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The Future Challenge of Phosphorous in Africa

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ABSTRACT

Phosphorous (P) is essential element to all living things and plays vital role in many physiological and chemical process and cannot be replaced by any other elements. The ultimate sources of Phosphorous in soils are the primary minerals. Africa is endowed with numerous phosphate ore deposits which are potential sources of phosphate fertilizer. Mixing phosphate rock (PR) increases soil available-P. Adequate supply off soil available-P is critical for normal plant growth. Phosphorous deficiency is a major constraint in the humid and sub-humid zones of Africa. Frequent application of P-fertilizer can build up P-stock in the soil which through time could be available to plants. It is important to select and develop P-efficient genotypes. Phosphorus recovery can be defined as a socio-technical system. In Africa phosphorous sources are not well managed and the P-cycle is broken. Soil and water conservation practices reduce P-loss by water and wind erosion. Most soil types in Africa are low in P and expose the farmer to use inorganic fertilizer to produce crops. Excess P-fertilizer application risks phosphorous losses via run-off which may result in eutrophication of water bodies. To improve the lifespan of existing PR deposits mining use of renewable P-sources in Africa, integrated soil fertility management and use of new crop germplasm with high P-use efficiency is needed. Launching waste treatment Phosphorous recovery from urban waste disposal is crucial for Africa. Finally this review work aims at creating awareness among policy makers, investors, farmers and scientists in Africa about the role of phosphorous in Agriculture for poverty reduction.

Keywords: Acid soils, Available phosphorous, Phosphorous deficiency, Rock phosphate, Phosphorous recovery, Eutrophication

INTRODUCTION

Phosphorus (P) is essential to all living things and plays vital role in many physiological and biochemical processes, and cannot be replaced by any other element [1]. Phosphorus is very reactive in the environment and in soil solution, it is mainly found as orthophosphate forms (PO_4^{3-}, HPO_4^{2-} or $H_2PO_4^-$) depending on the acidity of the solution. Soils might have a high overall P content, but only the P that is soluble in water is useful for plants [2]. Phosphorus inputs to farmer fields in Africa consist primarily of inorganic fertilizers and organic sources such as biomass, manures, and composts gathered from outside the field. However, the P content of plant residues and manures is normally insufficient to meet crop requirement [3]. However, Africa has numerous phosphate ore deposits, which are a potential source of phosphate fertilizers. In Senegal, Tunisia and Morocco few of the developed deposits have been targeted for export. Thus, use Phosphate Rocks (PRs) in Africa should be studied to replenish the lost loop in highly weathered, low P and acid soils [4]. Mixing PR with compost increased the availability of African PRs in Kodjari PR in Burkina Faso and Minjingu PR in Tanzania [5]. Particularly, PR application in P deficient soil has advantages of P investing the capital stocks which in the long run which available to the plant and may future reappointment to the invested PR in the soil [6]. High P-Sorption, clayey, red soils of East and southern Africa will therefore have different replenishments strategies as compare to low P-sorption, sandy soils of the Sahel, where smaller and more frequent applications are required [6]. Soil-fertility depletion is the main biophysical root cause for declining per capita food production particularly in sub-Saharan Africa [7]. Understanding, huge soil loss from agricultural lands many African Countries are launching soil conservation strategy to conserve soil and water loss. This may lead to the most effective long-term solution to prevent phosphorus losses and water pollution

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with phosphorus and decrease the erodible soil to water bodies [8]. Microbes assimilate phosphate ions in the soil solution into organic forms in their biomass, a process referred to a P immobilization. Mineralization of soil organic P, including recently immobilized biomass P, releases it once again to soil solution P, which is readily available to plants, thus providing an additional service flow [9]. The by-product in phosphate rock process is phosphogypsum, which contains significant amounts of cadmium, uranium and of fluoride [10]. Long-term phosphate fertilizer application accumulates cadmium in soil and could increase the risk of uptake by crops and transfer through the food chain [11,12]. Agronomic practices such as crop rotation, fertilization, and tillage affect the extent of mycorrhizal colonization and arbuscular mycorrhizal fungi (AMF) facilitated nutrient uptake of crops and management of arbuscular mycorrhizal fungi has the potential to improve the profitability and sustainability of agricultural systems. Though urban agriculture (UA) is a small subsystem, it may prove to be a valuable asset to increase urban P sustainability by becoming a catalyst of increased city recycling. Sewage sludge represents one possibility of permanent P-supply, but heavy metal contamination and high pathogenic risks; the usage of untreated sewage sludge in agriculture has to be regarded critically. Different sources present opportunities to recover phosphates such as sewage sludge ashes (SSA), meat and bone meal ashes (MBMA) and struvite [13]. The by-product in phosphate rock process is phosphogypsum, which contains significant amounts of cadmium, uranium and of fluoride [10]. Long-term phosphate fertilizer application accumulates cadmium in soil and could increase the risk of uptake by crops and transfer through the food chain [11,12]. At last, this paper reviews the great concern of Phosphorous in Africa and proposes further study of this non-renewable element.

ROLE OF PHOSPHOROUS FOR LIVING THINGS

Phosphorus (P) is essential to all living things and plays vital role in many physiological and biochemical processes, and cannot be replaced by any other element [1]. Phosphorus occurs in complex DNA and RNA structures which hold and translate genetic information and so control all living processes in plants, animals and man, transport of energy system in all cells. Phosphorus does not occur by itself in nature always but combined with other elements to form phosphates. Hence, African counties must pay attention to use phosphate resource and reserves for the benefit of their nation [14].

PHOSPHORUS IN SOILS

The ultimate sources of phosphorus are primary minerals, such as apatite (calcium phosphate). Phosphate-bearing minerals are found in many different rocks and soils; through mineral weathering process and phosphorus is released into the soil. Phosphorus is very reactive in the environment and in soil, solution is mainly found as orthophosphate forms (PO_4^{3-}, HPO_4^{2-} or $H_2PO_4^-$) depending on the acidity of the solution. If plants or soil microorganisms do not quickly take up orthophosphate, it will react with other compounds (such as calcium, iron, aluminum and Manganese) associated with the soil, making it unavailable to many plants [15]. Hence, phosphorus is the limiting nutrient in many agricultural soils [16]. Along with nitrogen (N) and potassium (K), phosphorus (P) is one of the most important nutrients for crops. Organic P sources in the soil include decomposing plant matter, microorganisms, and compost or animal manure. Inorganic P is found in the mineral matter component of the soils and in fragments of P-containing rocks and minerals. Soils might have a high overall P content, but only the P that is soluble in water is useful for plants [2].

SOURCE OF PHOSPHOROUS

Africa is endowed with numerous phosphate ore deposits, which are a potential source of phosphate fertilizers. In Senegal, Tunisia and Morocco few of the developed deposits have been targeted for export **(Figures 1-6)**. Here limited domestic markets and low phosphate prices in the global market does not justify foreign investment and operating costs [4]. Phosphorus inputs to farmer fields in Africa consist primarily of inorganic fertilizers and organic sources such as biomass, manures and composts gathered from outside the field. The P content of plant residues and manures is normally insufficient to meet crop requirement [3].

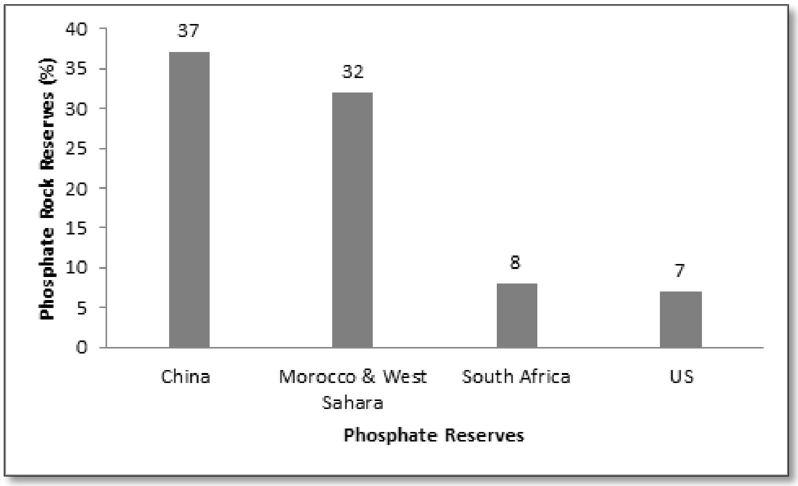

Figure 1. Phosphate rock reserves (%).

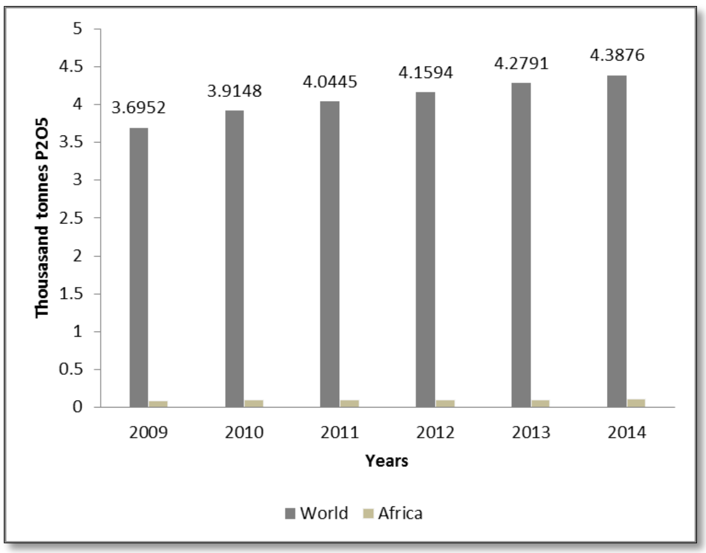

Figure 2. Phosphorous consumption in Africa compare to world.

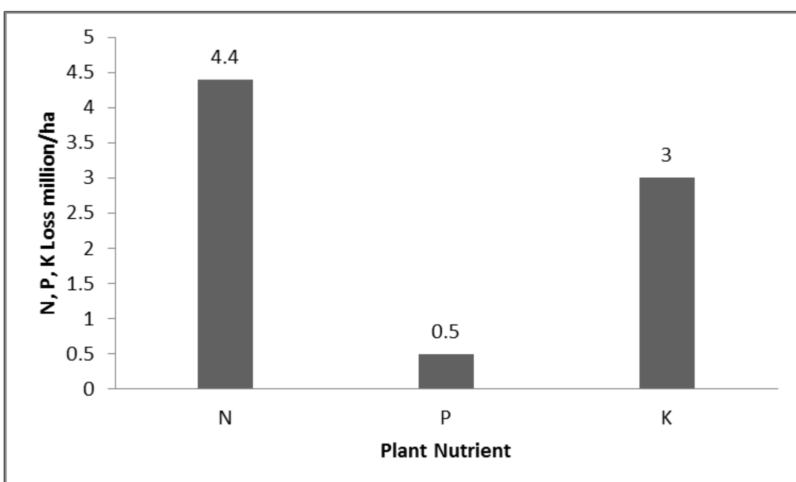

Figure 3. Nutrient loss from cultivated land in Africa.

Source: FAO, 1995

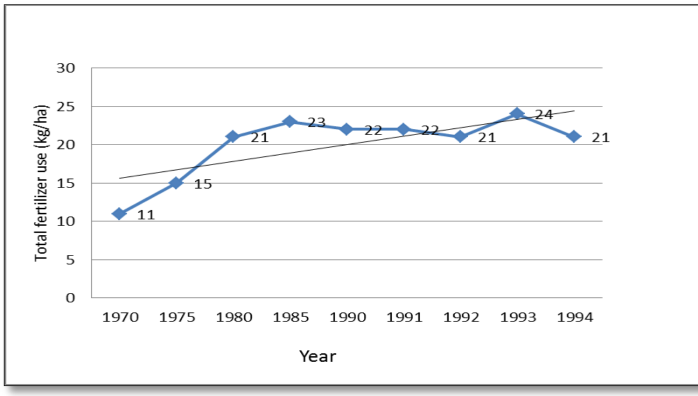

Figure 4. Total fertilizer use per hectare of arable land (kg/ha).

Source: FAOa, 2015

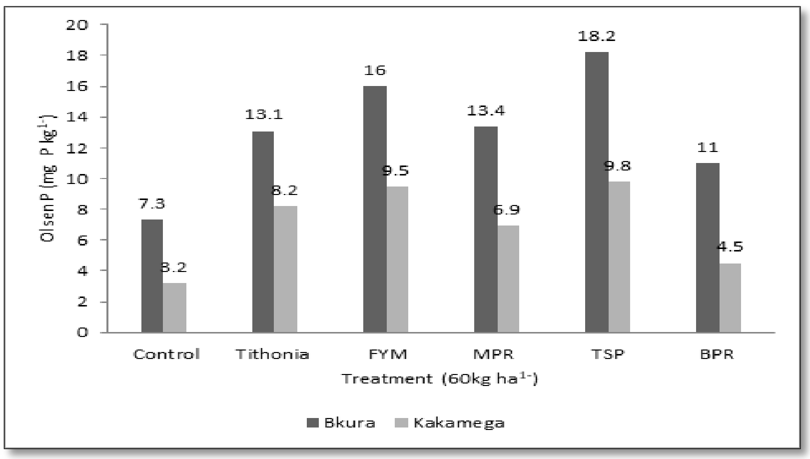

Figure 5. Effect of organic and inorganic P amendments on Olsen P (mg P kg−1) at Bukura and Kakamega in the laboratory incubation study (4 weeks after the start of incubation).

Source: Opala et al. (2012) [3]

Note: FYM: Farmyard Manure; TSP: Triple Superphosphate; MPR: Minjingu Phosphate Rock; BPR: Busumbu Phosphate Rock

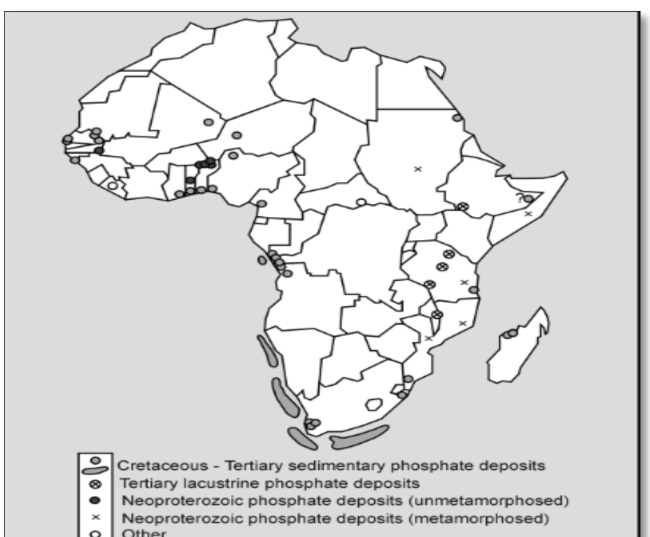

Figure 6. Ore of phosphate [84].

The primary source of P is from geological resources such as phosphate rocks [17-19]. Both organic and inorganic forms of P exist in the soil and are important for normal plant growth [20]. Complex and several forms of phosphate are found in soils, water and living things. However, the P mineral fertilizer is derived from non-renewable resource is dependent exclusively on mined rock phosphates [21]. Several studies in East Africa showed that direct rock P application increased soil P availability and crop yield in acid soils [3,22,23]. However, some of the low-quality rock phosphate from igneous rock showed low in P availability. Vaccari and Strigul [19] noted that though the problem of potential scarcity of rock phosphate is less urgent, but phosphate rock is a finite resource subject to eventual depletion under improper use.

Phosphate rocks (PRs) from diverse origins, reserves and characteristics are widely distributed in Africa. When, PRs is applied directly it has the potential to supply the commonly limiting P nutrient to crops and improved yields and food security. Use of PRs in Africa should be revisited to replenish the lost loop in highly weathered, low P and acid soils [4].

COMBINING INORGANIC AND ORGANIC PHOSPHORUS INPUTS

One of the problems of P replenishment in Africa is that acidifying agents are needed to facilitate the dissolution of PR. Many P-depleted African soils have pH values above 6.2, which are too high for rapid dissolution of reactive PR. The decomposition of organic inputs produces (i) organic acids that may help acidify PR or (ii) chelating agents that bind Ca dissolved from PR and thus stimulate further dissolution of the PR.

Mixing PR with compost has been shown to increase the availability of African PRs in Kodjari PR in Burkina Faso and Minjingu PR in Tanzania [5]. Finely-grounded PR mixed with poultry or cattle manure prior to application to nonacid soils increased P availability. Organic anions produced during the decomposition of plant materials temporarily reduces the P-fixation capacity of soils by binding to the Fe and Al oxides and hydroxides at surfaces of clay particles. Nziguheba and Smolders [12] found that the rapid decomposition of tithonia dry biomass reduced the P sorption and increased the available P pools of an acid. This was attributed to the blocking of P sorption sites by organic anions produced during biomass decomposition. The integration of locally available organic resources with commercial P fertilizers may be the key to increase and sustain levels of P capital in smallholder African farms [2,24].

SUPPLY OF PHOSPHOROUS TO PLANTS

Adequate supply of phosphorus is crucial for normal plant growth, and low level of phosphorus will result in a reduction of crop yield [25,26]. Studies in Africa showed that phosphorous is a limiting factor in agriculture, because most of the African soils are low in phosphorous content compared to other continents [27]. Highly weathered Ferralsols, Acrisols and Luvisols soils are generally deficient in phosphorus [28,29]. Phosphorous deficiency is common on Ultisols and Oxisols, because of fast fixation of soluble P into insoluble forms through reactions with iron and aluminum oxides.

The acid soils in Africa fix P and the best solution is to apply liming and addition of organic matter to increase crop yield [17,30]. In Ruanda application of lime alone in acid soils increased P availability by 3 mg/kg and maize grain yields by 13.5 times compared to control treatment [17]. The more acid the soil, the more rapid the dissolution rate of PR, and high P sorption enhances the dissolution of PR by reducing the concentration of P in solution around the PR particle.

PHOSPHOROUS DEFICIENCY IN SOIL AND PLANTS

Phosphorus deficiency is a major constraint to crop production on highly weathered, low activity clay soils in the humid and sub humid zones of sub-Saharan Africa [7]. For acidic soils, it is assumed that the sorption of phosphorus (P) by the hydrous oxides of iron (Fe) and aluminum (Al) binds added P and that the reverse reaction controls the concentration of P in soil. Understanding, the contribution of different soil properties to P sorption and the interactions among their effects could lead to new ways to control the concentrations of P in soil [31]. Amount of phosphorus adsorbed by soils is highly correlated with exchangeable aluminum, total iron, organic matter, and low pH. In highly weathered soils, phosphorus is mainly in the organic and combined forms; iron-phosphate is dominant in an active form [20,32].

FREQUENT APPLICATION OF P FERTILIZER

Fertilizer consumption in Africa is very low compared to other continents **(Figure 2)**. Frequent application of P fertilizer can build P in the soil which trough time could be available to plants. Particularly PR application in P deficient soil has key advantages of P investing the capital stocks which in the end available to the plant and may future reappointment to the invested PR in the soil [6,25]. Use of inorganic fertilizers is a fast and immediate way to avail P mostly for plant uptake and boost crop yields. Organic fertilizers either alone or combined with inorganic fertilizer have also shown its importance in rising up soil available P and other adjacent contribution to promote nutrient uptake and lastly increase crops yield [33]

The current rate of consumption of P fertilizers, the fast exhaustion of high-grade phosphate ores worldwide clearly challenges the sustainability of current P fertilizer use in Africa in the coming decades [27]. Using lower quality resources and paying a greater cost clearly requires a major shift in P fertilizer use [34].

RESIDUAL EFFECTS

Crop yield response to P applications depends on the duration of P amount applied, the soil's P sorption and cropping intensity. The larger the P application rates the longer the residual effect. Low P-sorption soils have shorter residual effects than high P-sorption soils [35]; the higher the number of crops harvested per year the shorter is the residual effect. High P-sorption, clayey, red soils of East and southern Africa will therefore have different replenishments strategies as compare to low P-sorption, sandy soils of the Sahel, where smaller and more frequent applications are required. Given these variables, as well as logistical, financial and infrastructure considerations, the choice of P fertilizer source and the rate used for replenishment is site and situation specific.

ORGANIC RECYCLING OF P

Plants convert inorganic P absorbed from the soil solution into organic forms in their tissues. The addition of plant material grown in situ to the soil as litter fall, root decay, green manure incorporation, crop-residue returns and animal excreta (in grazing systems) and its subsequent decomposition results in the formation of organic forms of soil P [36,37]. Microbes assimilate phosphate ions in the soil solution into organic forms in their biomass, a process referred to a P immobilization. Mineralization of soil organic P, including recently immobilized biomass P, releases it once again to soil solution P, which is readily available to plants, thus providing an additional service flow [9,33].

P EFFICIENCY GENOTYPES

For smallholder farmers in Africa to fill the scarcity of phosphorus (P) resources, available technologies are needed that increase efficiency of P fertilizers [38,39]. This should focus for P-fixing soils where P fertilizer use efficiency may remain low due to strong P adsorption and fixation. One of such technologies is the selection and development of P-efficient genotypes [31,40]. P efficiency may be the result of either the development of certain root traits leading to enhanced P uptake or of certain mechanisms leading to enhanced P utilization [41,42]. In Africa already different soybean genotypes showed high P efficiency and P efficiency correlates with P uptake. P utilization efficiency may play a more important role at higher levels of P supply, and breeding programs aiming at increasing plant growth at suboptimal P supply should exploit genotypic variation in P uptake [40,43,44].

BROKEN P-CYCLE

The main causes of broken phosphorous cycle in the ecosystems are extensive crop production systems, deforestation, and soil erosion by both water and wind [45]. Traditional African fallow system practice has been forgotten due to small land holdings and arable land fragmentation attributed to rapid population increase [26]. Crop-livestock system has been disturbed by overgrazing and grazing land encroachment that supplements with dung and manure to crop land [46-48]. Farm management practices, intensification of agriculture, and other human activities also caused phosphorus deficiencies **(Figure 3)**. In Africa whenever, crops are harvested, P is removed from the soil system. Burning and removing crop residues, failing to return organic matter to the soil, and allowing soil erosion have all led to loss of phosphorus from soils [36,41,49] indicated that phosphorus recovery and re-use can be defined not just as a technology, but also as a socio-technical system involving collection and storage, treatment and recovery, transport, refinement and reuse. Animal manure and other parts of animals such as blood and bones, is widely used as a source of phosphorus fertilizer in many regions of the world [36,50] and the collected livestock wastes must not too far away from arable land for transport to be economically viable [51].

MANAGEMENT OF PHOSPHOROUS SOURCES

Phosphorus sources are not well managed in African it seems the P-cycle is broken and farmers do not understand the role of phosphorous from organic and in organic sources **(Figure 4)**. Regarding nutrient cycle the policy in many African countries is not well defined. As the result widespread malnutrition and severe land degradation are direct consequences of inappropriate policy that resulted in large scale soil nutrient mining [52-55]. Soil-fertility depletion is the main biophysical root cause for declining per capita food production particularly in sub-Saharan Africa [7]. Phosphate ore deposits are a potential source of phosphate fertilizers with good agronomical valuable and high quality phosphate rock deposits exist in Africa, which can be applied to the soil with simple processing or directly to very acid soils [56,57].

Therefore, knowledge of drought tolerance and nitrogen fixation mechanisms induced by phosphorus may contribute to improve the management practices for the farmers' land. Further, selection of plant genotypes that produce good yield under low-P soil or those with high-P response efficiency can be a low-input approach to solving this problem [20]. Clearly, an integrated approach combining plant traits improvement and optimum land management needed to revitalize the crops performance under climate change and degraded land conditions [58].

LOSS OF PHOSPHORUS

Significant phosphorous loss from African agricultural is field driven by cultivation on nutrient-poor soils; a breakdown of traditional soil-fertility practices and poverty in rural Africa, which does not permit effective fertilizer management practices, hinders agricultural production [58]. Land ownership is also the major cause for soil fertility maintenance in some African Countries as the land belongs to the government and the farmers are not interested to improve the soil fertility of their farm. Extensive farming practice is causing the depletion of soil-P and hinders to use new technologies and innovations.

Application of too much P fertilizer to the soil can increase amounts of phosphate in the insoluble form and the soluble form also increases. This increases the risk that phosphate will be lost via soil run-off or leaching through the soil [20]. Soil conservation practices such as reduced tillage without removal of crop residues; terracing on sloping land; cultivation and planting along the contour; and, maintaining a soil cover of actively growing vegetation or plant residues can harness soil loss [20,31,38,50]. Understanding huge soil loss from agricultural land many African Countries are launching soil conservation strategy to conserve soil and water loss **(Figure 5)**. This may lead to the most effective long-term solution to preventing phosphorus losses and water pollution with phosphorus and decrease the erodible soil to water bodies [8].

FORMS OF INORGANIC PHOSPHORUS

Most inorganic P compounds in soils fall into one of two groups: those containing calcium (Ca) and those containing iron (Fe) and aluminum (AI). The availability of P in alkaline soils is determined largely by the solubility of the Ca-compounds in which the P is found. In acid soils, Fe and Al minerals control solubility of inorganic P [20]. When soluble P is added to soils, insoluble phosphates are formed with Ca or Fe and AI. With time, continuous interactions of soluble P with Fe and Al minerals (in acid soils) and Ca-compounds (in alkaline soils) results in formation stable phosphate minerals. This process results in significant decrease in bio-available forms of P. The inorganic P fractionation schemes identified the following pools: (i) exchangeable P, (ii) Fe and AI-P, (iii) Ca- and Mg-bound P, and (iv) residual P.

SOIL AVAILABLE PHOSPHOROUS

Due to low solubility of natural phosphorus-containing compounds and the slow natural cycle of phosphorus, the agricultural industry in Africa is heavily reliant on imported mineral fertilizers containing concentrated phosphoric acids [59-62]. Low phosphorus availability in soils decreases the amount of food farmers can grow to feed their families. Small-scale farmers often lack the resources to buy mineral fertilizers [63]. P availability is opposite to total P due to Al and Fe content of the soil, which reflects P sorption capacity. In light textural soils, such as sandy or silty soils, P is more readily available for plants and for lateral transfers. Including pH, clay or organic matter content which depends from land use can have impact on P availability.

Soil available P is the fraction of total P in soil that is readily available for absorption by plant roots. It is estimated in the laboratory using extracting solutions that rely on the dual contact time between the soil and the extracting solution (kinetic reaction) to capture inorganic P from the soil solution and the soil solid phase during a predetermined period of time (minutes to hours). The dominant inorganic P form extracted from soil is orthophosphate (HPO_4^{2-} and $H_2PO_4^-$ ions) that can be absorbed directly by plant and microbial cells. Polyphosphates (including pyrophosphate) are another form of inorganic P that may be present in soils, of biological origin and generally in low concentrations relative to orthophosphate [6].

PHOSPHOROUS DEFICIENCY

Most soils in sub-Saharan Africa naturally have low fertility. Over long periods of time, the nutrients have been lost due to rain and leaching, hot temperatures and chemical weathering processes. Sandy loam soils and soils derived from granite, common in Africa, have low nutrient levels and low water holding capacity. In much of sub-tropical soils in Southern Africa, the predominant soils are sandy with low P fixing potential and P deficiency is mainly due to low inherent fertility and low soil organic matter contents. Soil phosphorus deficiency is recognized as a major factor limiting maize production in smallholder farming systems in East and Southern Africa. P deficiency is particularly acute in the highly weathered and acidic tropical soils in East Africa, which have a high P-fixing capacity [6,21].

Farm management practices, intensification of agriculture, and other human activities also caused phosphorus deficiencies. Whenever crops are harvested, P is removed from the soil system. Poor farm management techniques, such as burning crop residues, failing to return organic matter to the soil, and allowing soil erosion, have all led to the loss of phosphorus from soils [64,65]. Unfortunately farmers are removing the P that has been transferred to the plant. Eventually P levels get low when crops are harvested. Hence the nutrient needs to be replenished for future plant needs [30].

Use of inorganic fertilizers is a fast and immediate way to correct P deficiency mostly for plant uptake and boost crop yields. Organic fertilizers either alone or combined with inorganic fertilizer is important in buildup soil available P, promote nutrient uptake and increase crops yield. Improving the crop productivity requires efficient use of limited P resources available to farmers through selection of the right P sources and applies them at right rate, time and place. Mineral P fertilizers offer the best option to reduce P deficiency but their use is restricted by poor accessibility and unaffordable to farmers. Use of reactive P rocks, partial acidification of low reactive P rock and the application of various organic matter sources can improve agricultural production at small holder level [20].

PHOSPHORUS AND CLIMATE

Applied phosphorus fertilizer in excess to soils makes more available to crop plants, but increases the risk of phosphorus loss via run-off, leaching or soil erosion, finally accumulates in lakes, rivers and oceans. It may result in eutrophication by phosphorus and nitrogen fertilizers and use of highly soluble inorganic P in fertilizers and feeds, specialization and regionalization of farming systems, deforestation and increased urbanization are key activities promoted greater losses of P in dissolved and particulate forms from land to rivers and the oceans. Cadmium can accumulate in crops leading to concentrations in the edible portions of the crop that may be harmful for human health [66,67].

After phosphorus fertilizers are applied, only a small proportion of it is immediately available to plants. The rest is stored in soils in varying degrees of availability to plants. Applied phosphorus fertilizer in excess to soils makes more available to crop plants, but increases the risk of phosphorus loss via run-off, leaching or soil erosion, finally accumulates in lakes, rivers and oceans [43,68]. This represents a financial loss and environmental damage. An excess of nutrients in water systems – eutrophication is a major and common problem worldwide, driven mostly by overuse of phosphorus and nitrogen fertilizers [10].

The by-product in phosphate rock process is phosphogypsum, which contains significant amounts of cadmium, uranium and of fluoride [10]. Long-term phosphate fertilizer application accumulates cadmium in soil and could increase the risk of uptake by crops and transfer through the food chain [11,12] **(Photos 1 and 2)**.

Photo 1. Eutrophication of Lake Tana (Ethiopia).

Photo 2. Lake Tana (Ethiopia) - Eutrophication, Who cares for this lake?

PHOSPHORUS CYCLE IN THE PLANT-SOIL SYSTEM

The P cycle in a cropped field is characterized by transformations among several P chemical forms. Pool sizes of these P forms vary by five to six orders of magnitude. Soil P compounds can be categorized as follows: (1) soluble inorganic and organic P in the soil solution; (2) weakly adsorbed (labile) inorganic and organic P; (3) insoluble P; which is associated with Ca in calcareous and alkaline soils or bound to Fe and Al in acidic soils; (4) P strongly adsorbed and/or occluded by hydrous oxides of Fe and Al; and (5) insoluble organic P in decomposed plant, animal, and microbial residues within the soil organic matter (SOM) [63,69]. In the plow layer of cropped soils, about 70% of the total P is present in inorganic forms, more than 20% is in organic forms, and only few percentages are in the soil microbial biomass (bacteria and fungi).

LIFESPAN OF THE EXISTING PR DEPOSITS

To improve the lifespan of existing PR deposits mining use of renewable P sources in Africa, integrated soil fertility management and use of new crop germplasm with high P-use efficiency is needed. Use of human excreta (urine and feces) is potential renewable sources, which contains P, N and K, has a readily available form of P, provided safety measures and perception issues are addressed [57,70] revealed that in Zimbabwe and Sweden nutrients emerging in one person's urine are sufficient to produce 50-100% of the food requirement for another person. Based on this the large populations of urban areas of Africa can produce substantial amounts of excreta which contains considerable P.

USE OF ORGANIC RESOURCES

Plants and animal parts added to soils have a wide role in agricultural production system [71]; they increase soil organic matter content and improve soil physical properties. Soil organic matter (SOM) leads to slow release of macro elements to crop and improve buffering capacity of the soil and cation exchange capacity [71]. Manures improve soil structure which in return improve water storage, infiltration capacity and reduce erosion and loss of nutrients [65,72,73]. Crop residues incorporated in the soil replenish nutrients and requires presence of soil microorganism to decompose the organic material and make P through mineralization process [31]. Manure applied to the soil may form complex with ions of Fe and Al in soil and affect availability of P [74,75].

PHOSPHORUS-SOLUBILIZING BACTERIA AND MYCORRHIZAS

Enhancement of microorganism activity by regularly returning organic material to the soil increases cycling and best use of phosphorus [20,76]. Addition of inoculants increase phosphorus availability in pastures and cropland soils from reserves in the soil and applied rock phosphate. Organic farms will often be using practices that promote higher levels of mycorrhizas, which in turn can help uptake of phosphorus by crops [69]. Mycorrhizal symbiosis is a highly evolved mutually beneficial relationship found between arbuscular mycorrhizal fungi (AMF) and vascular plants and they increase plant uptake of phosphorus and other non-mobile soil nutrients such as zinc and copper [75]. Crop plants differ in their dependence on AMF nutrient uptake, ranging from flax which is highly dependent on AMF for the uptake of phosphorus, to canola, a completely non-mycorrhizal crop [76,77]. Agronomic practices such as crop rotation, fertilization and tillage affect the extent of mycorrhizal colonization and AMF mediated nutrient uptake of crops. Proper management of arbuscular mycorrhizal fungi has the potential to improve the profitability and sustainability of agricultural systems [78].

RECOVERY AND REUSE OF PHOSPHORUS FOR AFRICA

Recovery and reuse of phosphorus is very important for Africa. It is better to establish waste water treatment which consists of an activated sludge system without primary sedimentation and chemical phosphorus removal with iron salts [79,80]. Several streams digested sludge, and fecal deposit from any source should be established at every urban area to catch free phosphate content using standard methods. High free phosphate and high quality struvite granules (MgNH4PO4.6H2O) can be harnessed [13,59,81]. The recovery overproduced struvite will replace artificial fertilizer. The recovered phosphorus can be reused locally as a fertilizer, contributing to a reduction of the environmental P pollution.

Urban agriculture (UA) contributes to increase P-recycling by recycling cities' high-P waste into very local food production [82]. Though UA is a small subsystem, it may prove to be a valuable asset to increase urban P-sustainability by becoming a catalyst of increased city recycling. Sewage sludge represents one possibility of permanent P-supply, but heavy metal contamination and high pathogenic risks; the usage of untreated sewage sludge in agriculture has to be regarded critically. Different sources present opportunities to recover phosphates such as sewage sludge ashes (SSA), meat and bone meal ashes (MBMA) and struvite [13]. The main challenge is to include these streams in the existing production processes without jeopardizing quality and plant-availability. Direct sewage sludge application in agriculture would be the most simple and appropriate method to recover P from waste water. But due to potential environmental risks as heavy metals (HM), acceptance is decreasing. Thus, numerous technologies have been developed to recover ideally great amounts of plant available P with reduced environmental risk [83]. Considerable amount of phosphorus entering the Earth systems is lost in human urine and excreta [36]. African countries should create real sustainable facilities to recovery

P and Nitrogen form in urine and feces which could recovered and used to fertilize agriculture lands [80].

SUMMARY

Phosphorous is very important element for all living things. Phosphorous is found on earth only combined with other elements. This makes phosphorous scarce element and less available to plants. Few scientists believe that phosphorous is not renewable hence everybody should use wisely this scarce element. The main sources of phosphorus fertilizer are the rock phosphate (RP), organic matter and weathered minerals. Africa endowed with the deposits of rock phosphate rock (RP). The huge amount of global rock phosphate is found in Africa (Morocco). Besides the west, central, south and east Africa have several phosphate deposits. Few phosphate fertilizer processing from RP are emerging to improve the phosphate fertilizer availability in the continent. However, the yearly demand of Phosphorous fertilizer is growing at higher rate to produce more agriculture crops to feed the rapid growing population. With this huge P-resources use of phosphate fertilizer ruse in Africa is very low. African soils are very low in phosphorus attributed to very acidic soils, very high content of Al, Fe and low soil organic carbon content. Thus most soils are deficient in soil-P which resulted in low agricultural productivity. Loss of phosphorous from agricultural land is aggravated by removal of crop residue and very low organic phosphorous addition to the soil. Several studies are going on in developing P observant plant genotypes and P-solubilizing plant genotypes under stressed P and weather conditions. Studies are going to promote Phosphorus-solubilizing bacteria and mycorrhizas. Care should be taken around rock phosphate process plant to minimize the Cadmium and Uranium contamination of the water and surrounding soil, because these elements are highly toxic to all living things. Though the eutrophication level appears to be low in general, but the big lakes like Victoria Lake are exposed to rapid eutrophication. Urban wastes, faces and urine could be additional P-sources if properly processed to extract P with appropriate technologies [84,85].

IMPORTANT SUGGESTIONS

The following suggestion may be helpful to alleviate some of the land degradation problems encountered in Africa. Phosphorous is not a renewable element, hence we must create awareness among farming community, policy makers and scientists about the role phosphorous fertilizer for all living things. Use phosphate resources efficiently and launch appropriate technologies for P-processing plants. Improve the Phosphorus soil balance by using organic sources such as livestock manure. Protect the phosphorus soil reserve and protect it from any loss by runoff and poor management of agricultural land. Utilize the local available RP mixing with other organic matter, develop and look for plant genotypes which solubilize fixed soil-P and use efficiently. Acid soil of Al and Fe content fix the available-P hence it is important to improve such soils through improved agricultural practices, soil and conservation practices. Availability and behavior of soil phosphorous have been done, however management of phosphorous element for agriculture needs more attention. Population in African is growing at faster rate and this needs food growth symmetrically, which needs more fertilizer use and processing factories. Studies revealed that most of the RP in Africa can be mixed with other organic sources simply which is a promising venture to overcome the huge investment cost and foreign market opportunities [86].

Early planning to protect the water bodies, soils and environment from RP processing is very important. Protection of rivers, lakes, beaches and oceans from eutrophication is very important for Africa. Phosphorous extraction from, animal manure, forest debris and urban wastes could improve the broken P-cycle if we use the available technologies [87].

REFERENCES

1. Daniel P, Schachtman DP, Reid RJ, Ayling SM (1998) Phosphorus uptake by plants: From soil to cell. Plant Physiol 116: 89-80.
2. Girma T (2001) Land degradation: A challenge to Ethiopia. Environ Manag 27: 815-824.
3. Opala PA, Jama BA, Othieno CO, Okalebo JR (2007) Effects of phosphate fertilizer application methods and nitrogen sources on maize in western Kenya: An agronomic and economic evaluation. Exp Agric 43: 1-11.
4. Nakamura S, Fukuda M, Nagumo F, Tobita S (2013) Potential utilization of local phosphate rocks to enhance rice production in Sub-Saharan Africa. J Agric Qual 47: 353-363.
5. Ikerra ST, Semu E, Mrema JP (2007) Combining *Tithonia diversifolia* and Minjingu phosphate rock for improvement of P availability and maize grain yields on a chromic acrisol in Morogoro, Tanzania. In: Bationo A, Waswa B, Kihara J and Kimetu J (Eds). Advances in Soil Fertility Management in Sub-Saharan Africa: Challenges and Opportunities, Springer, Germany, pp: 333-344.
6. Sanchez PA (1999) Improved fallows come of age in the tropics. Agroforestry Systems 47: 3-12.
7. Gichangi EM, Mnkeni PNS, Muchaonyerwa P (2008) Phosphate sorption characteristics and external p requirements of selected South African soils. Journal of Agriculture and Rural Development in the Tropics and Subtropics 109: 139-149.
8. Carpenter SR, Bennett EM (2011) Reconsideration of the planetary boundary for phosphorus. Environ Res Lett 6: 014009.

9. Badgley C, Moghtader J, Quintero E, Zakem E, Chappell MJ, et al. (2007) Organic agriculture and the global food supply. Renewable Agriculture and Food Systems 22: 86-108.
10. US EPA (2011) Radiation protection: Fertiliser and fertiliser production wastes. United States Environment Protection Agency. Available at: http://www.epa.gov/radiation/tenorm/fertiliser.html
11. Chen W, Chang AC, Wu L (2007) Assessing long-term environmental risks of trace elements in phosphate fertilizers. Ecotoxicol Environ Saf 67: 48-58.
12. Nziguheba G, Smolders E (2008) Inputs of trace elements in agricultural soils via phosphate fertilizers in European countries. Sci Total Environ 390: 53-57.
13. Times of India (2011) Country's first urine bank to come up at Musiri. 2011-02-18/india/28614510_1_fertiliser-initiative-nutrients
14. Van Vuuren DP, Bouman AF, Beusen AHW (2010) Phosphorus demand for the 1970-2100 periods: A scenario analysis nod resource depletion. Glob Environ Change 20: 428-439.
15. Nwoke OC, Diels J, Abaidoo R, Anginga NS (2005) Low phosphorus availability in West African moist savanna soils: Effect of sparing soluble P sources on the growth of soybean, cowpea and maize. African Crop Science Conference Proceedings 7: 1157-1161.
16. Kanyanjua SM, Ireri L, Wambua S, Nandwa SM (2002) Acidic soils in Kenya: Constraints and remedial options. KARI Technical Note No. 11
17. Nabahunga LL, Semoka JMR, Zaongo C (2007) Limestone, Mjingu phosphate rock and green manure application on improvement of acid soils in Rwanda. In: Bationo A, Waswa B, Kihara J, Kimetu J, (Eds). Advances in Soil Fertility Management in Sub-Saharan Africa: Challenges and Opportunities, Springer, Germany, pp: 703-711.
18. Jasinski SM (2010) Phosphate rock. USGS Minerals Yearbook. Available at: http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock
19. Vaccari DA, Strigul N (2011) Extrapolating phosphorus production to estimate resource reserves. Chemosphere 84: 792-797.
20. Soil Association (2010) A rock and a hard place: peak phosphorus and the threat to our food security. Soil Association, UK.
21. Verde B, Matusso J (2014) Phosphorus in Sub-Sahara African Soils - Strategies and options for improving available soil phosphorus in smallholder farming systems: A review. Acad Res J Agric Sci Res 2: 1-5.
22. Waigwa MW, Othieno CO, Okalebo JR (2003) Phosphorus availability as affected by application of phosphate rock combined with organic materials to acid soils in western Kenya. Exp Agric 39: 395-407.
23. Kifuko MN, Othieno CO, Okalebo JR, Kimenye LN, Ndungu KW, et al. (2007) Effect of combining organic residues with Minjingu phosphate rock on sorption and availability of phosphorus and maize production in acid soils of western Kenya. Exp Agric 43: 51-66.
24. Dawson CJ, Hilton J (2011) Fertilizer availability in a resource-limited world: Production and recycling of nitrogen and P. Food Policy 36: S14-S22.
25. Smaling EMA, Nandwa SM, Janssen BH (1999) Soil fertility in Africa is at stake. In: Replenishing Soil Fertility in Africa.
26. Greenpeace International (2009) Greenpeace's Climate Vision. Briefing, May 2009. Available at: http://www.greenpeace.org/international/en/publications/reports/Greenpeace-climate-vision/
27. Lunze L, Abang MM, Buruchara R, Ugen MA, Nabahungu NL, et al. (2012) Integrated soil fertility management in bean-based cropping systems of eastern, central and southern Africa. Soil Fertility Improvement and Integrated Nutrient Management: A Global Perspective.
28. Batjes NH (2011) Global distribution of soil phosphorous retention potential. Wageningen, ISRIC-World Soil Information (with dataset), ISRIC Report 2011/06, 42pp.5fig. 2tab. 106ref.
29. Jin J, Tang CX, Armstrong R, Sale P (2012) Phosphorus supply enhances the response of legumes to elevated (FACE) in a phosphorus-deficient vertisol. Plant and Soil 358: 86-99.
30. Kisinyo PO (2011) Constraints of soil acidity and nutrient depletion on maize (*Zea mays* L.) production in Kenya. D. Phil. Thesis. Moi University, Eldoret, Kenya.
31. Schroder JJ, Smit AL, Cordell D, Rosemarin A (2011). Improved phosphorus use efficiency in agriculture: A key requirement for its sustainable use. Chemosphere 84: 822-831.
32. Van Diepeningen AD, De Vos OJ, Korthals GW, Van Bruggen AHC (2006) Effects of organic versus conventional management on chemical and biological parameters in agricultural soils. Appl Soil Ecol 31: 120-135.
33. Smithson PC, Giller KE (2002) Appropriate farm management practices for alleviating N and P deficiencies in low-nutrient soils of the tropics. Plant Soil 245: 169-178.

34. Cordell D, Drangert JO, White S (2009) The story of phosphorus: global food security and food for thought. Glob Environ Change 19: 292-305.
35. Sattari SZ, Bouwman AF, Giller KE, Van Ittersum MK (2012) Residual soil phosphorus as the missing piece in the global phosphorus crisis puzzle. Proc Natl Acad Sci 109: 6348-6353.
36. Cordell D, Rosemarin A, Schroder JJ, Smit AL (2011). Towards global phosphorus security: A systems framework for phosphorus recovery and reuse options. Chemosphere 84: 747-758.
37. Odedina JN, Odedina SA, Ojeniyi SO (2011). Effect of types of manure on growth and yield of cassava (*Manihot esculenta*, Crantz). Researcher 3: 1-8.
38. Syers JK, Johnston AE, Curtin D (2008) Efficiency of soil and fertilizer phosphorus use: Reconciling changing concepts of soil phosphorus behavior with agronomic information. FAO Fertilizer and Plant Bulletin 18. Food and Agricultural Organization of the United Nations. Rome, ISBN 978-92-5-105929-6.
39. Syers JK, Johnston AE, Curtin D (2010) A new perspective on the efficiency of phosphorus fertilizer uses. World Congress of Soil Science, Soil Solutions for a Changing World 1-6 August 2010, Brisbane, Australia.
40. Namayanja A, Semoka J, Buruchara R, Nchimbi S, Waswa M (2014) Genotypic variation for tolerance to low soil phosphorous in common bean under controlled screen house conditions. Agric Sci 5: 270-285.
41. Tirado R, Cotter J (2010) Ecological farming: Drought-resistant agriculture. Greenpeace Research Laboratories Technical Note, 02/2010.
42. Niu YF, Chai RS, Jin GL, Wang H, Tang CX, et al. (2012) Responses of root architecture development to low phosphorus availability: A review. Ann Bot 112: 391-408.
43. Kimani P, Buruchara R, Lubanga L (2006) Enhancing the resilience of agroecosystems in Central Africa through improved, nutrient dense and marketable bean germplasm tolerant to low fertility acid soils. CIALCA Second Planning Workshop, Kigali, 28 August-1 September, 2006.
44. Ma W, Ma L, Li J, Wang F, Sisák I (2011) Phosphorous flows and use efficiencies in production and consumption of wheat, rice and maize in China. Chemosphere 84: 814-821.
45. Blanco-Canqui H, Stephenson RJ, Nelson NO, Presley DR (2009) Wheat and sorghum residue removal for expanded uses increases sediment and nutrient loss in runoff. J Environ Qual 38: 2365-2372.
46. Girma T, Mohamed Saleem MA, Astatke A, Wagnew A (2002a) Effect of grazing pressure on biomass productivity, plant attributes and soil properties in the sloping lands. Environ Manag 29: 735-750.
47. Girma T, Mohamed Saleem MA (2002b) Effect of livestock grazing to physical properties of cracking and self-mulching vertisol. Aust J Exp Agric 42: 103-223.
48. Girma T, Mohamed Saleem MA, Astatke A, Wagnew A (2002c) Impact of grazing on plant species richness, plant biomass, plant attributes and physical and hydrological properties of vertisols in the east African highlands. Environ Manag 29: 279-289.
49. Fairlie S (2010) Meat: A benign extravagance. Permanent Publications, Hampshire, UK.
50. Ghebremicheal LT, Watzin MC (2011) Identifying and controlling critical sources of farm phosphorus imbalances for Vermont dairy farms. Agric Syst 104: 551-561.
51. Elser J, Bennett E (2011) P cycle: A broken biogeochemical cycle. Nature 478: 29-31.
52. Girma T, Endale B (1995) Influence of manuring on certain soil physical properties in the middle Awash area of Ethiopia. Journal of Communications in Soil Science and Plant Analysis 26.
53. Girma T (1998) Effect of cultivation on physical and chemical properties of a vertisol in middle Awash valley, Ethiopia. Communications in Soil Science and Plant Analysis 29.
54. Girma T (1999) Potassium supplying capacity of fluvisols and vertisols in the middle Awash valley. SINET Ethiop J Sci 2: 199-208.
55. Childers DL, Corman J, Edwards M, Elser JJ (2011). Sustainability challenges of phosphorus and food: Solutions from closing the human phosphorus cycle. Bioscience 61: 117-124.
56. Buresh RJ, Sanchez PA, Calhoun F (2011) Soil Science Society of America and American Society of Agronomy, Madison, WI, pp: 47-61.
57. MacDonald GK, Bennett EM, Potter PA, Ramankutty N (2011). Agronomic phosphorus imbalances across the world's croplands. Proc Natl Acad Sci 108: 3086-3091.
58. Rittmann BE, Mayer B, Westerhoff P, Edwards M (2011) Capturing the lost phosphorus. Chemosphere 84: 846-853.
59. Pathak H, Mohanty S, Jain N, Bhatia A (2010) Nitrogen, phosphorus and potassium budgets in Indian agriculture. Nutr Cycl Agroecosystem 86: 287-299.

60. Food and Agricultural Organization (FAO) (2005a) Fertilizer use by crop in South Africa. First version, published by FAO, Rome.
61. Food and Agricultural Organization (FAOb) (2005b) World Fertilizer Trends and Out Look to 2015. Food and Agricultural Organization of the United Nations, Rome, Italy.
62. Food and Agriculture Organization (FAOc) of the United Nations VialedelleTerme di Caracalla 00100 Rome, Italy. Fungi and nutrient concentrations in maize, wheat and canola. Agronomy J 92: 1117-1124.
63. Toor GS (2009) Enhancing phosphorus availability in low-phosphorus soils by using poultry manure and commercial fertilizer. Soil Sci 174: 358-364.
64. Ekholm P, Turtola E, Grönroos J, Seuri P, Ylivainio K (2005) Phosphorus loss from different farming systems estimated from soil surface P balance. Agric Ecosyst Environ 110: 266-278.
65. Salahin N, Islam MS, Begum RA, Alam MK, Hossain KMF (2011) Effect of tillage and integrated nutrient management on soil physical properties and yield under tomato-mungbean-*T. aman* cropping pattern. Int J Sustainable Crop Prod 6: 58-62.
66. Zhang H, Shan B (2008). Historical records of heavy metal accumulation in sediments and the relationship with agricultural intensification in the Yangtze-Huaihe region, China. Sci Total Environ 399: 113-120.
67. Pan J, Plant JA, Voulvoulis N, Oates CJ, Ihlenfeld C (2010) Cadmium levels in Europe: Implications for human health. Environ Geochem Health 32: 1-12.
68. Da Conceciāo FT, Bonotto DM (2006) Radionuclides, heavy metals and fluorine incidence at Tapira phosphate rocks, Brazil and their industrial (by) products. Environ Pollut 139: 232-243.
69. Owen D, Williams AP, Griffith GW, Withers PJA (2014) Use of commercial bio-inoculants to increase agricultural production through improved phosphorus acquisition. Appl Soil Ecol 86: 41-54.
70. Cordell D (2008) The story of phosphorus: 8 reasons why we need to rethink the management of phosphorus resources in the global food system. Sustainable Phosphorus Futures website.
71. Gachene CKK, Kimaru G (2003) Soil fertility and land productivity. A guide for extension workers in the eastern Africa region. Regional Land Management (RELMA) Technical handbook No. 30.
72. Rasoulzadeh A, Yaghoubi A (2010) Effect of cattle manure on soil physical properties on a sandy clay loam soil in North-West Iran. J Food Agric Environ 8: 976-979.
73. Liang W, Wu X, Zhang S, Xing Y, Wang R (2011) Effect of organic amendments on soil water storage in the Aeolian sandy land of northeast China. Proceedings of the Electrical and Control E Engineering (ICECE), International Conference. 16th-18th September 2011, pp: 1538-1540.
74. Fliebach A, Oberholzer HR, Gunst L, Mader P (2007) Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agric Ecosyst Environ 118: 273-284.
75. Krey T, Maria C, Christel B, Ruppel S, Eichler-Löbermann B (2011) Interactive effects of plant growth-promoting rhizobacteria and organic fertilization on P nutrition of *Zea mays* L. and *Brassica napus* L. J Plant Nutr Soil Sci 174: 602-613.
76. Smith S, Smith A, Jakobsen I (2003) Mycorrhizal fungi can dominate phosphorus supply to plant irrespective of growth response. Plant Physiol 133: 16-20.
77. Lekberg Y, Koide RT (2005) Is plant performance limited by an abundance of arbuscular mycorrhiza fungi? A meta-analysis of studies published between 1988-2003. New Phytol 168: 189-2004.
78. Li JF, Zhang SQ, Huo P, Shi S, Miao YY (2013) Effect of phosphates solubilizing rhizobium and nitrogen fixing bacteria on growth of alfalfa seedlings under P and N deficient conditions. Pak J Bot 45: 1557-1562.
79. Bandara JM, Wijewardena HV, Bandara YM, Jayasooruya RG, Rajapaksha H (2011) Pollution of River Mahaweli and farmlands under irrigation by cadmium from agricultural inputs leading to a chronic renal failure epidemic among farmers in NCP, Sri Lanka. Environ Geochem Health 33: 439-453.
80. Mihelcic JR, Fry LM, Shaw R (2011) Global potential of phosphorus recovery from human urine and feces. Chemosphere 84: 832-839.
81. Heinonen-Tanski H, Wijk-Sijbesma CV (2005) Human excreta for plant production. Bioresour Technol 96: 403-411.
82. UNEP and UNCTAD (2008) Organic Agriculture and Food Security in Africa. United Nations, New York and Geneva.
83. Young SM, Pitawala A, Gunatilake J (2010) Fate of phosphate and nitrate in waters of an intensive agricultural area in the dry zone of Sri Lanka. Paddy Water Environ 8: 71-79.
84. Bashir J, Van Straaten P (2006) Potential of East African phosphate rock deposits in integrated nutrient management strategies. Anais da Academia Brasileira de Ciências 78: 781-790.

85. AmelIdris OA, Sirekhatim Ahmed H (2012) Phosphorous sorption capacity as guide for phosphorous availability of selected Sudanese soil series. Afr Crop J 20: 59-65.

86. Carey PL, Benge JR, Haynes RJ (2009) Comparison of soil quality and nutrient budgets between organic and conventional kiwifruit orchards. Agric Ecosyst Environ 132: 7-15.

87. Itchon GS, Holmer RJ, Tan MLB (2009) The public health safety of using human excreta from urine diverting toilets for agriculture: The Philippine experience. 34th WEDC International Conference, Addis Ababa, Ethiopia. Available at: http://wedc.lboro.ac.uk/resources/conference/34/Itchon_G_-_25.pdf