Annex 1. Mention of fertilizers in INDCs submitted by African States

Country	Text	Location in INDC
Burundi	"Agriculture: Gradual **replacement of 100% of mineral fertilizers with organic fertilizer** by 2030."	Mitigation contributions—Conditional objective p. 8
	"Key measure: Promotion of intensified water-efficient agriculture: • Intensify and diversify agricultural production by **simplifying access to inputs (fertilizer**, subsistence crop seeds, drought-resistant fodder and crop protection products) and to agricultural equipment • Develop an agro-ecological approach (**soil fertility management practices, use of manure and compost,** development of agroforestry, and water and soil conservation)"	Adaptation needs—Technical and technology transfer needs p. 5
Benin	"Promouvoir les **engrais spécifiques** et autres **intrants organiques biologiques** pour une gestion durable de la **fertilité des sols.**"	Annexe 1-Synthèse des mesures d'atténuation au titre des contributions prévues déterminées au niveau national—Secteur agriculture p. 17
Chad	"National priorities in terms of adaptation to climate change: Improve production techniques by developing water infrastructure, **access to improved and adapted inputs** (food crop and fodder seeds, animal gene banks, **manure management, compost management, etc.**)"	Adaptation—National priorities in terms of adaptation to climate change—Cross-cutting priorities p. 4
	"Develop intensive and diverse cultivation, using improved inputs, (**organic fertilizers including composts**, adapted plant varieties), agroforestry, land and water conservation, (implementation of soil restoration works) and preparation and distribution of new cropping calendars"	Adaptation—National priorities in terms of adaptation to climate change—Priorities by sector—Agriculture p. 5
	"**Intensify and diversify agrarian production whilst facilitating access to inputs (organic fertilizers,** seed for food crops and fodder resistant to drought and certified and approved phytosanitary products) and agrarian equipment."	Adaptation—Summary of adaptation needs—Technical needs, technology transfers and funds p. 7
	Scope and field of contributions: Agriculture/Livestock: "Enteric fermentation, manure management, rice cultivation, **agricultural soil**, controlled burning . . ."	Mitigation—Mitigation objectives by 2030 p. 9
Côte d'Ivoire	"**Rationalisation de l'utilisation des intrants chimiques et facilitation de l'emploi des intrants biologiques**."	Atténuation—Actions d'atténuation—Agriculture/Foresterie p. 6
	Réduire la vulnérabilité et accroitre la résilience: • "Développer l'approche agro-écologique (pratiques de **gestion de la fertilité des sols,** développement de l'utilisation des **engrais organiques** et du compost issus des déchets ménagers, l'association agriculture-élevage)" • "Améliorer les technologies de production grâce à l'accès **aux intrants améliorés et adaptés** (semences vivrières, fourragères, sylvicoles résistantes à la sécheresse, banque de gènes animale, alevins de qualité, **gestion du fumier et du compost pour améliorer la fertilité des sols,** etc.)"	Adaptation—Activités p. 12

Annex 1 continued

The Gambia	System of Rice Intensification–"**Reduce methane emissions** through water management, less flooded areas, **reduced fertilizer usage"**	Information to facilitate clarity, transparency and understanding—Emission reduction targets p.1
Malawi	"The mitigation options for agriculture are: (...) **optimizing fertilizer application with regards to product, rate, timing and placement and encouraging the application of organic amendments such as manure and crop residues that contain the potential to contribute to soil carbon levels; the planting of nitrogen fixing plants to reduce fertilizer usage; as well as potentially reduced and zero tillage."** "The mitigation measures suggested in the agricultural sector will **unconditionally contribute 100 Gg CO_2 equivalent mainly from reduced synthetic fertilizer application**, and around 400 Gg CO_2 equivalent per annum from implementing climate smart agriculture extensively by 2040, conditional upon support."	Mitigation Contributions—Agriculture p. 5
Mali	"Dans le secteur de l'agriculture, les mesures d'atténuation des émissions de GES, les plus appropriées concernent trois sous-secteurs qui sont : la riziculture irriguée, l'élevage et **la gestion des engrais.** (…) Pour les sous secteurs de l'élevage et des engrais chimiques, **la mesure d'atténuation sera axée sur la substitution de l'urée à forte teneur en azote par la fumure organique** dont la production permettra de réduire les émissions des fumures liées à la décomposition anaérobie."	Prévision des émissions de GES du Mali—Prévisions des émissions pour la période 2015-2030—Emissions de GES dans le secteur de l'Agriculture—Coût des mesures d'atténuation p.15
Namibia	"Measures evaluated in the AFOLU (Agriculture, forestry and other land uses) sector are: Reducing N_2O emissions by about 10% through production of biogas from the feedlot manure; **Reducing chemical fertilizers by 20%** through conservation and climate smart agricultural practices, use of organic manure and composts"	Mitigation contributions p. 9
Nigeria	"The livelihoods of Nigeria's poorest farmers are already at risk from climate change. Rising temperatures, too little rain or too much rain, thriving pests all lead to crop losses. **Without access to improved seeds, fertilizer and appropriate technologies, such as irrigation systems and finance, Nigeria's food security will be at risk.** With growing food demand from a growing population, declining harvests would strain supply, increasing malnutrition and possibly reverse recent progress in alleviating poverty."	Mitigation contributions by sector—Agriculture, forests and land use change p. 12
Rwanda	"Rwanda intends to promote **recovery and reuse of both organic waste and wastewater in order to restore and maintain soil fertility. Organic waste use through composting, currently used at a small scale, will be implemented to reach 100%** of the households involved in agriculture production countrywide by 2030."	Adaptation contribution—Agriculture p. 3-4

Annex 1 continued

Rwanda continued	Using fertilizer enriched compost: "Rwanda relies on **imported inorganic fertilizers** for its agriculture intensification activities. For instance, 36000 Mt of these were imported in 2014 and these importations are likely to increase in the near future. Although good at increasing yields, intensive use of inorganic fertilizers has adverse impacts to the environment in general and climate change in particular. **In contrast, the use of organic fertilizers** by composting has many environmental benefits whereby it provides an excellent way to manage the huge volume of organic waste and utilise it in a productive manner. **The effectiveness of composted organic waste can be further improved by enriching and blending it with nutrients (nitrogen, phosphorus).** This technique ensures a more efficient use of inorganic fertilizers, and adds valuable organic matter to soils, which also maximizes terrestrial carbon in farm soils. **Rwanda intends to ensure the use of fertilizer enriched compost and shift from using pure inorganic fertilizers by 2030**."	Adaptation contribution—Agriculture p. 5
Sao Tome and Principe	"Reduce the use of **nitrogen fertilizers in agriculture** by 2030."	Contribution in term of adaptation—Reporting on long-term and near-term adaptation visions, goals and targets p.5
Senegal	"Les activités qui génèrent des réductions d'émissions de GES seront réalisées dans les sous-secteurs suivants: (...) (2) l'Agriculture Foresterie et Autres Affectation des Terres (AFAT) **à travers la gestion des fumiers, la riziculture, les sols agricoles, les engrais organiques, les terres forestières et les plantations"**	Mesures d'atténuation—Activités sectorielles p. 7
	"Application des bonnes pratiques d'Agroforesterie, de Régénération Naturelle Assistée (RNA) et **d'utilisation de la fumure organique sur la moitié des superficies emblavées à l'horizon 2035."**	Activités Sectorielles—Tableau Secteur Agriculture p. 11
Zambia	Program objectives "promote CSA", co-benefits "**Reduced GHG emissions due to reduced fertilizer use** and less turning of soil; Biodiversity preservation due to reduced tillage; Improved soil productivity leading to improved crop productivity"	Mitigation—Zambia's Programs Contribution to its National Mitigation Goal—Sustainable agriculture p.3
	"Guaranteed food security through diversification and promotion of Climate Smart Agricultural (CSA) practices for crop, livestock and fisheries production" (…) "Key activities: Promote CSA practices through conservation agriculture, agroforestry, use of drought tolerant varieties, water use efficiency management and **fertilizer use efficiency management"**	Adaptation—Planned Actions—Priority adaptation actions p.7

Annex 2. The "4Rs" of efficient fertilizer use

Various methods and technologies exist to facilitate the application of the 4R principles, also in Africa. Some examples are:

- Right source: Choose blends or combine single-nutrient sources to provide a balanced supply of all essential nutrients that matches crop demand for the respective nutrients. Alleviate micronutrient deficiencies. In choosing N fertilizers (urea-, ammonium- or nitrate-based), take soil properties and expected loss processes into account. Local soil quality indicator schemes can be used, rather than formal soil analysis which is often unavailable.
- Right time: Fertilizers should be applied at optimal times relative to the crop development stage, soil moisture status, and weather conditions (crop growth; nutrient losses). Timing should account for nutrient supply from the soil itself, environmental risks, and field operation logistics.
- Right place: Place nutrients to take advantage of the root-soil dynamics considering nutrient movement, spatial variability within the field, and potential to minimize nutrient losses from the field (e.g. fertilizer deep placement). Row application can increase apparent fertilizer N recovery in maize by 20% relative to broadcast application. Placement at the base of individual plants is especially effective for phosphorus, given its relative immobility due to adsorption in soil, aggravated by Fe- and Al-compounds in strongly weathered tropical soils (P fixation). Seed coating can be effective, too.
- The Right amount is defined—in economic sense—by the target marginal return set by the product/fertilizer price ratio. The dose that corresponds to this target depends on soil fertility and other nutrient sources used (residues, green manures, animal manures), on inevitable losses, and of course on the farmer's yield goal. Sensors (e.g. Greenseeker) or simple leaf colour charts can help monitor crop demand, to account for interannual variation in yield and associated nutrient requirement (Crain et al. 2012; Verhulst et al. 2008).

Annex 3. Case study: Ethiopia's position on fertilizer use as part of its Climate Resilient Green Economy Strategy

Ethiopia has published its strategy for developing a climate-resilient green economy by 2030 (Federal Democratic Republic of Ethiopia. 2010). The strategy recognizes that the conventional development path would result in dramatically increased GHG emissions and unsustainable use of natural resources. The strategy identifies four pillars of development in the green economic action plan: (1) Improve crop and livestock production practices for higher food security and farmer income while reducing emissions; (2) Protect and re-establish forests for their economic and ecosystem services, including as carbon stocks; (3) Expand electricity generation from renewable sources of energy for domestic and regional markets; and (4) Leapfrog to modern and energy-efficient technologies in transport, industrial sectors, and buildings.

Soil is a significant contributor of GHG emissions, with its role set to further increase if no measures are taken. The soil includes three sources of emissions: crop reintroduction, mineral fertilizer use (direct and indirect emissions), and manure applied to cropland. Soil-based GHG emissions are significant and come from three main sources: 58% from using inorganic fertilizers; the rest from applying manure to cropland and re-introducing crop residues into the soil. In the business-as-usual (BAU) scenario, soil-based emissions will increase from 12 Mt CO_2e in 2010 to 61 Mt CO_2e in 2030.

Potential abatement levers

In total, the strategy has identified an abatement potential in 2030 of 40 Mt CO_2e of soil-based emissions and 38 Mt CO_2e through agriculture abatement levers that reduce deforestation, thereby achieving a combined abatement potential of 78 Mt CO_2e. The soil-related initiatives can be grouped into three categories:

1. Enhancing lower-emitting techniques for agriculture: By implementing low-emission techniques and sustainable land management practices, emissions would be reduced while maintaining production levels. These techniques include best agronomic and soil management practices to increase carbon storage, optimal nutrient management to improve nitrogen use efficiency, effective tillage and residue management practices, terracing and other water-harvesting techniques, and agro-forestry practices to prevent soil erosion and degradation. Within this lever, massive community-based watershed development and natural resources conservation activities are highly important.
2. Enhancing yield-increasing techniques for agriculture: This initiative would promote and introduce best practices aimed at increasing agricultural yield and value per tonne, thereby reducing the need for new agricultural land created from forest areas.
3. Creation of new agricultural land in arid areas through irrigation: Through small, medium, and large-scale irrigation schemes, new agricultural land can be created from uncultivated non-forest areas, thereby reducing emissions from the expansion of total cropland. The creation of new agricultural land in arid areas through irrigation has an abatement potential of 10.6 Mt CO_2e in 2030.

Annex 4. Nutrient management with a site-specific lens: A joint research project

A new joint project of CCAFS, Wageningen University & Research, the University of Nebraska (UNL), the International Fertilizer Association (IFA) and Yara, called Crop Nutrient Gaps, will provide further insight on strategies for closing yield gaps with high nutrient use efficiency. The project takes the current yield gap of crops in sub-Saharan Africa (www.yieldgap.org) as a starting point to calculate nutrient and fertilizer gaps. Using current practices as a reference, it will assess quantities of extra nutrient inputs required to bridge the yield gap towards e.g. 30%, 50% and 70% of water-limited yield potential in a sustainable manner. In context of this project, "sustainable" means: with a minimum of GHG losses, in a manner that curbs current widespread soil degradation, and avoiding peak intensification classically associated with rising affluence (Zhang et al. 2015). Nutrient gaps will be mapped at national and sub-national level in Ethiopia, Kenya and Tanzania. At selected locations in these countries, integrated nutrient management packages (using organic and mineral sources) will be defined that provide the required quantities of nutrients. Variants of the 4Rs will be used in the definition of the packages. Promising options will be tested on farm, and trade-offs between nutrient management, crop yields, financial results, soil organic carbon and N_2O emissions will be estimated.