LEGUME-BASED CROPPING SYSTEMS FOR IMPROVING SOIL ENVIRONMENTS IN SUB-SAHARAN AFRICA

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Robert Abaidoo

ABSTRACT

Soils in Africa are less resilient for crop production. The soils range from stony and shallow with poor life-sustaining capabilities to deeply weathered soils with inherently poor fertility status. The soils are situated in five major agro-ecological zones depending on the length of the growing period. The agro-ecological zones are humid, semi humid, semi arid, arid and highlands. The dominant soils in these agro-ecological zones are Ferralsols and Acrisols in the humid zones; Ferralsols and Lixisols in sub-humid zones; Lixisols, Arenosols and Nitosols in semi-arid zones and Lithosols in the arid zones. Among these major soils, Ferralsols, Acrisols and Arenosols are laden with severe fertility constraints. Ferralsols have extremely low nutrient retention, low water holding capacity, high P fixation and deficiencies in magnesium, calcium, potassium and molybdenum. Acrisols also have high P fixation, low nutrient retention capacity, as well as boron and magnesium deficiencies. In addition, the structure is weak and internal drainage is poor. Arenosols have low water-holding capacity, low nutrient content, low nutrient-retention capacity, and chronic deficiencies in nitrogen, potassium, sulfur, zinc, manganese, copper and iron. Furthermore, Arenosols are weakly structured and prone to soil compaction. In contrast, Nitosols have good structure and high nutrient retention. Grain legumes such as cowpeas, soybeans, groundnuts and common beans are commonly grown as mono crop, intercrop or in rotation with other crops in the sub-humid and semi-arid zones. The grain legumes have contributed in diverse ways to the restoration and maintenance of soil fertility. Nitrogen is the most limiting nutrient element in the soils of sub-saharan Africa. The contribution of grain legumes to biological nitrogen fixation varied widely depending on the crop, variety and the management practices adopted. Large number of on-farm trials carried out by N2Africa in West, East and Southern Africa showed that the amounts of N fixed were 12 - 266 kg N ha^{-1}by cowpea, 3 - 166 kg N ha^{-1} by soybean, 10 - 124 kg N ha^{-1} by groundnut and 5 - 31 kg N ha^{-1} by common bean. These studies also identified the choice of variety and application of P fertilizers as the key determinants for enhanced biological nitrogen fixation. The choice of an improved variety of cowpea increased N-fixed by 120 kg ha^{-1}in one study, while the application of 30 kg P ha^{-1} increased the N-fixed by 58 kg ha^{-1} in another study. Nutrient mining is a widespread soil fertility challenge in Africa. Over the last three decades, nutrient depletion has been estimated at an average of 660 kg N ha^{-1}, 75 kg P ha^{-1} and 450 kg K ha^{-1} in 37 African countries. Studies conducted by the International Institute of Tropical Agriculture in 52 farms in northern Nigeria showed that retention of cowpea haulm at a rate of 100 kg/ha could reverse N mining within 2 to 54 years and P mining within 2 to 10 years of continuous practice. Undoubtedly, grain legumes are endowed with enormous potentials which, when harness appropriately could propel the attainment of the much needed green revolution in Africa.

KEYWORDS

Biological nitrogen fixation, soil types, grain legumes, nitrogen and phosphorus mining

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Outline

- Introduction
- Major soil types in Africa
- Fertility constraints of major soils
- Contributions of legume interventions
  - Case study 1: N2Africa Project
  - Case study 2: Gatsby Crop-livestock project
- Concluding remarks

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Introduction

African Soils

- Africa Continent covers over 3 million ha and has wide range of soils and climatic conditions.
- Among the major soils in Africa, Ferralsols, Acrisols and Arenosols have severe fertility constraints.
- In contrast, Nitosols have good structure and limited fertility constraints.

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African soils....

- Inherently poor in fertility because they are old and lack volcanic rejuvenation, for example.
- There is decline in soil nutrient stocks due to soil erosion, loss of vegetation and poor land management.
- Soils in Africa are less resilient for crop production.

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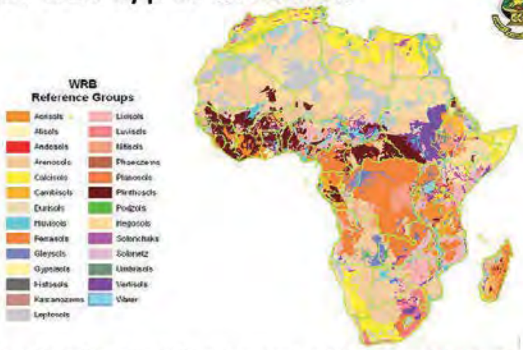
Major soil types in Africa



- **Ferralsols, Lixisols and Acrisols are dominant soils in the humid and sub-humid zones**
- **Lixisols, Arenosols and Nitosols are dominant soil in semi-arid zones**
- **Small holder farms predominant**

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Fertility constraints of major soils

1) Ferralsols

(L. *ferrum*, iron and *alum*, aluminium)

Source: NRCS, 2016

General description:

Red and yellow tropical soils with a high content of sesquioxides.

Soil Fertility limitation:

1) Extremely low nutrient retention,
2) Low water holding capacity
3) High phosphorus fixation
4) Deficiencies in magnesium, calcium, potassium and molybdenum.
5) Prone to erosion

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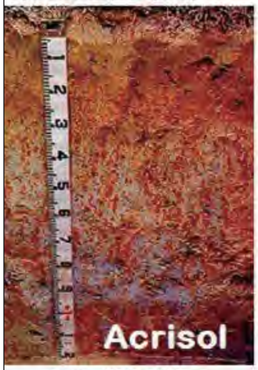
Fertility constraints of major soils

2) Acrisols

(from L. *acris*,= very acid)



Source: ISRIC, 2016

General description:

Strongly weathered acid soils with low base saturation

Soil Fertility limitation:

1) Al and Mn toxicities,
2) High phosphorus fixation,
3) Low nutrient retention capacity,
4) Boron and magnesium deficiencies

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Fertility constraints of major soils

3) Arenosols

(from L. Arena = sand)

Source: ISRIC, 2016

General description:

Sandy soils developed from weathering of quartz-rich rocks

Soil Fertility limitation:

1. Low water and nutrient holding capacity
2. Weak structure

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Fertility constraints of major soils

4) Lixisol

(L. *lixivia = washed-out substances)*

Source: ISRIC, 2016

General description:

Consists of strongly weathered soils in which clay has been washed down from the surface soil

Soil Fertility limitation:

1. Low nutrient holding capacity.
2. Prone to slaking and erosion in sloping land.

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Fertility constraints of major soils

5) Nitisol

(from L. *nitidus* =shiny)

Source: ISRIC, 2016

General description: *deep, red, well-drained tropical soils with* shiny ped faces.

Soil Fertility limitation:

1) Mn toxicities,
2) high P fixation

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Contributions of legume interventions to soil fertility improvement

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Contributions of legume interventions to soil fertility improvement

Two case studies would be used to illustrate the impact of legume interventions on soil fertility restoration.

Case study 1: N2Africa - Putting nitrogen fixation to work for smallholder farmers in Africa

Case study 2: Gatsby Crop – livestock project

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Case study 1: N2Africa - Putting nitrogen fixation to work for smallholder farmers in Africa

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Case study 1: N2Africa .....

Justification

- Nitrogen is the nutrient element most limiting to plant growth.
- Average fertilizer consumption is still low (ca. 8 kg ha^{-1}) (Sanginga and Woomer, 2009).
- Grain legumes offer an economically attractive and ecological sound means of reducing external N inputs through biological nitrogen fixation (Bohlool et al., 1992).

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Case study 1: N2Africa .....

Yet the average yields of some economically important grain legumes in **Africa are very low**

Grain yields of major grain legumes in Africa

Region	Grain yield (t/ha)						
	Beans	Cowpea	Groundnut	Bambara groundnut	Chickpea	Pigeon pea	Soybean
Africa	0.92	0.94	0.91	0.68	0.81	1.01	1.47
Yield potential	5.00	4.00	3.50	4.00	5.50	5.00	5.00

Source: FAOSTAT (2008)

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Case study 1: N2Africa .....

Why are the grain yields so low?

- Successful BNF by legumes in the field depends on

$$(G_L \times G_R) \times E \times M$$

Where:
G_L = Legume genotype
G_R = Rhizobium strain

E = Environment
- climate (temperature x rainfall x daylength, etc) - to encompass length of growing season etc
- soils (nutrient limitations, acidity and toxicities)

M = Management (crop and soil)

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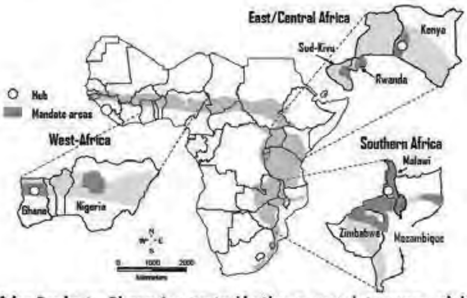
Case study 1: N2Africa .....

Geographical focus of the project



N2fixAfrica Project – Phase 1operated in three mandate areas, eight target countries through three sub-regional hubs

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Mobilizing the best varieties

- Varieties of grain legumes with high potential for BNF and yield were selected from existing breeding programs and evaluated on farmers fields.
- In total, 301 varietal tests were conducted across the project
  - Nine best soybean varieties,
  - Six best bean varieties
  - Six best cowpea varieties
  - Seven best groundnut varieties

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Harnessing Rhizobia and Advancing Legume Inoculants

Need-to-Inoculate tests

- Estimation of soil rhizobia populations
- Soils with fewer native rhizobia (<50) rhizobia per g soil) are more likely to respond to inoculation
- Populations range from zero to several thousands depending on legume crop

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Collecting African rhizobia and identifying elite strains

•Bioprospection

Uprooting of a leguminous plant

Isolation of rhizobia in the laboratory

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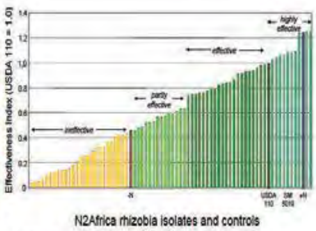
Evaluating for strain effectiveness under range of controlled and field conditions

Screen house evaluation

Symbiotic effectiveness assay of African rhizobia strains



Effectiveness of 80 isolates nodulating soyabean,

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Case study 1: N2Africa .....

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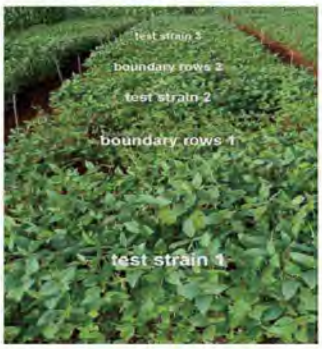
Demonstrating the winning technologies

Field evaluation



Candidate elite strains emerging from N2Africa bio-prospecting and effectiveness evaluation, were:

- ***Climbing bean: NAK 67***
- ***Common bean: NAK 45, NAK 104, NAZ 18, NAZ 23***
- ***Soyabean: NAC 19, NAC 73, NAK 84, NAK 128, NAN 109, NAN 177, NAZ 21, NAZ 25***

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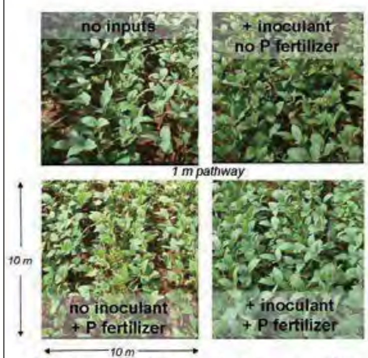
The Phosphorus story..........



Basic layout of BNF technology demonstrations

Table Number of demonstrations, in the eight N2Africa countries.

	Number of on-farm demonstrations[1]
Ghana	1167
Nigeria	347
DR Congo	78
Rwanda	104
Kenya	355
Malawi	753
Mozambique	812
Zimbabwe	1257
Total	4873

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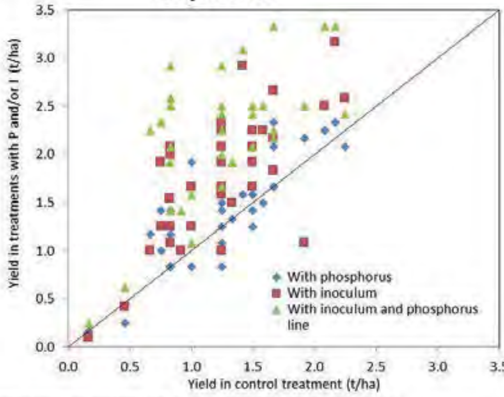
Response to P and inoculation with soybean



N_2Africa demonstration trial results in Mushomo, Sud Kivu, DRC 2010

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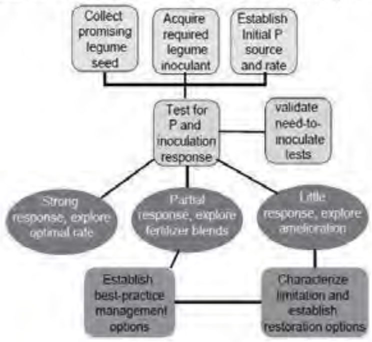
Adhere to the concepts and process

- A stepwise approach for developing best-practice management options will lead to improved legume production



Proven and flexible best-fit management practices are required to realize the potential of improved varieties.

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Case study 1: N2Africa .....

Key outputs

Table summary of the seasonal impacts achieved through BNF technology dissemination over four years by the N2Africa Project

parameter	baseline	after 4 years	change	increase
farmer yield (kg grain ha^{-1})	1,001	1,147	+ 146	15%
legume area (ha farm^{-1})	0.18	0.35	+ 0.17	94%
legume harvest (kg farm^{-1})	179	397	+ 218	122%
crop value ($/ farm^{-1} season^{-1})	154	378	+ 224	145%
BNF (kg N farm^{-1})	10	28	+ 17	169%

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Case study 2: Gatsby Crop – livestock project

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Case Study 2: Gatsby Project - The use of cowpea haulm to reverse N and P mining in the dry savannas of Nigeria

Justification

- Nutrient mining is a widespread soil fertility challenge in Africa.
- Nutrient depletion has been estimated at an average of 660 kg N ha^{-1}, 75 kg P ha^{-1} and 450 kg K ha^{-1} in 37 African countries (Bationo et al., 2006).
- Incorporation of grain legume residues can supply as much as 140 kg N ha^{-1} depending on the legume variety (Giller, 2001).
- The retention of cowpea haulm on the farm after harvest could reverse nutrient mining in the savannas of Nigeria.

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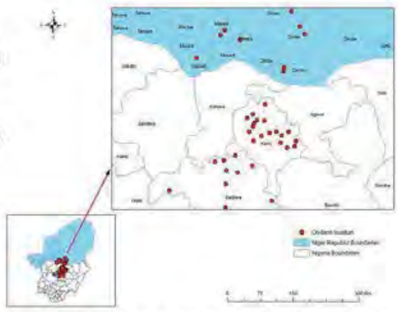
Case Study 2: Gatsby Project.......

Geographical focus of the project

Northern Guinea Savannah (Kaya) : 32 farms

Sudan Savannah (Bichi): 20 farms



Gatsby legume cropping system project sites in Nigeria and Niger Republic

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Case Study 2: Gatsby Project…….

Legume interventions

1) Northern Guinea Savannah: Maize-double cowpea strip cropping (cereal: legume, 2:4)

2) Sudan Savannah: Cereals (sorghum, millet and maize) - cowpea strip cropping [cereal: legume, 2:4]

3) Sole cropping (rotation)

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Quantification of farmer managed flows

- Structured questionnaire for data on:
  Manure (IN 2), allocation of Crop products and Crop residue

Calculations

Nutrient flow	Equation
IN1, IN2, OUT1, OUT2	Amt of material (kgha^{-1})×(nutrient conc (%))
BNF (IN4)	$[\{(N_G \times Y_G)+(N_H \times Y_H)\}\times 0.6]$
Partial balance	**IN1+IN2+IN4 - OUT1- OUT2**

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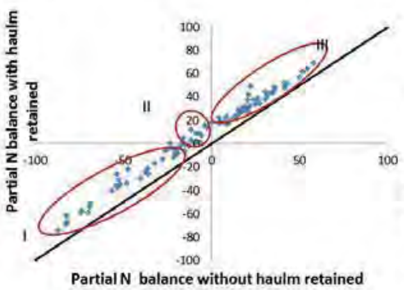
Case Study 2: Gatsby Project…….

Key findings



Three farm groups were identified:
Group 1: farms having –ve partial N balances with or without haulm retention.

Group 2: farms having -ve partial N balances without haulms retention but +ve balance with haulm retention

Group 3: farms having +ve partial N balances with or without haulm retention.

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Case Study 2: Gatsby Project…….

Time frame for reversing negative N balances

	Season 1		Season 2	
	Bichi	**Kaya**	**Bichi**	**Kaya**
Intercept	2.6756	66.44378	18.004	56.321
Coefficient	-0.013	-0.15476	-0.016	-0.022
Amount of Haulm (kg/ha)	**Projections (years)**			
100	1.4	51.0	16.4	54.2
200	0.1	35.5	14.7	52.0
300	0.0	20.0	13.1	49.8
400	0.0	4.5	11.4	47.6
500	0.0	0.0	9.8	45.5
1000	0.0	0.0	1.6	34.6
2000	0.0	0.0	0.0	12.9
3000	0.0	0.0	0.0	0.0

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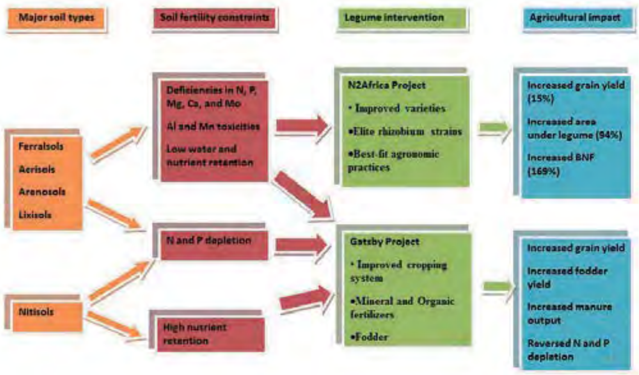
Contributions of legume interventions to soil fertility improvement-Summary



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Concluding remarks

- By disseminating best-fit BNF technologies directly to 253,299 household in eight African countries, N2Africa increased grain yield by 78-272 kg ha^{-1}, BNF by 7-41kg N ha^{-1} and average household income by US$ 355.
- By extending best-fit legume cropping systems to farmer, the Gatsby Project showed that the use of cowpea haulm alone could reverse N and P mining.
- Certainly, grain legumes have enormous potentials which, when harness appropriately could propel the much needed green revolution in Africa.

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Chair Tobita
Next, let me call the second speaker, Dr. Robert Abaidoo. I have known him for more than 10 years when he was working for IITA, Ibadan, Nigeria, as a soil microbiologist. He is currently working for Kwame Nkrumah University of Science and Technology, Kumasi, Ghana as Dean of the School of Graduate Studies. Today, he will speak about the research results, impacts, and lessons from two projects implemented for more efficient utilization of legumes in agriculture systems of sub-Saharan Africa. Okay, Robert, the floor is yours.

Dr. Robert Abaidoo
Okay. Thank you very much Satoshi. Let me also thank the organizers for having me here today. And I think from yesterday I have been quite excited about research in and around legumes.

Today, as he said, I will speak to you on legume-based cropping systems for improving soil environments in sub-Saharan Africa. Briefly, we will talk about the major soil types and their fertility constraints and how legumes can be introduced to intervene in these soil-related problems. I will do this by sharing with you two case studies, one from the N2Africa Project and another one from the Gatsby Crop-Livestock Project. Then, we will share some concluding remarks.

Now, Africa, the continent covers over 3 million hectares including water, with a wide range of soils and climatic conditions. Among these are the Ferralsols, the Acrisols, the and Arenosols which have severe fertility constraints. In contrast, we have the Nitosols that have some good structure and limited fertility constraints. This makes the soils in Africa inherently poor in fertility because they are also old and as suspected we have lack of volcanic rejuvenation. There is therefore decline of soil nutrient stocks due to soil erosion, loss of vegetation, and poor land management. And consequently, as you may expect, the soils in Africa are less resilient in crop production.

Now, we will share with you again here that we have several types from the Acrisols to the Vertisols. But, of course, the predominant ones are the ones we want to pick on today, the Ferralsols, Lixisols, and the Acrisols that are dominant in the humid and sub-humid zones. The Lixisols and the Arenosols and the Nitosols are also dominant soil in semi-arid zones. Why are we picking on these soils? We are picking on them because these are the areas where you have the smallholder farming activities occurring.

I would like to share with you some nice pictures of the profiles. I would like to say that these nice profiles have shadows, and the shadows are largely in respect of their soil fertility constraints. The Ferralsols, for example, are extremely low in nutrient retention, they are low in water holding capacity, they have high phosphorus fixation, and they are deficient in magnesium, calcium, potassium, and molybdenum. And they are also prone to erosion.

The Acrisols are very acid soils, which means that they have high aluminum and manganese toxicity, also high phosphorus fixation, low nutrient retention capacity, they lack boron and magnesium.

We have the Arenosols that are sandy soils, which come from old quartz-rich rocks, which are also low in water and nutrient holding capacity and also have a weak structure.

Lixisols are the ones that are strongly weathered soils in which clay has been washed downwards, which means that the top soils are very poor in clay and as such we expect low nutrient holding capacity and they are also prone to slaking and erosion when they occur on sloping lands.

Here, we have the deep, red Nitisols; deep, red, well-drained soils with shiny ped faces. But of course, they are also limited by the fact that they have high manganese toxicity and also high phosphorous fixation. Now, since these are the predominant soils in the areas where we have smallholder entities, how will we support the livelihood of such smallholder entities? By way of cropping these soils.

Now, as I said, we will use two case studies. The N2Africa is putting nitrogen fixation to work for smallholder farmers in Africa, and the case study 2 is Gatsby Crop-Livestock Project.

Now, why legumes? Briefly, it has been said, this one, by David how wonderful these crops are and how we can use them for environmental sustainability. Because they make natural use of the nitrogen, and by so doing, if they develop high roots systems, they obviously will leave high amount of organic matter in the soils. For the N2Africa, we believe that nitrogen is the most limiting nutrient, and as you might know, in Africa, there is the lowest use rate, about 8 kilograms per hectare, and we also know that the grain legumes will offer an economically attractive and ecological sound means of reducing external N inputs. But of course, we have a precarious situation in Africa where the use of these grain legumes as compared to the huge potential, I can easily estimate it to be less than 25% of this potential. From beans to soybean, they are all very low yielding in these farmer fields. Why it is so? It is so because, probably I am not able to exploit fully the benefits of biological nitrogen fixation by these legumes – why? Because we have probably emphasized too much on breeding. Why? Because probably we do not understand very much the soil environment that support this group.

In this equation, we will say that the variety is very important, the type of Rhizobium is extremely important, the environment that covers the climate, temperature, rainfall, and day length, and also length of growing season become very important and the soils, the natural and nutrient limitations, the acidity and toxicities also influence upon growth. Now, when you have all these conditions, how do you put a management in place to offset some of these limitations? This is what N2Africa tried to do in that project.

Now, the Phase 1 actually spread around eight countries, two in West Africa, three in South and East and Central Africa, and three in Southern Africa.

Now, how was it perceived? First and foremost, looking at the equation, we tried to mobilize the best varieties. So having tested over 300 varietal types, we could identify nine best soybean varieties, six best of bean varieties, six best of cowpea varieties, and seven best of groundnut varieties.

We also stepped into looking at the need-to-inoculate. At this point, let me say that we introduced rhizobia into the soil to enhance the BNF capacity of these legumes. Then, if we have high population of rhizobia in the soil, then your reintroduction of inoculants may be minimized, so you need to establish whether or not you have to introduce new strains into the soil. Normally, when you have population from 0 to 50, you expect some responses to inoculation. In the N2Africa project across the countries, you could observe from zero to several thousands depending on the legume and the soil environment, and whether or not the soil environment has been grown to legumes has explanation inoculation trials in the past.

Now, we exploited the phenomenon of looking at the natural population where did bioprospect looking for strains that have already adapted to the soils in this country, trying to isolate this rhizobia from them and trying to establish how effective these are by comparing them with a standard strain USDA110 here. So, you find that the number of isolations that made - we find those that are really ineffective, those that are partially effective, those that are effective in relation to USDA110, those that are highly effective which meant that you can still have strains that are better than those are already in circulation.

How do you measure effectiveness? Depending on where you are the grain pods are the ones that have made sectioning of the rhizobium inoculation to maximize the – for the synthesis and accumulates more chlorophyll.

On the front, you will be excited to see that these ones are the ones that are dealing with ineffective nodulation or nodules that did not store and these ones are the ones that’s encountering effective rhizobia for high productivity.

Now, having done this, we tried to share the winning technologies with farmers through series of evaluations. As you go up here, you have many strains being tested, and at the moment, we have many of the strains that are kept in the countries. NAK is N2Africa Kenya and these are the nomenclature given them and they are stored in the urban countries.

Now, the phosphorus story. In order to search information of all P fixing, in which case it’s important that we introduce some amount of P into the food when growing these legumes and from several trials and demonstrations, which encompass the good varieties, the rhizobia strains and P addition, you will find that anywhere you have P addition plus inoculation, that is by way of these cones, you will find that they are far, far higher than when you have only phosphorus and only inoculate addition. At this point, it is important to stress that growing legumes would need to supply with additional phosphorus in this soil that’s actually P fixed.

By summary, we are saying that when you do the collection, legume genotypes, you acquire the inoculant and you establish the P initial sources, you can either come by a strong response, a partial response, or little response. This two point-of-need to further diagnosis, to establish that you need to optimize whatever is resistant.

From these activities, N2Africa could increase the farmer yield by 15%, legume yield by 94%, and BNF by close to 170%.

I will take the second one very quickly. It is also on the same premise that as we have the grains back home, we deprive the soil of its inherent stocks. And therefore there is a need to retain some of the produce, especially the nonconsumable parts like the haulms. Now, this project took place in Nigeria and part of Niger where farmers were exposed to improved cropping systems. Here you have soybean and maize if it's in the Northern Guinea Savannah and sorghum or millets if it's in the Sudan Savannah. And also the one crop that is below.

Now, by interviewing farmers and knowing how much of the haulms they take home and how much of it is fed into the animals and how much of the animal manure is brought back to the soil, we could do a simple partial analysis where you estimate all your inputs that is inorganic fertilizer, organic fertilizer, BNF that is other position. When you subtract the output that is the grain and output that is the haulm, you will find that you may come by three groups of farmers. The lower group are the ones that will still have a negative balance, that is you are taking more from the soil than left behind, whether they apply the haulms or not. You have a second group that will retain some positive if we don't apply the haulms, and we have a third group that will be positive whether you apply the haulms or not. And these so that the inherent soil cartridges are very important in establishing whether or not we have a positive balance or a negative balance.

Now, the interesting point is that we tried to look at how many years will we need to repair or reverse the negative balance, in this case, with respect to nitrogen. You could find here that when you apply only 100 kilograms per hectare of the haulms, you will take for example in Bichi where there was very little negative balance, about 1.4 years, whereas in Kaya where you have huge negative balance, you need more than 50 years to reverse this. Now, coming down here, we know that there is recommendation for applying haulm at the rate of 2000 or 3000 kilogram per hectare, in which case in areas where you have literal negative balance, that will easily be corrected. And even in where you have a high negative balance, we are able to use a huge amount of 3000 kilogram per hectare, you may have that correction done over a year.

In summary, I want to say that these are the major soils we spoke about and the deficiencies we also spoke about and the legume intervention by N2Africa and by Gatsby Project. You will find that I have said there is increase of 15% up to about an increase of about 170% of BNF. Now, in the Gatsby Project, you will find that there is increased grain use, there is increased fodder use, there is increased manure output, and you can reverse nitrogen and P depletion.

So, we can say that by disseminating the best-fit BNF technologies to over 300,000 households in eight African countries, N2Africa made a substantial increase in grain yield, in BNF, and also household income by about US$ 300.

Again, by extending best-fit legume cropping systems to the farmer, the Gatsby Project showed that the use of cowpea haulm alone could reverse N and P mining, which certainly means that grain legumes have enormous potentials which when harnessed appropriately could propel the much needed green revolution in Africa. Thank you so much for your attention.

Chair Tobita
Okay. Thank you Robert. We have learned the soil health is in danger in sub-Saharan Africa and legumes can alleviate it through their power. It is clearly shown from your presentation about the two projects. Thank you very much. We can have several questions and comments from the floor. Anybody? Yes.

Male Questioner
My question is about the strains, nitrogen fixing strains. You have successfully screened the very effective strains. Have you ever made a comparison between those effective strains with other strains already found in the United States or so? Which is more effective is my interest.

Dr. Robert Abaidoo
Okay. Thank you very much. As I said, these effective strains have been compared with the existing soybean strain USDA110. So, as long as they perform better than USDA110 under these conditions, we can safely call

them very effective strains. Now, the question that has not been addressed so far is how competitive are these strains with the indigenous strains? Now, when you obtain the strain, for example, from this pot in this room, then you need to apply some others, it is likely possible to go into encounter competition from those or the other strains. And we also know that for the legumes that are dealing with groundnuts, the cowpea, the promiscuous soybeans are difficult to deal with because of the high populations on indigenous rhizobia, that always interfere as a successful nodulation by the introduced rhizobia. So, it would be interesting to find how these locally identified strains would compete, and we believe that because they have come from the same environment, they will not have so much difficulty. But that has to be established. So, a direct answer to your question simply is that, yes USDA110 when it comes to soybean is what has been recommended worldwide. Now, we have strains from Brazil that are supposed to do rather well on groundnut and cowpea, and these strains that we have isolated are also comparable with that. Now, we need to do a molecular titration to establish whether or not these are already introduced strain or it could be really indigenous strains from this environment.

Male Questioner
I need to discuss more but time is limited. I will discuss with you later.

Chair Tobita
Okay. Thank you. Another, yes.

Male Questioner
Okay, thank you very much for your presentation, especially about the N2Africa that I often receive some reports monthly. If you succeed to have very efficient rhizobia, I know that you work with farmers, my concern is how do you – is it easy or hard to get the farmers master the technique of inoculation? Do you perform seminars or – I am interested in how you transfer the technology to the main users. How they do the inoculation technique or…?

Dr. Robert Abaidoo
If I got it right, you ask how we will disseminate the technology, is that correct?

Male Questioner
Yes, exactly.

Dr. Robert Abaidoo
Okay. Now, as I said, the N2Africa Project has dissemination integral to its implementation. So, as long as we are disseminating imported inoculum, it shouldn’t be too difficult disseminating these ones that we have isolated, provided they perform better than your imported rhizobia. Three is challenge as to how the smallholder farmers handle this inoculum, and by education, we think that they will overcome the initial problem that they have with inoculum handling. In many cases, because this contains life materials, poor handling needs to be addressed before they apply it. So, it’s important that the farmers get educated in how to handle these organisms safely.

Male Questioner
Thank you very much.

Chair Tobita
Okay. Time is up. Thank you very much Dr. Robert. Yes, please give a big hand.


Questioner