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Balanced Replacement of Global Animal-Based Nutrition with Whole-Plant Crops: Land Use, Nutrient Requirements, Biogas Potential, and Fertiliser Offsets Based on FAO 2023 Data

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Abstract: ***This study evaluates the feasibility of replacing global animal-based nutrition with whole-plant foods without fortified or industrially processed products. Using FAO 2023 cropland baselines and nutrient substitution models, we estimate the land required to supply equivalent protein, fats, and micronutrients. Crop residues (~467.9 Mt collectable) and cattle/buffalo dung (~7.04 Bt) were assessed for biogas and organic fertilizer potential. Practical constraints necessitate a 30% resilience buffer, bringing total required cropland to 681.278 Mha—exceeding current feed-crop land by ~230 Mha.***

Keywords: whole-plant diet; land use; biogas; digestate; FAO 2023; sustainability; livestock emissions; crop residues

1. Introduction

Global food systems rely heavily on animal-source foods (ASF). This study quantifies the cropland, nutrients, biogas potential, digestate, and fertiliser offsets when replacing ASF entirely with whole-plant foods using FAO 2023 data.

2. Methods

This study integrates FAOSTAT data, livestock populations, yield trends, residue-to-product ratios, methane yields, digestate nutrient analysis, and global fertiliser application rates.

2.1 Plant-Based Replacement Model

Plant portfolio: 45% carbohydrates (rice + wheat), remaining energy from pulses, legumes, nuts, seeds, vegetables, fruits. Protein and fat equivalence matched to global ASF supply. A 30% resilience buffer was applied.

2.2 Land Requirement Framework

Core cropland required: 474.06 Mha. Practical cropland with buffer: 681.278 Mha (43.31% of global cropland).

3. Results

The practical whole-plant model exceeds existing feed-crop land by ~230 Mha but remains within global cropland capacity.

3.1 Land Requirement Comparison

Feed-crop land (FAO 2023): 451.3608 Mha.
Plant-based practical area: 681.278 Mha.
Additional land required: 229.9172 Mha.

3.2 Biogas Potential from Crop Residues and Dung

Residues CH_4: 56.14 B m^3; Dung CH_4: 175.93 B m^3.
Dung provides nearly 3× more methane potential than residues.

3.3 Digestate Nutrient Offsets

Digestate: 36.59 Mt N, 7.27 Mt P_2O_5, 36.36 Mt K_2O. Offsets 54–77% N needs and fully offsets K_2O needs.

4. Expanded Discussion: Why 230 Mha Additional Land Is Needed

Reasons include lower protein density of plants, fat replacement needs, higher land-intensity of vegetables, post-harvest losses, agronomic variability, nutrient diversity requirements, and loss of manure nutrient cycles.

5. Recommendations

A plant-forward system with regenerative livestock nutrient cycling is the most balanced pathway. Key actions include yield improvement, residue management, digestate utilisation, crop diversification, loss reduction, and protection of forests.

Conflict of Interest

The author declares no conflict of interest.

Funding Statement

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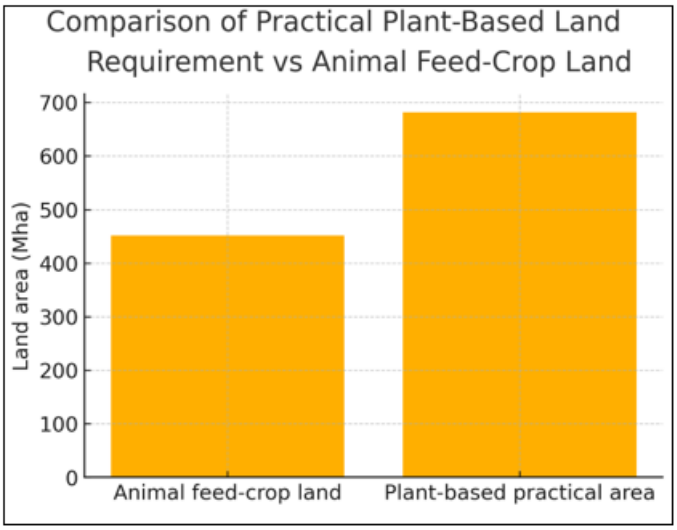

Figure 1: Practical Plant Area vs Animal Feed-Crop Land

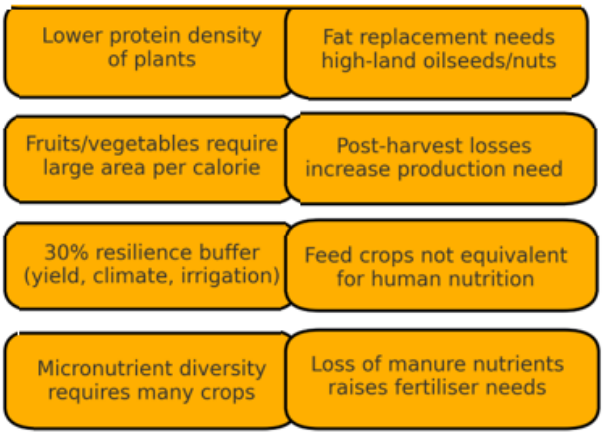

Figure 2: Drivers of the 230 Mha Land Deficit

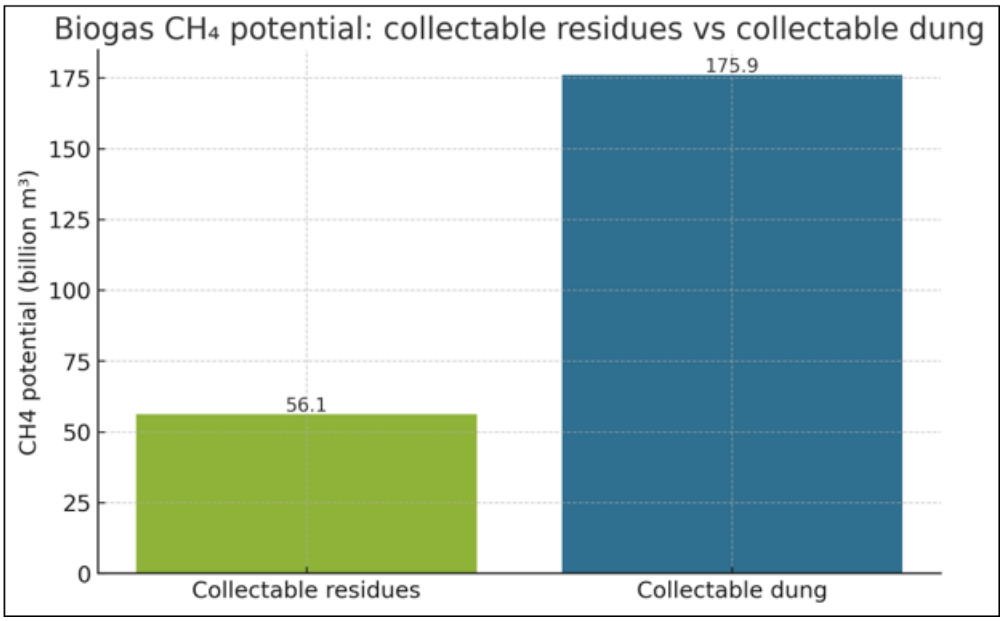

Figure 3: CH4 Potential: Residues vs Dung

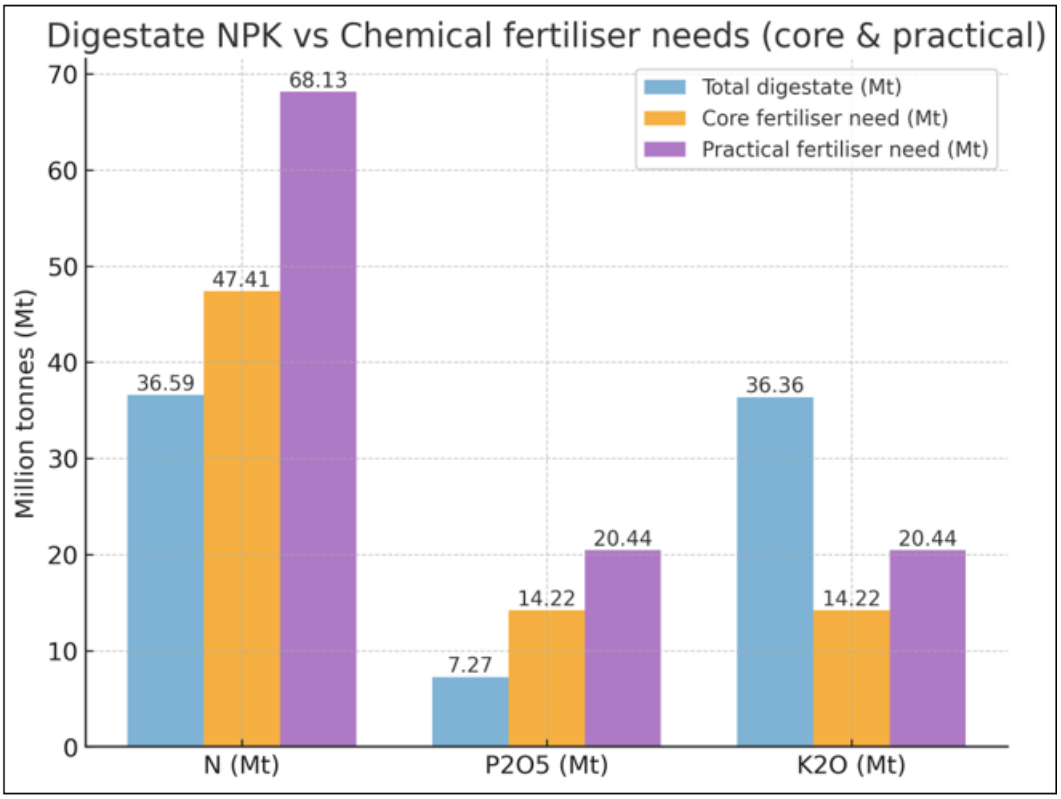

Figure 4: Digestate vs Fertiliser Needs

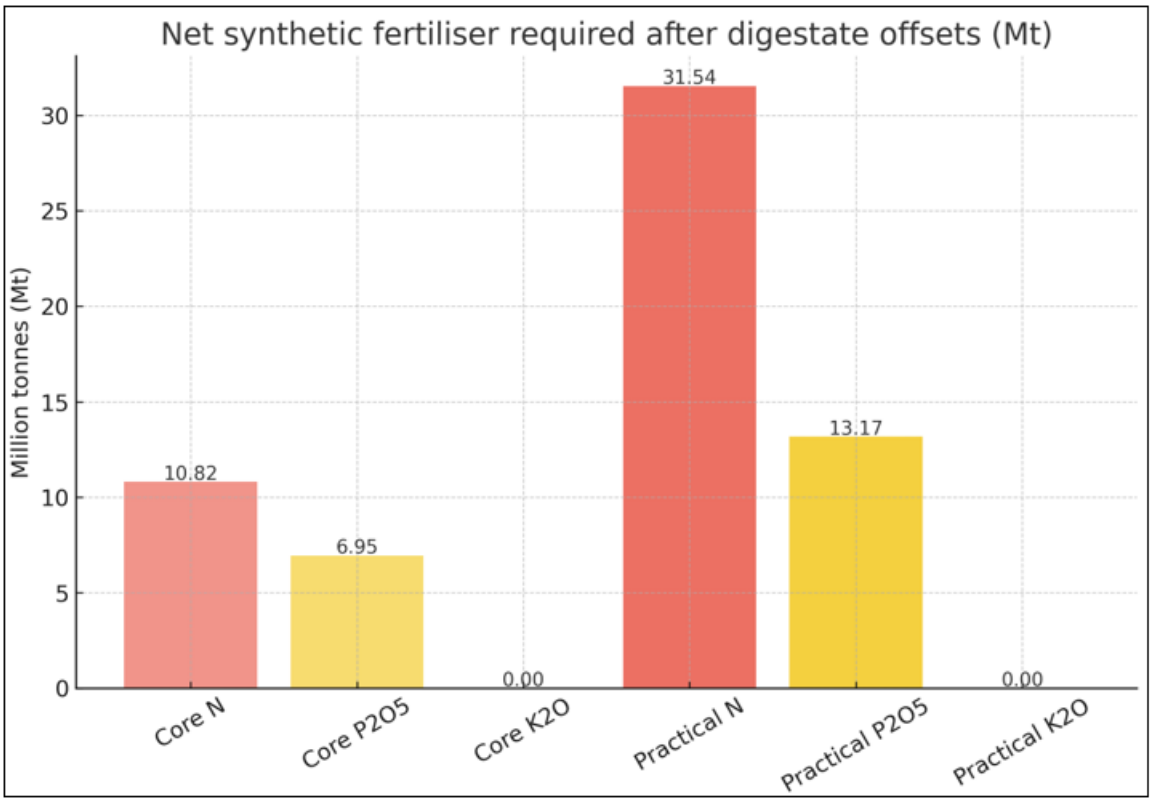

Figure 5: Net Synthetic Fertiliser Requirement