient losses through gasification and leaching of nutrients. Effective manure management begins with proper housing design, ensuring all dung and urine are collected and nutrient losses are minimized. Proper manure storage is crucial, with roofing and flooring to prevent nutrient losses from runoff, leaching, and volatilization. Composting is an effective method for storing manure, although it is labor-intensive. Drying manure reduces its volume but causes significant Nitrogen loss. When applying manure, it is essential to incorporate it into the soil during or immediately after spreading to minimize nutrient loss[9].

How Much Manure and Fertilizer Do You Need?

A typical cow can produce 15 to 30 kg of fresh manure daily, which adds up to about 5-10 tons of manure annually. Therefore, the amount of manure one cow can supply can be enough to cover the requirements of 1 to 2.5 acres of land. During topdressing, supplying the plant with additional nutrients can help satisfy the peak demand. The amount should depend on how well plants react to fertilizer at your specific location. Typically, the amount of Nitrogen should be 12-24 kg per acre, and half of that for Phosphorus and Potassium. A NPK fertilizer that supplies Nitrogen, Phosphorus and Potassium in the ratio 20-10-10 is usually a good choice for this.

It's important to note that the effectiveness of mineral fertilizer can vary depending on your soil type. This means that the increase in yield you see after applying additional mineral fertilizer might differ across different soils. To ensure that your crops are positively responding to the additional mineral fertilizer, you can conduct a simple test. Choose a small section of your field and leave it without any mineral fertilizer. This will serve as your control plot for comparison. At harvest time, compare the yields from the fertilized parts of your field with the yield from the test plot. If the fertilized sections of your field have significantly higher yields than the test plot, it indicates that your crops are responsive to the mineral fertilizer, and it would be beneficial to continue using it. However, if there's no significant difference in yield, it suggests that your crops might not be responsive to mineral fertilizer. In this case, to avoid unnecessary expenses, you may choose to apply less or no mineral fertilizer. Remember that this test only works if your field doesn't experience any severe moisture stress during the season. If you typically do not apply mineral fertilizer, you can test its effectiveness by applying it to a small section of your field and comparing the yield from this section to the rest of the field at harvest time. This will help you make informed decisions about fertilizer use on your farm.

Get in Contact for More Information:

Patrick Nyaga (Farm Africa, Kenya); PatrickN@farmafrica.org

Dr. Rebecca Yegon (University of Embu, Kenya); yegon.rebecca@embuni.ac.ke

Dr. Moritz Laub (ETH Zurich, Switzerland); moritz.laub@usys.ethz.ch

Prof. Johan Six (ETH Zurich, Switzerland); jsix@ethz.ch

More Information can be Found in the Following Articles:

(1) Kihara, J.; Bolo, P.; Kinyua, M.; Nyawira, S. S.; Sommer, R. Soil Health and Ecosystem Services: Lessons from Sub-Sahara Africa (SSA). *Geoderma* **2020**, *370*, 114342. https://doi.org/10.1016/j.geoderma.2020.114342.

(2) Sanderman, J.; Hengl, T.; Fiske, G. J. Soil Carbon Debt of 12,000 Years of Human Land Use. *PNAS* **2017**, *114* (36), 9575–9580. https://doi.org/10.1073/pnas.1706103114.

(3) Cobo, J. G.; Dercon, G.; Cadisch, G. Nutrient Balances in African Land Use Systems across Different Spatial Scales: A Review of Approaches, Challenges and Progress. *Agriculture, Ecosystems & Environment* **2010**, *136* (1), 1–15. https://doi.org/10.1016/j.agee.2009.11.006.

(4) Laub, M.; Corbeels, M.; Couëdel, A.; Ndungu, S. M.; Mucheru-Muna, M. W.; Mugendi, D.; Necpalova, M.; Waswa, W.; Van de Broek, M.; Vanlauwe, B.; Six, J. Managing Soil Organic Carbon in Tropical Agroecosystems: Evidence from Four Long-Term Experiments in Kenya. *SOIL* **2023**, *9* (1), 301–323. https://doi.org/10.5194/soil-9-301-2023.

(5) Laub, M.; Corbeels, M.; Mathu Ndungu, S.; Mucheru-Muna, M. W.; Mugendi, D.; Necpalova, M.; Van de Broek, M.; Waswa, W.; Vanlauwe, B.; Six, J. Combining Manure with Mineral N Fertilizer Maintains Maize Yields: Evidence from Four Long-Term Experiments in Kenya. *Field Crops Research* **2023**, *291*, 108788. https://doi.org/10.1016/j.fcr.2022.108788.

(6) Sileshi, G. W.; Nhamo, N.; Mafongoya, P. L.; Tanimu, J. Stoichiometry of Animal Manure and Implications for Nutrient Cycling and Agriculture in Sub-Saharan Africa. *Nutr Cycl Agroecosyst* **2017**, *107* (1), 91–105. https://doi.org/10.1007/s10705-016-9817-7.

(7) Washaya, S.; Washaya, D. D. Benefits, Concerns and Prospects of Using Goat Manure in Sub-Saharan Africa. *Pastoralism* **2023**, *13* (1), 28. https://doi.org/10.1186/s13570-023-00288-2.

(8) Sileshi, G. W.; Jama, B.; Vanlauwe, B.; Negassa, W.; Harawa, R.; Kiwia, A.; Kimani, D. Nutrient Use Efficiency and Crop Yield Response to the Combined Application of Cattle Manure and Inorganic Fertilizer in Sub-Saharan Africa. *Nutr Cycl Agroecosyst* **2019**, *113* (2), 181–199. https://doi.org/10.1007/s10705-019-09974-3.

(9) Teenstra, E.; de Buisonjé, F.; Ndambi, A.; Pelster, D. *Manure Management in the (Sub-) Tropics: Training Manual for Extension Workers*; Wageningen UR Livestock Research, 2015. https://hdl.handle.net/10568/70993.