

## Support of Drainage for Management of Nitrogen Cycle in Africa

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### Abstract

Drainage engineering known to provide mere relief from excess surface water, water logging, rise in ground water table, and removal of accumulated toxic salts from the fields. However, since 1994 its scope was broadened and poised to cater functions of bringing social goods by enhancing food security and protection of environment. The continent Africa has the minimum area under irrigation so drainage has not been promoted in general, beyond the small areas under irrigation. The useful transformations of stages of nitrogen cycle occur under aerobic conditions. This study presents how good drainage will help bring aerobic condition. The study presents innovative technologies to enhance productivity of agriculture, grasslands and forest and reduce contribution of nitrous oxide. Provision of drainage on entire land uses has great potential in both irrigated and rainfed agriculture, natural or manmade forest and grasslands that will promote reduction of insect, pest and diseases in Africa. An innovative technology of auto drainage devised by author is to go long way in bringing drainage condition both under irrigated as well as the rainfed agriculture. This study while elaborating support of drainage in bringing management of nitrogen cycle depicts lack of appreciation by the professionals that limit application and cope in utilisation of potential of drainage. The study presented sufficient Justification for the change of names of existing departments of water engineering to production of professionals for execution and that for using the water related facilities for both engineering and agriculture disciplines of research and academic developments. Good scientific knowledge in the course curriculum should be broad based to bring food security and reduce global environmental problems of Greenhouse gases. Convergence of services for nitrogen and water use efficiency amply supports the need for the broadened curriculum of drainage for professional developments.

**Keywords:** Decomposition; Drainage engineering; Environment; Nitrogen cycle; Nitrous oxide; Productivity

### Introduction

Drainage, the activity of removal of excess water, from surface, in ponded or saturated, lowering of ground water table below the root zone, removal of salts accumulated in the root zone soil [1,2]. Because of large volume of water and salts etc, it involves engineering skill and activity to carryout work with convenience and feasibility. In Africa irrigated agriculture has been mere 5 percent [3,4]. Provision of drainage has been limited to such low hactarage of irrigated agriculture. The remaining 95% of land uses have been subjects of natural drainage and water logging and ponding, salinization and rise in ground water table causing large scale anaerobic decompositions to continue to go in their own pace. This means nitrogen cycle largely operated through the bad path and produced  $N_2O$  and nitrogen use efficiency remained far low. The drainage technology brings relief by modifying the process of anaerobic decomposition which causes denitrification and in turn production of nitrous oxide ( $N_2O$ ), one of the green house trace gases (GHGs) that depletes ozone layer.

Nitrogen is a primary nutrient essential for living organisms and development of primary productivity. Pastures, grassland, agriculture, and forestry land uses are the primary producers enabling browsers, the primary consumers in the ecosystem to produce secondary produces viz milk, meat, hides, dung, urine and energy etc. The nitrogen cycle (Figure 1) depicts transformation of N in various forms. The microbial transformations are organic nitrogen  $RNO_2$ , Ammonia  $NH_3$ , Ammonium  $NH_4$ , Nitrite  $NO_2$ , Nitrate  $NO_3$  Nitric acid  $NO$ , nitrous oxide  $N_2O$  and reformed nitrogen gas  $N_2$ , that goes back to the atmosphere.

The transformation of nitrogen into its many oxidation stages is key to productivity in the biosphere and highly dependent on the activities of a diverse assemblage of microorganisms such as bacteria, algae and fungi. Nitrogen fertilizer is expensive and losses can be detrimental to the environment. The health issues include respiratory ailments, heart disease and several cancers. In any situation all the phases of

decompositions and transformations continue simultaneously, of course on different organic wastes and so are the emission of nitrous oxide is continuous. The  $N_2O$ , important minor GHG is produced during the formation of nitrite  $NO_2$  (nitrification) and again during reformation of nitrite (denitrification) [4,5]. The flux of release will vary with time and situation of the material under decomposition.

The situation of surrounding environment and water interactions brings good and bad transformation stages in any decomposition process. The decomposition under aerobic condition is different from that under anaerobic condition. The decomposers work differently and produce lot of environmental hazards. The decomposition forms the detritus chains and decomposers such as bacteria, algae, and fungi play their dominant roles. The insects such as flies and mosquitoes, and fungus thrive on the detritus food chain and produce nuisance for the environment. These detritus consumer become food chain for creeping, crawling and flying insects and further add to the problem of environmental concern. The example of such detritus food chain consumers and secondary consumers those bring bad environmental impacts such as malaria, Tse Tse fly responsible for yellow fever, known in Africa. Thus, if by any means, the decomposition process can be controlled, it will improve the environmental quality. Yadav [6] established that provision of good drainage will bring large scale transformation of the decomposition process from anaerobic to aerobic. Drainage which used to be taken as mere rectifier of bad developments of misdeeds in the irrigated agriculture such as water ponding, water logging, rise in ground water table and salinization,

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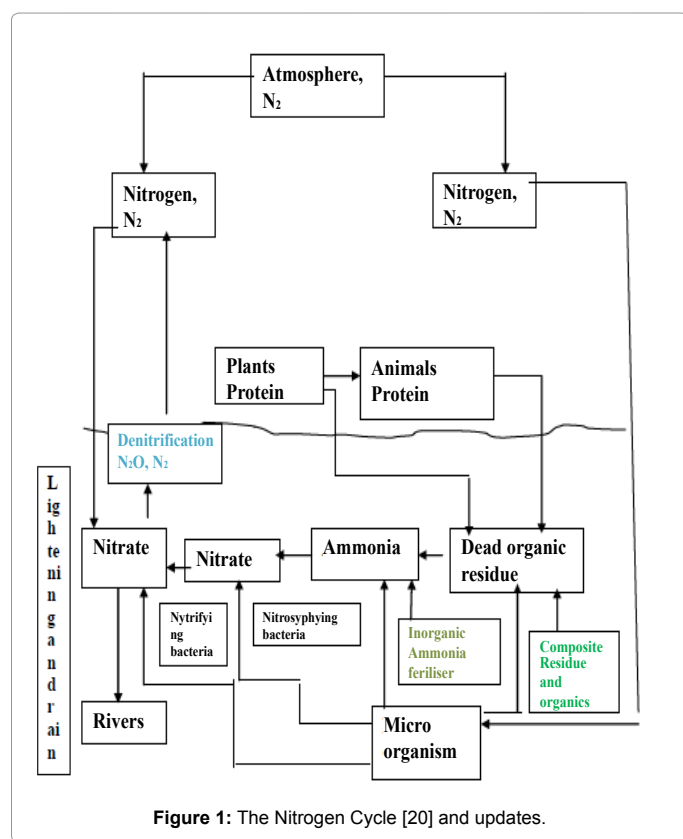


Figure 1: The Nitrogen Cycle [20] and updates.

alkalinisation and removal of salts by leaching, will play significant role in improving environmental condition of all land forms and land uses. Thus, implication of the nitrogen cycle has to be looked at in association with drainage (aerobic condition) and no drainage (anaerobic condition). The misdeeds in nitrogen cycle caused dis balance and brought several undesirable results of local as well as global domain. Clear understanding of the nitrogen cycle opens avenues for enhancing productivity and development of entrepreneurship to generate employment and become people supported environment protective self driven process. This automation will enable enhance stabilised sustainable productivity and protection of environment for the present and posterity.

The agriculture, forest and grasslands remained as emitter of  $N_2O$  gas. As the domain of drainage has enlarged since 1994 [7] to cover the society and environment, its applicability has broadened. Thus, drainage has become a saviour of enhancement of productivity and environment [6]. It has wider applicability in vast land stretch in Africa having grassland, forest, rainfed agriculture and large cattle and wild animal population as depicted by presence of many insect, diseases, and low productivity. The innovative nature agriculture and allied technology can be demonstrated to become saviour for Africa too. Thus, objective of this study was to present aspects where drainage has prospect of managing nitrogen cycle for tackling productivity and environmental problems in Africa. These technologies will find better appreciation if the academic teaching and research endeavours are rightly supplemented and complemented to understand the natural process. Thus, this study was carried out to make beneficial use of Nitrogen cycle to enhance productivity and protect environment.

The manuscript comprises after introduction materials and method; the nitrogen cycle, nitrogen cycle in soil, strategy of management of

nitrogen cycle, and technology capsule. The results section comprises subheads; Broadened scope of drainage to cover aspects of environment and society, Biological nitrogen fixation in different land uses are viz agriculture under sub head of intra row banding, and inter cropping, nitrogen fixation in grassland and pasture, with annual leguminous crops, that by perennial crops, and innovative cropping practice in the green fodder fields and N for forestry again with annual and with perennial leguminous crops. Reformation of cropping and agro forestry practices, Innovative universally applicable green technology -Racy nature agriculture-racy combo, Sanitary, sewage and waste water treatment, Industrial process enabling transfer from N excess to N deficit sites and Convergence of other sciences for promoting activities of nitrogen cycle are included. Following results under these sub heads, is the SWOT analyses, ie strength, weakness, opportunity and threat. The action initiatives and conclusion and research needs are described. Thus, the manuscript presents a unique scenario of subject of management of nitrogen cycle in Africa trough the support of drainage engineering.

## Materials and Method

### The nitrogen cycle

Nitrous oxide ( $N_2O$ ) is third trace gas in the order of dominance of GHGs. Anthropogenic ally induced mainly originates from soil and agricultural activities. GHG- $N_2O$  is also responsible for ozone depletion. The nitrogen containing compositions viz. ammonium, nitrite and nitrate resulting in reaction of nitrogen with water due to hydrolysis are the radicals [8]. Chemistry related to nitrogen N cycle in the troposphere, terrestrial, hydro-ecosystems and ground water etc is highly researched upon science. There are four main ways by which nitrogen can naturally be made available for use in ecosystems. Firstly, by plants themselves, when bacteria, most notably those associated with leguminous (bean or pea) plants, trap nitrogen from the air and combine it with hydrogen to form ammonia ( $NH_3$ ). The second way is by thunder and rains that bring down nitrogen in the nitrate form (Figure 1). Third way is the decomposition of plants and animals that release organic nitrogen in to the soil as ammonia. Fourth way of nitrogen build up in the soil is by addition of nitrogenous fertilisers. Bacteria and fungi in the soil then convert this ammonia into ammonium ( $NH_4$ ), which can be used by plants. Further, chemical reactions by nitrosomonas bacteria transform the  $NH_4$  into nitrite  $-NO_2^-$ . The nitrobacters then convert the nitrite  $NO_2^-$  to  $NO_3^-$  nitrate. This nitrate is very soluble and used by plants. The cycle is concluded when denitrifying bacteria in soil convert nitrates in anaerobic soil to either nitrogen gas ( $N_2$ ) or nitrous oxide ( $N_2O$ ) and these gasses then return to the atmosphere. In order to reach at scientific interventions in the nitrogen cycle process knowledge would be necessary. Hence the processes are included in the following section.

### The Nitrogen cycle in soil

The Nitrogen Cycle in soils is a very dynamic process and has great practical implications on modern agriculture and protection of nitrate pollution of water courses and pollution of air by nitrous oxide. Most plants can absorb nitrogen in both the nitrate and ammonium forms. However, ammonium-N is rapidly nitrified to nitrate-N which is the main form absorbed by agricultural crops. Nitrous oxide can be produced during nitrification, denitrification, dissimilatory reduction of  $NO_3^-$  to  $NH_4^+$  and chemo-denitrification. Since soils are a mosaic of aerobic and anaerobic zones, it is likely that multiple processes are contributing simultaneously to  $N_2O$  production in a soil profile. The

$N_2O$  produced by all processes may mix to form one pool before being reduced to  $N_2$  by denitrification.

Understanding the N Cycle is important in managing the nitrogen needs of the future. The N from atmosphere by the action of microbial fixation is well known since ancient time. During the primitive time many crops were sown as mixed crop by broadcasting. The association of nitrogen fixing crop and nitrogen using crops were closer. Application of scientific method of line sowing and mechanization kept both the types of nitrogen fixing and fixed nitrogen using crops at distance, thereby weakening association by the distance between sole lines of mixed crops/intercrops. Thus, the transfer of fixed organic  $RNO_2$  got reduced.

**Nitrogen transformation by bacteria:** Nitrogen cycle depicts entire domain of nitrogen circulation. Bacterial transformation is main route and the other route being the thundering and sparking as depicted in (Figure 1). The bacterial transformation is by following four reactions [9] is given in the following.

#### Nitrogen Fixation by *Rhizobium*

The atmospheric  $N_2$  is fixed as organic nitrogen.



**Nitrification is the process of *nitrosomonas* and *nitrobacter* bacteria**



#### Nitrate reduction



**Denitrification which involves the reduction of  $NO_3^-$  and  $NO_3^-$  to  $NO_2^-$  followed by recycling of  $N_2$  to the atmosphere**



It is evident from the five reactions that transformations of nitrogen

in the nitrogen cycle require presence of oxygen which can be brought in by provision of good drainage. This fact implicates that aerobic condition can be brought in all land uses which comprise land terrain, crops/vegetation. The eq (5) reveals that reaction under anaerobic condition brought about by water logging forms denitrification, which will get transformed to release nitrous oxide, a green house gas.

#### Strategy of management of Nitrogen cycle

Management of any aspect of things, behaviour and situation requires certain strategy with a view to bring change. In case of the nitrogen cycle where all process are aimed at to function under aerobic reactions, the entire cycle is discretised and each segment is manoeuvred to function in the desired manner.

**Discretisation of the nitrogen cycle:** The nitrogen cycle discretised in various functions of stages are listed in (Table 1). The steps are reduced to single function in the cycle for better understanding and isolation of aspects for management. The discretised sub sections of nitrogen cycle are to be looked at so that it functions in its best possible manner.

**Strategy of management:** Strategy was to devise ways and means so that nitrogen fixation is the maximum by the nitrogen fixing bacteria. Further, strategy was to maintain, as far as possible, the aerobic condition so that the denitrification is the minimum. Incorporation of crops that nitrogen fixing crops remain in close association and for long duration crop is able to utilise the biologically fixed nitrogen to the maximum extent possible. The fact that presence of sulphate in low concentration enhances nitrogen and water use efficiency demands chartering of sulphur cycle in the crop to function by creating decomposition of cellulose in sulphate which occurs during aerobic decomposition. Thus, it becomes scientific need of addition of organic cellulose to decompose under aerobic condition and produce sulphate. The sulphate is good remedy of overcoming of salinity is one of the benefits of drainage or management of saline soil and water. Any agricultural system where water and crops are to have good interactive actions, drainage becomes a precondition. Thus, management of nitrogen cycle is aimed bring good effect on yield and reduce imbalance

Stages	Type of transformations	From	To	Problems	Needed engineering improvements
I	BNF	Nitrogen gas $N_2$	Organic nitrogen $RNO_2$	By microbial nodulation	Enhancing efficiency of fixation
		$R NH_2$	Ammonia $NH_3$	By natural process	-
II	Ammonification	$NH_3$	Ammonium $NH_4$	Receptacle for quick acceptance and mixing	Restrict escape from the site by modular transformation of decay process.
	Mineralization	$NH_3$	$NH_4$	Conserving N during intervening period	By repeated ploughing
III	Nitrification	$NH_4$	Nitrite $NO_2$	By nitrosifying bacteria	Provide aerobic condition
	Volatisation	$NH_3$	Capture and mixing	It is loss of soil stored N	Quick incorporation by ploughing
IV	Nitrification	$NO_2$	$NO_3^-$	Nitrate leaching is problem	Avoidance of nitrate leaching by
	Natural fall from atmosphere	Thunder, Storm and rain	$NO_3$		Conservation by arresting in soil root zone
V	Denitrification	$NO_2$	Nitric acid $NO$	Loss as volatile ammonia	Arrest $N_2O$ at critical peak times of release by biochar
	Urea addition	$CO NH_4$	From industrial sources		Quick incorporation and split doze application
VI	Immobilisation	$NH_4$ and/ or $NH_3$	Organic $RNH_2$	-	Building N in the intervening season.
VII	Denitrification	$NO_3$	Nitrous oxide, $N_2O$	GHG emission	Reduce quantum of balanced Nitrate that may get under denitrification.
		$N_2O$	$N_2$	Nitrogen gas back to atmosphere	Arrest $N_2O$
Combo	Racy nature agriculture	Accommodates all stages and encompass all processes to reduce adverse effects and combine integrated nutrient management.			

**Table 1:** Transformations in the Nitrogen cycles, gain and loss and effective measures to enhance utility and reduced GHG burdens.

require integral support of drainage. That means nitrogen cycle can not be managed to bring good function without support of drainage. Any academic documentation on land water management should give cognizance to this effect. These facts support the importance of drainage beyond the irrigated agriculture. In the rainfed areas also drainage will help enhance productivity even without requirement of excess water, high ground water table or excess of salt needing removal by washing or leaching. For the management of various sub components in (Table 1), the measures should eliminate release of nitrous oxide, nitric acid and nitrogen oxide from the cycle. These harmful gases release reducing measures are situational with respect to utilisation of  $\text{NH}_4$  and  $\text{NO}_3$  from the agriculture and plantations. It is necessary to have minimum reserve balance, hence the quantum of release of the nitrogen based harmful gases will be the minimum. Presence of well drained condition is basic for the aforesaid situation to develop that will eliminate release of the GHGs.

Further, the N load in waste water should be low so as to eliminate the eutrophication to develop in the water bodies. The different approaches and strategies are necessary to bring down the net result of balance in N cycle. The excessive N under any situation will result in dis balance that will produce bad effect on environment and food commodity.

### The technology module

From the fore mentioned facts it is clear that for management of nitrogen cycle to bring beneficial effects under any plant production system the aerobic condition has to be maintained by providing good drainage provision of the land. The nitrogen cycle should always remain and function under aerobic condition. Nitrogen fixations should continue to function all the time so that other plants are in position to make use during the company of the companion crop as well as after the cessation of the growth of short duration crop, as well. This situation will keep the emission of nitrous oxide in low magnitude. Vegetation will be able to extract nitrogen to the maximum extent. During the period of no crop in the fields, nitrogen present in the soil should be mineralised and immobilised to eliminate the loss from the root zone. With these aspects the new technologies were devised which are presented under different subheads in the results.

## Results

### Broadened scope of drainage

**Drainage for protection of environment and welfare of society:** Earlier belief was that drainage is required as an accompanying component in irrigated field to remove water ponding, remove water logging, control rise in the ground water table and control salinization and removal of salts from the root zones by leaching. But, since the year 1994 the scope of drainage has been broadened to cover aspects related to society and environment [7]. However, this realisation came late. Innovative application of scientific facts devised by the author enables one to realise that, as a phenomena, excess water triggers anaerobic decomposition which leads to emission of green house gases namely, methane and nitrous oxide. Thus, water ponding, water logging and salinisation do occur in the lands under the rainfed situation as well. Thus, drainage becomes the need of rainfed land under various land uses such as agriculture, grasslands and forests etc. Application of drainage for creating aerobic condition should be global activity for enhancing productivity and enhancement of environment. This broadened scope of drainage emphasised that tropical countries such as Brazil and Asia with intense rainfall during rainy season, which

bring intensive water ponding, water logging and rise in water table contribute more GHG percentage contribution of GHG build up in the environment. In the temperate regions receiving winter rainfall, the anaerobic condition might exist but the due to low temperature the emission of GHGs such as methane and the nitrous oxide remains low. Thus, contribution of agricultural GHG is high in the tropics and low in the temperate region. It means that the need of drainage to account for environment protection is more than that for irrigated agriculture. Hence, the domain of drainage in consideration of environmental aspect i.e. emission of GHG is more broadened. This chemical phenomenon has existed all the time, but late realisation came due to lack of perception of application of environmental sciences and environmental engineering principles. The late appraisal of application of process based knowledge lead to damage to environment; set back of GHGs and accumulation and cause of global warming. This fact was sufficiently substantiated by [10]. Thus, it is evidently clear that need of drainage exists in the global land percentage far more than percentage of land under agriculture. In Africa land under irrigated agriculture is mere 5%, but drainage requirement is to cover almost all land of the continent i.e. 100%.

**Drainage in Ethiopia- a Highland:** Ethiopia is a high land country at altitude ranging from 2000-3000 m, maintaining about one third height of troposphere (11 km). That means Ethiopian climate will depict climatic feature of stratosphere above mean sea level at height of 5-6 km. Natural green house gases contributions are  $\text{H}_2\text{O}$  vapour (62)  $\text{CO}_2$  (22),  $\text{O}_3$  (7),  $\text{N}_2\text{O}$  (4) and  $\text{CH}_4$  (4) percent. Likewise, contribution of anthropogenic green house gases are  $\text{CO}_2$  (61),  $\text{CH}_4$  (15), CFC (11),  $\text{N}_2\text{O}$  (4) and ozone  $\text{O}_3$  (unknown) [3]. The ultraviolet radiation is intensive as sky is largely clear of atmospheric pollutants. Contribution of methane from low land rice (lack of rice cultivation) fields is very low, but it can be compensated by many lakes and large cattle population. Since the country is not intensively industrialised, contribution to green house gases would be largely from grasses, upland agriculture, rainfed grains namely wheat, sorghum, pearl millet and *teff* (a famous cereal produce) etc. Due to low temperature contribution green house gas through CFC is also to be the minimum because of minimum use of fridges and air conditioners. However, specific data on these factors are not available.

Because of altitude, the problem of drainage is not visible, but there are marshy lands stretches close to the water bodies such as lakes and rivers, River Nile originates from the Ethiopian highlands and traverses long route. Thus, there does exist local problem of drainage. These local problems of drainage at far distance do not come to attention of the local gentry. There seems to be no example of built drainage as the irrigated area itself is little and all soil salts get washed by the runoff to join the River Nile upland branches.

Now the role drainage has to be looked from enhancing productivity of grass lands and upland agriculture. Management of nitrogen cycle for enhancing productivity is very relevant. The cereal crops when grown with intra row banding of leguminous crops [11] or as intercrops in fine grain cereals, it will make sure way of nitrogen fixation in the field to enhance yield and reduce  $\text{N}_2\text{O}$  emission [9]. The nitrogen content of grasses and cereal food grains will increase that will improve health of animals and people. General health of cattle in Bale Robe, (South Western) Ethiopia, a grassland valley with good rainfall, is good and animals keep heavy weight due to availability of ample grasses to graze.

The implications of nitrogen cycle have further to be seen. When animals are adding nitrogen by way of dung and urine the urea and



ammonia are added and in due course of decomposition will encompass ammonification, nitrification, to convert ammonium to nitrite and nitrate and then denitrification to again convert nitrate to nitric oxide and nitrous oxide. Thus, there is likely build up of nitrous oxide from the grass land in the wetland to the atmosphere and nitrate movement to rivers. The nitrate content of water of the river Nile is high. Similarly the nitrate poisoning may happen. On the other hand movement of nitrogen and phosphorus rich runoff may cause profuse weed infestation and decomposition of cellulose under anaerobic condition (in deep lakes water) will make ground water acidic. Therefore, as a security measure, the wetlands what so ever may be, application of drainage is warranted in Ethiopian highland in particular and any high land in general.

**Drainage need in the low land countries:** The low lands are more susceptible to water logging due to physiographic setting to retain more excess water for longer duration. The gravity of drainage is going to increase as a result of increase in the extremes and frequency of its occurrence during the ongoing phenomena of global warming and climate change.. The utility and role of drainage will be gaining still greater importance under the lowland condition than any highland situation. In the lowland situation sub surface drainage will be additional burden towards bringing the aerobic condition.

### Biological nitrogen fixation in different land uses

The results of high esteem value with regard to management of nitrogen cycle are presented under different sub heads of phases (Table 1) as accomplished in the present study listed in Table 2.

**Agriculture:** In order to avoid losses due to volatisation the organic manure as well as the inorganic nitrogen fertiliser, the intervening period free from crops or when the nitrogen extraction is low during initial stage of crop developments, the field should be as far as possible, kept tilled or inter tilled, as may be the case, to keep process of

mineralisation and immobilisation to work. The nitrogen present in the fields will be saved from the losses by nitrification and denitrification. This aspect of tillage requirement in reducing the GHGs was covered in detail in study [10], that indicated need of tillage in winter season cropping in lieu of zero tillage. The zero tillage is justified to conserve soil and nutrient losses by surface runoff, but no thought was given to the reduction of emission of GHG nitrous oxide.

**Cyno bacterial leguminous crop intra-row banding:** The situation of crop cultivation with tillage facilitated mineralisation and immobilization in the soil hence build-up of N in such fields. Since the process is continuous, devising ways and means of N fixation of crop by the leguminous crop in the closest vicinity of the user crop will enable enhanced N transfer efficiency [11] devised an innovative method of leguminous crop banding right in the lines of cereals or oil seeds. The referred to study established that sowing of leguminous crops such as green gram and lentil @50% of normal seed rate right in the line of cereals and oilseeds produced contrasting visible effect of N fixation. The protein content was highest in this banding. Further, efficiency of N fixation and transfer can be enhanced by microbial inoculation of the legumes N before sowing [12].

**Inter cropping:** Inter cropping of leguminous crop in pure band of cereals and oil seed has been known practice worldwide. Researches [11] have established that intercropping of short duration legume crop in the long duration legume crop also extracts advantage of nitrogen fixation. Thus, it became a practice of growing green gram or black gram in pigeon pea and castor. Thus, natural process of biological nitrogen fixation has been extended to enhance yield of legume with another legume. It needs to extend this nitrogen fixing characteristics of leguminous crops for roots and tuber crops such as sweet potato and potato and vegetable production. In addition to enhancement in yield, the quality of produce will also be better than that without nitrogen fixing crops, as prevalent worldwide.

Agro-ecosystems	Innovative technology	Resulting benefits after implementation
<b>Biological Nitrogen fixation BNF</b>		
<b>Agriculture</b>	Intra row banding	Fix nitrogen in cereal and oilseeds by intra row banding of inoculated leguminous crop.
	Inter cropping	Carry out Annual legume in another annual legume of longer growing period
	Racy nature agriculture	Both the two systems can be applied in the new green technology of racy nature agriculture, described in the following part of the results.
<b>Grasslands</b>	Legume intercropping	Intercropping of legume in pasture transfers about 50% of the nitrogen fixed bay leguminous crops
	Annual legume	Annual legume in grassland
	Perennial legume	Perennial legume in grassland
<b>Forest</b>	Understory plantation of legumes	Annual legume in tree basin
	Perennial legume inter tree plantation	Perennial legume in tree basin.
<b>Green technology combo</b>		
All terrestrial ecosystems	Racy nature agriculture	It encompasses all needed good effect for green technology for enhancing food productivity and protection of environment.
<b>Reduction of N and P in waste water disposal</b>		
<b>Waste Water disposal</b>	Grow Reeds to conserve biodiversity by saving wood and forest.	Protection from eutrophication. Enhancement in ecosystem services.
<b>Transfer from N excess to N deficit places</b>		
<b>Industrial N transfer technology</b>	Preparation of Diammonium sulphophosphate (DASP)	The local excess n resources used to prepare DASP which will be transferable from N excess to N deficit places
<b>Convergence of other sciences</b>		
<b>Agriculture, grassland and water resources</b>	Biological control for eradication of aphids and other secondary detritus consumer Biological control of malaria	By promoting parasitic action of feeding wasp on aphids
		Inactivation of mosquito larva by spreading mustard seeds.

**Table 2:** Innovative technologies for management of nitrogen cycle.

## Nitrogen fixation in the grassland and pastures

**Provision of drainage:** The grass and pasture land are naturally drained and at places there may be pot holes. Since there is no use of mechanisation, the grass and pasture lands should be drained by providing random field ditches and water led to suitable site where it can be stored for further use by the animals.

**Incorporation of Annual legume bands at regular interval:** In the established grasslands and forest annual legume should be sown that will fix the nitrogen and keep the grasses active in utilising the nitrate by the plants, to eliminate losses in runoff water. Nitrate and phosphorus movement in runoff cause eutrophication, a process undesirable for the water bodies. Leguminous crop will solubilise the phosphorus added by animal dung and urine. The role of leguminous crop in phosphate solubilisation is available in research presented by [13]. The production of organic acid is related to phosphate solubilisation of  $\text{Ca HPO}_4$  and  $\text{Fe PO}_4 \cdot 2\text{H}_2\text{O}$ . Thus, in addition to nitrogen fixation some effect of phosphate solubilisation is brought in the rangelands and pastures. The combined effect will be that reduction of release of nitrous oxide to the atmosphere. The cultivation in the grass and pasture will bring some effect of sulphur cycle and enhance grass yield and its palatability for the animals. Since the grasslands and pastures are largely not externally supplemented with fertilisers, incorporation of legume will supplement them by biological nitrogen fixation.

**Incorporation of Perennial legume in rangelands and pastures:** The extensive root system and permanent ground cover tend to provide greater nutrient retention, erosion reduction and carbon sequestration relative to annual plant covers [14]. A central tenet of ecological theory is that increasing biodiversity increases the stability of ecosystem properties, such as net primary productivity (NPP). The species composition can shift in response to environmental changes, buffering the sensitivities of species to environmental changes. The transfer of N from the legume to the grasses facilitates grass NPP in grass legume mixture in grasslands where N is limiting. Therefore, one potential benefits of grass legume mixture is their ability to optimise N retention and supply across a range of environmental condition. Red clover is known as one perennial legume suitable as mixture in the grasslands and pastures. In this study way as how to integrate the grass land and the red clover and bring nitrogen fixation in the grassland is new addition to the existing knowledge of nitrogen cycle management. The band of red clover at interval can be sown to enhance N land equivalent ratio (NLER), and land equivalent ratio (LER). Red clover is a tap root species while grasses have fibrous root system, their association increases total biomass, particularly, root biomass, resulting in greater soil C and N accumulation relative to corresponding monoculture. In order to increase this complementary association one or two rows of red clover should be banded in the entire grasslands. Studies [11] indicated that incorporation of perennial legume in grasses fixed 15-37 kg N/ha in soil and apparent transfer of N to the grasses was 8-16 kg/ha (almost 50%). However, it needs selecting suitable local perennial legumes to be inter sown in the grasslands and pastures. Grass legume mixture improve synchrony through slower decomposition of litter with higher C:N resulting in short term N immobilisation and retention in microbial biomass and soil organic matter pool. These results highlight the need to apply ecological theories to research in using plant functional diversity to enhance ecosystem services in ecosystems. It is utmost necessary to remember that irrigation and drainage systems are created and management to bring sustainable productivity and that can not be possible without application of nitrogen. Thus, management of nitrogen is essential function involved in drainage. This is covered in

the broadened scope of drainage.

## New cropping pattern for cultivated green fodder for animals

For animals especially dairy cattle green fodder are cultivated in some fields depending on the need of the cattle to be fed. The green fodders are harvested from one side continuously and irrigated. The fields get cultured and the fodder sown once is kept for many year after year. There is strong build up of nitrogen in such fields. In order to create biodiversity and utilise the nitrogen reserve sowing in bands other crops such vegetable green vegetables, leguminous and non leguminous crops which require high doses of nitrogen. The reserve of nitrogen will be utilised and scope for denitrification will get reduced. Thus, it will be new aspect of capitalising the N equivalent and LER of the field under fodder crops. This new practice will attract dairy owners and farmers around city make fodder cultivation to sell the green fodder and generate their income by cultivating vegetables. The net result will be capitalising that nitrogen existing at some sites. It will be new resource from ecosystem services involving concept of plant biodiversity.

**Incorporation of annual and perennial legumes in forest:** Sowing of leguminous annual and perennial crops in establishes forest enables nitrogen cycle to continue to function in fixation, nitrification, immobilisation, and volatilization and denitrification, whereby useful products are produced. This strategy will enable crop/plants use it the field. The scientific facts and experiences enable establishment of the fact that lead to development of practices that convenes aerobic condition under the crop bed alike appropriate technology. The reduction in denitrification was found to reduce  $\text{N}_2\text{O}$  emission [15]. N losses during the decomposition period could be controlled by synchronising the culture in legume based system. In permanent legume plantations, the availability of N to the forest species will be for longer duration than that for annual crops.

**Reformation of cropping and agro forestry practices:** Cropping of legume in legume of different growth durations e.g. pigeon pea and green gram, sowing of leguminous vegetable such as ladies finger in fodder clover /alfafa or *barseem*, cultivation of legumes in the pastures and plantation of legumes in lieu of sole crop enhance land equivalent ratio (LER) by enhancing nitrification and use by the crops leaving low N reserve to undergoes denitrification leading to  $\text{N}_2\text{O}$  emissions. Plantation of perennial legume surrounding the trees will be innovative way of reducing nitrous oxide. This will enhance scope of forest and trees in reducing global warming by adding new dimension of controlling nitrous oxide.

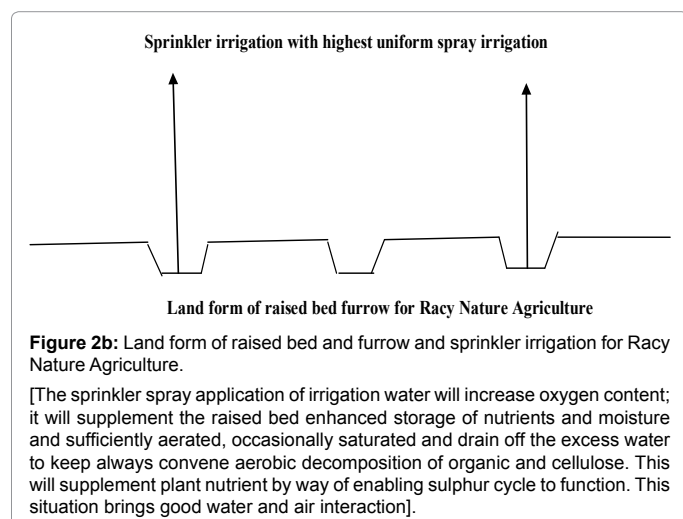
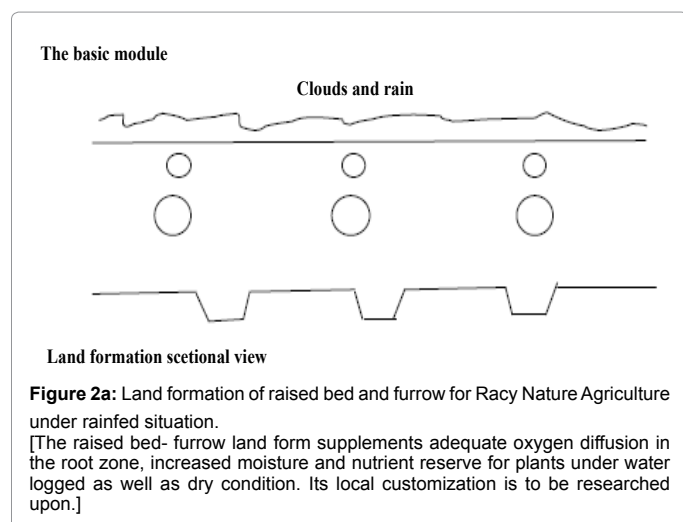
The most important for life the nitrogen use and nitrogen cycle are vitiated by human efforts to fulfil present and future needs of sustainable food security and environments. Earlier practices had focus to enhance yield but no emphasis on environment protections that generated problems of environment, disruption of ecosystem services, price rise and socio-political unrest in many countries, health hazards, resources constraints etc leading to worry for the world at large [9]. The policies and issues formulations were focussing problems and hoping emergence of scientific technologies to alleviate this global problem related to N use. The scientific innovative developments presented for N and all resources by development of racy nature agriculture, which has capability to overcome all misdeeds in agricultural practices and work as universally applicable panacea green technology for agriculture and environment.

Developments of  $\text{N}_2\text{O}$  induced pollution control measures in to entrepreneurship and business attract peoples' participation

to undertake difficult jobs in feasible and easy way for application. Example cases of nitrogen fertiliser plants, Ireland and northern European countries facing misdeeds of vitiations of nitrogen cycle can be easily alleviated by application of technologies developed in this study. Thus, developments go long way in scrapping global worry concerning future sustainable food security and protection of environment. The racy nature agriculture has raised niche of low sounding pro-genetic world opinions to raise harvest index of crops by land, water and crop husbandry management practices. Many terrifying estimates and foreseen dangers will get slowly diminished by application of technologies developed in this study.

**The auto drainage technology -Racy nature agriculture-racy combo:** The racy nature agriculture which has acquired status of sun technology [16] meaning thereby a green innovative universally applicable technology which suitable for all ecological reasons, all soils, all crops, all cropping patterns and for both irrigated and rain-fed agriculture be it under large scale or small scale peri-urban as well as control environment agriculture. The details of the technology are available in other research articles published by the author(s). The (Figure 2) gives self explanatory depiction of the technology particularly the land forms under the field.

The technology capsule special component of nutrient management



by primary and secondary natural resources that develop by chemical reactions [11,16,17]. The racy nature agriculture promotes productivity with existing situation and conserves resources for posterity. The technology has capacity to endure adverse impacts of droughts and floods that are likely to become severe due to global warming and climate change in future. The racy nature agriculture focuses and meets world over challenge in the use of natural and fixed resources for agriculture and environment conservation, which were not found in the existing scientific ventures.

Local optimizations of the technology will take care of customization accuracy to account for existing roles of agro-eco-regions, man- machine and socio economic status. The alteration of decomposition process, arrest of GHG gases and heavy metals will reduce GHG s load in atmosphere, reduce load of heavy metals that will reduce global warming and avert climate change. This aspect, totally new application in agriculture will produce food better than so called organic food. Thus, in lieu of some high profile accessible limited organic food, a better quality and accessible to all surpassed solution for all is developed. Further scope for refinements for the second generation research has opened so as to bring technology refinement. The lag in the situation and makeup in the shortfall in present day agriculture can be made by recognition of motivation by oriental saying i.e. late is better than never. Therefore, it requires to makeup of mind, without further delay, and come in action for implementation of the racy nature agriculture. The implementation will revamp all to join in mission to create Manson of global sustainable food sufficiency for present and posterity.

**Sanitary, sewage and waste water treatment:** Treatment of sewage, waste water and solid waste has been largely inadequate that has been causing problem due to excess nitrogen in its surrounding. One glaring example of excess nitrogen imbalance in the nitrogen cycle is the Ire Land. Most of Ise Lands have become oxygen deficient due to excess growth of water planktons which consume oxygen for respiration. Contrary to this, is a situation of Nitrogen deficiency in the sub Saharan region where excessive withdrawal of N through the crop is causing deficiency in the soil.

The waste water treatments are carried out up to secondary treatments where carbon is removed but nitrogen and Phosphorus rich content in waste water are released in the lower places, usually lakes, rivers and even sea. The excessive N and P result in eutrophication in the water bodies, leading to slow death water bodies. On one hand eutrophication impairs water quality and fish kills and on the other extinction of water resources, thus surrounding to bear adverse impact of drought. Some people believe denitrification as promoter of Nitrate conversion in to atmosphere instead of discharging the nitrate to the water bodies in the process of disposal. The land treatment of the N and P rich waste water by land application is known practice but that too is not being adopted as a popular practice. Utilisation of the N and P waste water through specially prepared bed and planting reed is simple and effective way of containing excessive nitrogen thus, reducing cause of building excessive N build-up. The fast renewable canes become source of alternative wood for manufacturing of house hold furniture and conserving biodiversity. The collect toxic materials will find use in preparation of bio bricks and bio char for further use in controlling reducing bioavailability of heavy metals and producing quality food. Thus, the problem can be converted as an opportunity for making use of the resources.

### Industrial process enabling transfer from N excess to N deficit sites

A new formulation of Diammonium sulphophosphate is designed as green DASP which will use nutrient recovered from waste water streams and adding cellulose and their decomposition in aerobic decomposition. The product can be physically transferable from N excess to N deficit place to make balance in N cycle.

### Convergence of other sciences for promoting activities of nitrogen cycle

**Crop protection from aphids:** There are many scientific areas where their contributions are needed either to promote or to protect nitrogen cycle activities bringing inimical effects. For example, when water is conserved in the water bodies in the grasslands and forest, malaria becomes a normal problems. Simple biological control of malaria spread suggested by [18] is spread of mustard seed that gets attached to the larva of malaria at the water surface and sinks in water where the larva do not further grow and die. Thus, this or similar material can be used for controlling spread of diseases of animals in the African grasslands and parasitism on these animals reduced.

### Harnessing biological nitrogen from the bird droppings

Bird droppings (known as guano) [18,19], contain high amount of nitrogen. The birds collectively sit and wait for long hours in search of their feed of small fish on the bank of rivers and on the boulders existing in the river bed having elevation more than the flow depths. These bird droppings when get washed away and accumulate in the water bodies cause eutrophication. The nitrogen is one of the major nutrients for the plants. The profuse growth of water hyacinth absorbs oxygen present in the water that leads of fish kill and deterioration in the water quality. This nitrogen can be manoeuvred by the application of nitrogen cycle to enhance productivity of crops. Therefore, whatever quantity of nitrogen that gets mixed up in the long stretch of rivers and brings bad effect to the quality of water on can be manoeuvred to eliminate the bad effect on one hand and produce useful good effect on the enhancement of productivity of nitrogen and water, on the other.

The collection of the bird droppings can be easily carried out from the trees where the birds sit for their night stay. Suitable litter or plastic sheets can be spread to collect the droppings, which can be replaced by the new ones at certain intervals at convenience say, 15 to 30 days. The collection of the bird droppings along strategic points (where bird cluster along the bank) can be done by erecting bird sitting stands/ raft for sitting of birds. The stands equipped with provision of collecting tray type channel as an when it is dropped or when the accumulated droppings get washed during rains in a jerry can attached to it. Further, in the river reaches of boulder zones, birds sit on boulder extruding above water surface and keep waiting for the fish for their feed. The protruding stones on which birds sit can be covered with a plastic cap with bottom edge formed as channel and having provision of a collection bottle to collect the washed down droppings as and when rain or mist occur. This cap and collection bottles can be again changed at intervals. Thus, the rare natural resource which produces undesirable effects to the water resources can be augmented to produce beneficial effects.

### Discussion

From the reactions that occur in transforming the nitrogen cycle, it is clear that drainage is utmost necessary to bring the aerobic condition that implicates need of drainage in Africa. The study has devised

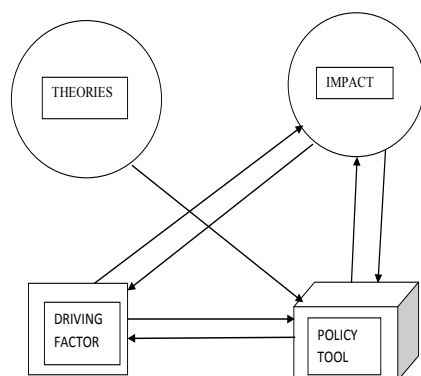
innovative management of nitrogen cycle for enhancing productivity and protection of environment. The new crops and cropping managements were devised based on innovative application of scientific facts of nitrogen cycle, and sulphur cycle. Since these concepts are new it will require producing data that will show the degree of effectiveness of application. In this study innovative application of the scientific facts has established the correct approach and direction of research work. It remains application and customisation of universal technology and establishment of its efficacy, and finding the shortfall, which can be made up by correction under the refinements.

The broadened scope of drainage still had not been realised by the drainage engineers as they failed to appreciate the role that drainage can play in bringing productivity and protecting the environment. The scope of drainage is limited for removal of excess water, lowering of ground water table and removal of excess salts etc. The conservation of drainage water for re use to reduce water stress due to water shortages, management of nitrogen and sulphur and waste products, reduction of eutrophication etc are not coming to the minds of drainage functionaries. The research endeavours remain limited to conducting conventional field experiments and monitoring the response to the enhancement in yield only. The extended role of drainage on protection of environment and welfare of the society is still not coming to the minds of drainage engineers. These aspects suffer lack of appreciation of the role that good drainage can play. The lack of appreciation culminated in pointing out the aspects towards more elaboration, and conventional field experimental results. The innovative concept and developments brought out in this study still need more appreciation and adopt to derive benefit from drainage. These aspects suffer set back of lack of appreciation due to unawareness of the existence on new concepts of the aspects presented in the article. It requires redesign of course curriculum of water resources facility creating professionals and the users of the facility. These aspects are dealt with in detail in authors other publication [17]. This study had already substantiated that drainage engineering is the best water resources engineering, because of its cost effectiveness, no risk of over drainage by any means, easily applicable to varied problems and field conditions.

In the present study importance of drainage in enhancing productivity and protection environment by reducing the emission of GHGs are brought in with sufficient justifications. The auto drainage technology will eliminate water logging, reduce salts and reduce adverse effect of rise in water table. These aspects are different and new from the earlier functions of drainage. Since these are new researches of the author, various references cited in the text are unique. As there have been lack of support of such references in the existing literature, large number of publications cited by the author is in support of innovativeness of this study on the extended utility and importance of drainage. Therefore, the fact of having many references from the author should be accepted as new development by the author. Acceptance of these facts in the scientific community will enhance utilisation of natural resources viz nitrogen, oxygen, carbon and water to some extent. Thus, drainage will bring lot of social good of food, environment in Africa.

The innovative developments on drainage and practices supported by the drainage for enhancing productivity and protection of environment are scale insensitive. These measures can be applied at any location and can be up scaled to any extent. In its new domain it is beyond the field experiment where conventional way of researched are carried out by executing site experiment, observe response and formulate recommendations. The other approach towards accomplishment of





**Figure 3:** Link network of Theory, Impact, Driving factors and Policy tools.

similar objective is formulation of recommendations based on theory which of course can be modified by customisation, as depicted by (Figure 3). This philosophy of research promotes think global and act local, as the most practical and feasible way of universalisation of researches. This study has excelled in the sphere water resources. It is no way contradicting the known and existing practices of drainage systems. In addition, new auto drainage technology ie racy (alive, smart and enthusiastic) nature agriculture practice is an advancement in the existing types of drainage systems.

## SWOT Analyses

### Strength

The study has substantiated that with drainage aerobic condition will get developed that will conduct nitrogen cycle to function by bacteria nitrogen fixation from the atmosphere to the soil and transform ammonia in to nitrate and from nitrate to nitrite and then to nitrate. The denitrification converts nitrate again in to nitrite and then to nitrous oxide. The nitrous oxide reserve is kept to minimum to reduce the emission of nitrous oxide to the atmosphere which remains as pollutant and also causes ozone layer depletion. The process based knowledge was applied to devise cropping pattern so as to capitalise the nitrogen build up and reduce excessive and surplus situation to exist. Such cropping patterns are not existence. The new cropping patterns, although suffer setback from the lack of appreciation of drainage experts, have large potential to increase productivity with betterment of quality and protection of environment by reduction of emission of the GHG  $N_2O$ . The cropping systems elaborated in this study add very good scientific strength in development of cropping practices to make good use of natural resources. Therefore, there is direct gain from nitrogen cycle management to the technology practising people and indirect gain to the environment. When people carry out their business there is reduction in the emission of nitrous oxide of which about 60% is contributed by agriculture. Methane is largely reported to be contributed by submerged paddy fields and cattle population. By providing drainage aerobic condition can be maintained and new practice of aerobic rice can be use. However, there is difference of opinion that for good yield of rice submergence of paddy fields is necessary. Study by [16] has substantiated that by good practice methane emission from the submerged paddy fields can be cut down to zero methane emission level.

The emission of green house gases such as methane and nitrous oxide will get eliminated to a great extent when drainage is provided to create condition for aerobic decomposition and eliminate anaerobic

decomposition. The study has capacity to transfer excess nitrogen from its place where it is in surplus to the place where it is in deficit. Thus it will be a new method of management of nitrogen cycle. The methods presented here have strong scientific strength and have capacity to produce ecosystem services on sustainable bases.

The scientifically reasoned expected effects of global warming are being experienced in the recent years that convince one to believe the fact of occurrence of global warming. Thus, it is clear that management of nitrogen is an important and appropriate approach to reduce emission of nitrous oxide and capitalise the processes of nitrogen transformations. The new technology i.e. racy nature agriculture is very strong in its formulation and strong in coping up all situations of soil, climate, crops, irrigated or rainfed agriculture. In general, in the rainfed agriculture always emphasis has been to enhance yields, but no consideration on the environmental aspects involved. This study has substantiated that how the role of nitrogen cycle is important in plant production systems. Appropriate management of N improves the services of ecosystems. Therefore, extension of provision of drainage facility in the rainfed agro- ecosystem is very important.

### Weakness

All the aspects of management of nitrogen cycle are devised on sound scientific basis and there is no any scientific flaw. Thus, the study has no weakness. Most of results presented here are well established and substantiated by the author in the present study by application of scientific facts or by other supporting results. This situation results incitation of several research articles of the author..

### Opportunity

The study makes very strong case that application of drainage engineering will come to alleviate environmental problem of emission of GHG such as methane and nitrous oxide. It has opened opportunities to harness the process for enhancing the ecosystem services by cropping management for nitrogen fixation from the atmosphere. This is a good example of secondary natural resources management. Development of enterprise from the methods presented here will make the methane and nitrous oxide get controlled by the indirect effects from the work that people would undertake for their own benefits. Thus, this is a case of bringing automation in exercising control of reducing emission of GHGs. The process of creating aerobic condition by application of drainage engineering work will be the foundation on which success stories can be transcribed. Thus, this study provides great opportunity for management of nitrogen cycle and produce global benefit to the atmosphere. Therefore, agricultural development in Africa, be it irrigated or rainfed condition, has to be based on provision of land drainage. Drained condition is necessary for bringing direct and indirect social good in Africa.

### Threat

There is no threat in the implementation of the results of the study. All the threats of adverse condition that promote deleterious effects on the environment in Africa are removed. The present study has added strength and created tremendous opportunities that will go long way for improving food and environmental situation in Africa.

It will be difficult to realise the discrepancies in knowledge of science of agriculture that did not care for environment, which remained discrepant in always bringing good effects, to accept the facts presented in the present study. It is expected that real realisations will develop soon that will attract attentions of those with the cons views

and go in favour of pros of the facts presented in this study.

## Action Initiatives

All agricultural practices involving in the management of nitrogen and productivity have been, largely, on the basis of carry out study, feel the benefit and again go for further verification on the pretext of change in agro ecological condition. There had been lack of universally applicable innovative technology. The green technology encompassing all necessary scientifically justified components was developed. However, appreciation and application of the technologies requires acquisition of process based knowledge of chemistry, physics, biological sciences, environmental sciences and environmental engineering. This can be supplemented by adding broadened scope syllabus of drainage engineering to the civil and water resources and irrigation engineering, which produces professionals for infrastructure developments. Equally important aspect is adding syllabus in the study curriculum of environmental engineering in the Agricultural Engineering in particular and Agriculture in general world over, who use the facilities of the infrastructure. Thus, in order to make it simple and justifiable to bring human resources development in drainage engineering, it is very necessary to change names of civil engineering department of Water Resources and Irrigation Engineering to Department of Water Resources and Irrigation and Drainage Engineering. Likewise, in Agricultural Engineering colleges, the existing departments of Irrigation Engineering should be changed to Department of Irrigation and Drainage Engineering. These academic supplementations to bring tuning in thinking will produce knowledgeable professionals in the domain of infrastructure executors and users of the facilities so created to appreciate needful aspects for enhancement in productivity and protection of environment. Thus, such initiatives will develop solid foundations on which mansions of food security and environment can be created. Development of human resources in this direction is possible by bringing slight strategic changes in the academic institutions. In any developmental programme role of human resources is very crucial that will all development pro productive or counterproductive, which has been the case in agriculture, irrigation and drainage and related infrastructure developments. The cases of convergence of services presented in the present support the need of process based broad knowledge to bring some innovative applications enhancing use of water and nitrogen.

The improvement in nitrogen fixation along with the enhancement in yield will be brought by the racy nature agriculture. Further, testing of food quality with respect to amino acid balance needs to be examined. Studies have shown that absorption and utilisation of protein are optimised when adults evenly distribute their protein uptakes throughout the day [20]. All technologies presented in the present study are applicable at global scale. Their application for local condition will indicate efficiency level to emerge from customisation. This study has opened opportunity for managing agriculture and environment scientifically at global scale as well as at local scale. This study enables capture under grip for manoeuvre the global worrisome problem emerging due to distortions in the nitrogen cycle. The scientific management of agriculture and environment will replace pseudo managements in vogue science of agriculture.

## Conclusion and Future Research Needs

The study presents prospects of drainage in creating condition favourable to apply and implement innovative technologies of management of nitrogen cycle in Africa. Creation of aerobic condition by providing drainage in all land uses is a foundation development

to conduct by itself necessary aspects of reduction of GHGs. Technological application will involve actions for harnessing direct benefits of enhancement in quantity and quality of primary produces and protection of environment will emerge as indirect automatic benefits. Technologies of nitrogen cycle management described are pertinent to situation in Africa. Technologies for biological nitrogen fixation in agriculture, grasslands and pastures and forestry will enhance N use efficiency and reduce emission of nitrous oxide, physical transfers of excess to deficit site and convergence of services that go in promoting management of N are developed. Being universally applicable, these technologies will be beneficial for global perspective developments. Needful action initiatives are suggested to be brought in human resources development. The universally applicable technologies need be applied in different regions to promote customisation of the technologies.

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