THE ROLE OF INTEGRATED SOIL FERTILITY MANGEMENT Technology ENHANCED CROP PRODUCTION AND SUSTAINED LAND PRODUCTIVITY IN SUB SAHARAN AFRICA: EXPERIENCE FROM ETHIOPIA

By

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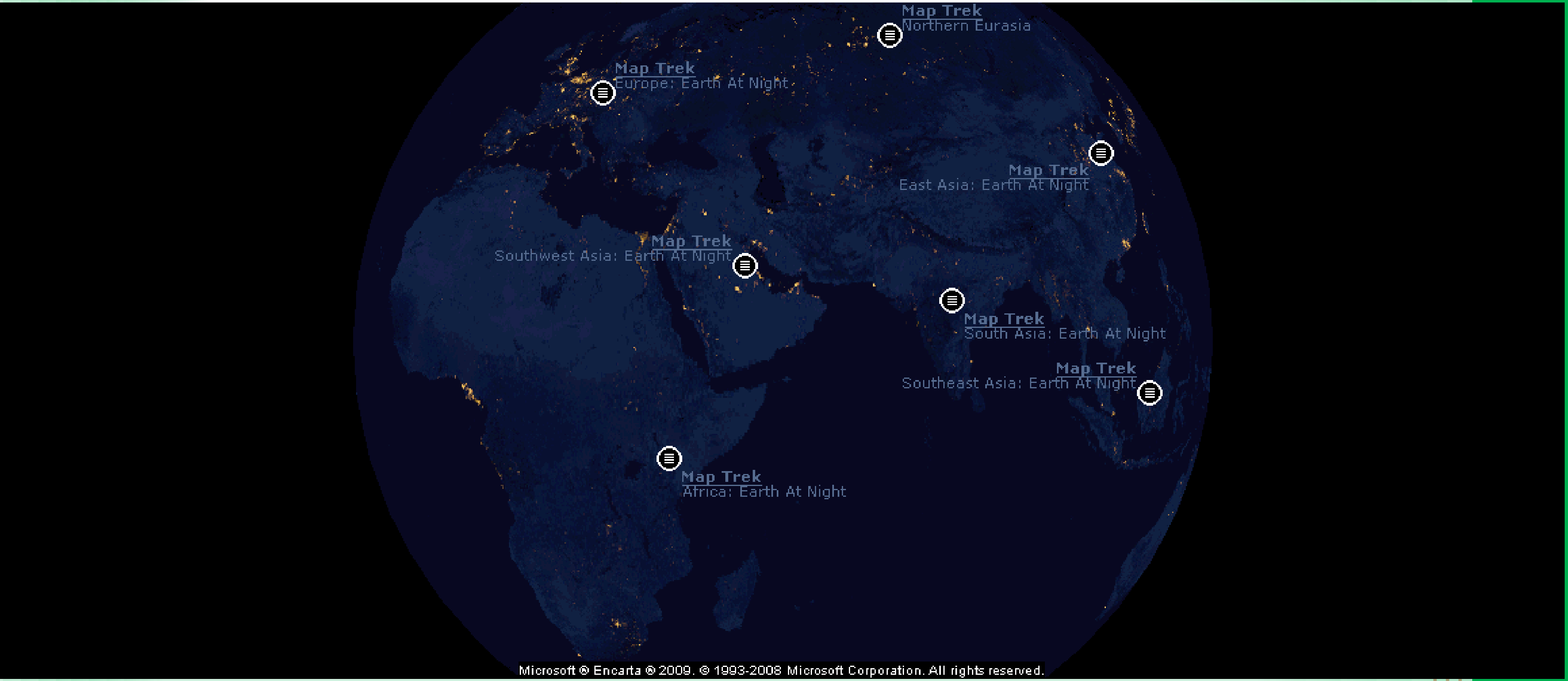
Outline

- 1. Introduction
- 2. Causes of Soil fertility decline in Africa
- 3. Overview of options for soil fertility improvement
- 4. Definition and concepts of integrated soil fertility management (ISFM) system
- 5. Review of the importance of integrated soil fertility management (ISFM) in increasing crop productivity
- 6. Research and extension experiences on ISMF in Ethiopia
- 6.1 ISFM Research advances in Ethiopia
- 6.2. Extension Dissemination of ISFM technology in Ethiopia
- 7. Challenges to and opportunities with ISFM in Africa

INTRODUCTION



Earth at Night

But Africa: Poverty in the middle of plenty

- Agriculture : the main source of livelihood & income in SSA
- Accounts for 30-60% of GDP, 60-90% employment and
- 25-90% for exchange earnings (AFS, 2006)
- High potential (land, water, climate, biodiversity, manpower etc..) for surplus food production
- Paradox: Despite heavy dependence on agriculture
- -High potential, it is unable to feed its growing population
- Witnessed from the fact that between 1961 and 1995, per capita food production showed decreasing trends in SSA (Brady & Weil 2002)
- against 70% in Asia and 20% increase in the world in the same period

- Green revolution (improved seed, fert. And irrigation) model that helped Asia achieve surplus food production
- it was tried in Africa and failed
- It also predicted that the existing gap b/n food pn and pop. Will be widened in the future
- Also losing its potential.

- -Consequently the continent suffers from food insecurity
- -According to UNU-INRA (2011),more than 40 % of the population is supposed to be food insecure in Africa
- -depends on recurrent food aid

- the commonly known causes that account for very low performance of agriculture in Africa include:
- -inadequate availability of improved technologies
- -insufficient use of existing technologies,
- lack of skill and knowledge,
- illiteracy,
- Poverty,

- decline in soil fertility,
- -lack of suitable policy (land tenure, subsidies etc..),
- -Brain drain,
- -insufficient investment for R & D,
- -Drought, climate change, HIV/Aids,
- -Poor market access and marketing systems, poor infrastructure, period civil conflict

- Declining soil fertility is by far the most challenging problem that threatening agriculture pn in SSAfrica
- B/c Agricultural production system in SSA is mainly based on of nutrient mining (crop export, residue removal, in sufficient organic inorganic fert., erosion & poor soil mgt (Fig. 1)

- Fig. 1. Plaughing on steep slope , south Ethiopia

- It is estimated that SSA countries are losing
- 6.1 million Mg of N, 0.74 million Mg of P and 4.6 million Mg of K yearly.

- -The most well known limiting nutrients in Africa:
- N & P, some extent K
- How about others?,
- Example the case with Bangladeshes (Fig. 2)

Nearly all nutrients became a limiting in 2010

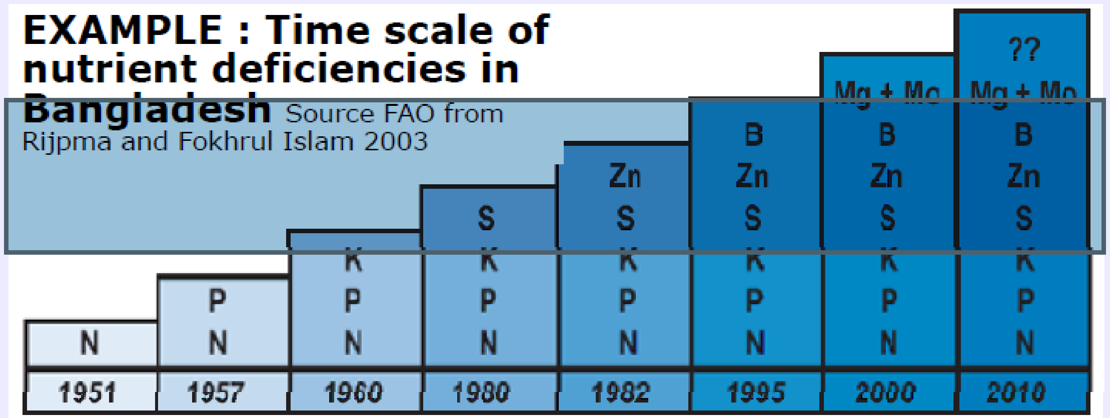


Fig. 2

These Nutrients have to be replaced with fertilization

AGRinputS

- What Happened to African soil?
- The same has happened or will happen soon.
- The problem is we did not investigate

- According to Sanchez (2002) per capita food pn will continue to decline in SSA unless soil fertility depletion is effectively addressed
- And if depletion is not reversed it will lead to overall crisis
- -Thus, reversing soil fertility decline should be a top priority in SSA more than anything else.
- -This needs
- -collaboration of stakeholders,
- -creating enabling environment
- Increasing knowledge and awareness about the risk associated with soil fertility decline
- Greater investment on soil resources

- From technical point of view, reversing soil fertility decline requires
  - ✓ integrated application or implementation of SWC measures,
  - ✓ increasing vegetation cover,
  - ✓ maintenance and builds of soil organic matter,
  - ✓ application of organic and inorganic nutrient sources, good agronomic practices etc. and
  - ✓ the use of integrated soil fertility management (ISFM) technology (combined app. Org-in nutrient source as its backbone).

- ISFM technology is currently considered as advanced way of soil fertility mgnt advocated for SSA
  - applicable in various agro ecologies and socioeconomic circumstances
  - it is knowledge intensive than input intensive
  - Flexible
  - find itself impt in densely populated areas
  - more beneficial in tropic than temperate areas (b/c tropical soils are poor in Om content)

- **Objectives**
- To give overview of what ISFM is (definition, concept and requirements of ISFM etc..)
- Importance of ISFM in enhancing crop productivity and land sustainability in Africa
- To share experiences from ISFM research in Ethiopia (Status of ISFM research and dissemination, important findings and lessons that add value to the existing Knowledge)
- To get feed back from ISFM research experience in Ethiopia

2. Causes of soil fertility decline SSA

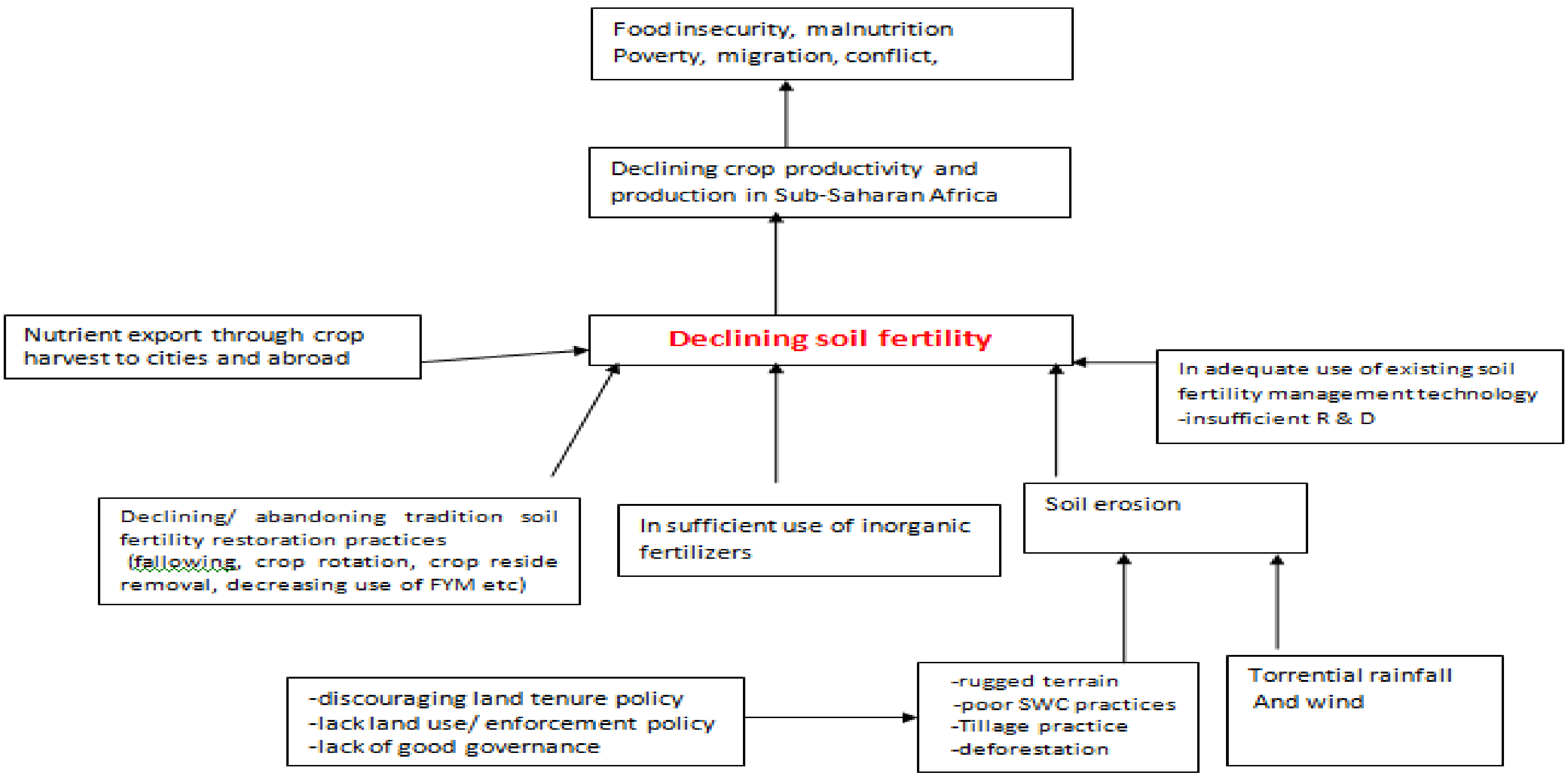


Figure 1. Causes of soil fertility decline and their interrelationship in sub-saharan Africa

Figure 3.

3. Overview of options for soil fertility improvement

- Education is the lasing/ultimate solution to soil degradation in particular and food security and development in in Sub-Saharan In general
- Back from that there are different solutions to different problems
- soil fertility decline problem can be addressed by fertilizer app.

- The use of such input have long been started in Africa
- dramatic increase in yield have been achieved
- but the per capita fertilizer consumption in Africa is very low
- It will take long before African farmers achieve optimum rate due to increasing price
- But currently there is a good opportunity to increase fertilizer use in Africa

- The use of organic nutrients such as FYM, compost and residue also contribute to address soil fertility problem
- There are also Green manure trees and shrubs know for their effectiveness as organic fertilizers
- Both inorganic fertilizer and organic inputs have limitations (Table)1

Both fertilizers and orgnic imnpots have problem

Table 1. Limitations of fertilizers and organic inputs

Inorganic fertilizers	Organic fertilizers
1. Highly soluble and subject to loss through various pathways (E.g) N fertilizers	1. High amount is needed/ha needs high labor for transport and incorporation
2. Repeated use of one or two types of the same types of fertilizers such as urea and DAP being in Ethiopia, affect the nutrient balance, ultimately decrease productivity and sustainability	2. Limited availability 3. Variable composition of nutrients 4. Low in some nutrient content
3. Negatively affect soil quality. E.g nitrogenous fertilizers acidify soil	
4. Pollution such as nitrate pollutes ground water	
5. Increasing cost of fertilizers	

So what?

Integrated soil fertility management technology which employs the combined application of organic and inorganic fertilizers as its backbone is the best solution curently

4. Concept and definition of ISFM System

ISFM research was started in mid 80's

-advanced in 2000's

The key concept is if organic and inorganic nutrient sources together, they give produce superior yield crops and AE than either source applied alone

-B/c both organic and inorganic fertilizer sources are not complete (Table 1) to stand best in increasing crop productivity

-Further more according to Vanlauwe (2010) combined app. Of two sources is a must in SSA b/c hard to get either of them in sufficient quantity in Africa

-But to make a best out of ISFM there is need to include improved germplasm and adapt the system to local condition

Accordingly ISMF is defined as

"Soil fertility management practice which necessarily include the use of fertilizer, organic input and improved germplasm, combined with knowledge on how to adapt these practices to local conditions , aiming at maximizing agronomic use efficiency of applied nutrients and improving crop productivity" (Vanlauwe, 2010).

So From the above discussion and definition has three requirements

1. Inorganic fertilizer and organic input & their mgt.
2. Improved germplasm
3. Adaptation to local condition (lime, swc etc..)

Inorganic fertilizer management for ISFM means identification of limiting nutrient in the soils of particular location, then determines the optimum fertilizer rate for a particular crop organic input that Should be:

-nutrient rich preferably N-fixing,

-locally available, fast growing, easy to propagate, high biomass producing and multipurpose if possible.

-then determine the right combinations of organic and inorganic nutrient sources that produce biological and economic optimum yield using the following procedure shown in Table 1. (Mutto and Palm, 1999).

Table 2. Protocol for development of optimum organic and inorganic fertilizer rate

No	Inorganic fertilizer	Organic fertilizer	Remark
1	0	0	Control
2	100	0	Optimum rate of particular nutrient e.g. N or P etc..
3	75	25	
4	50	50	
5	25	75	
6	0	100	Optimum organic fertilizer that give equivalent nutrient as in N0. 2

Adaption to location situation includes e.g

-Application of SWC measure if needed

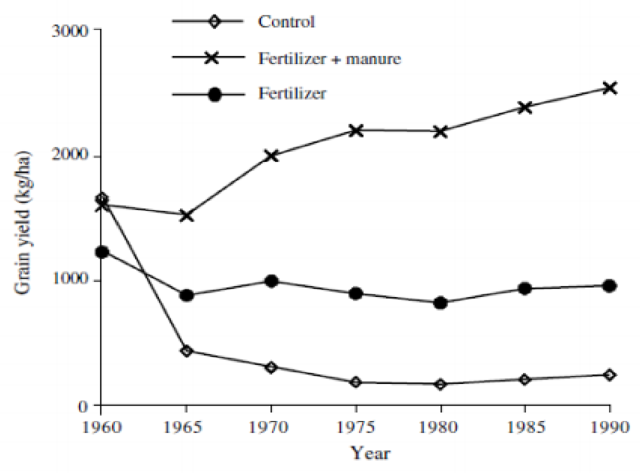
-lime

-water harvesting technology etc..

5. Review of the importance of integrated soil fertility management (ISFM) in increasing crop productivity

There are a number of evidences indicating
The superiority of ISFM
In increasing yield of crops (maize, cassava
Sorghum, potato etc.. In SSA

E.g. With Fertilizer + Manure
Grain yield was persistently
Increased from 1960-1990



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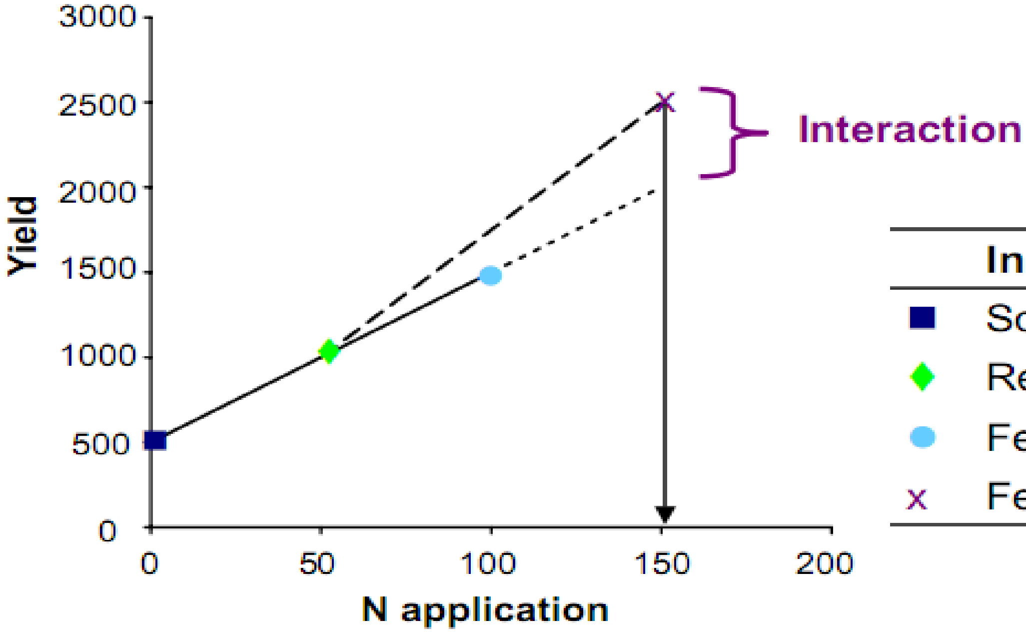
- Meta analyses of published data on the results of experiment on maize revealed that Fert. + OI with improved variety increased the grain yield by 114% compared with control

  &

- Increased by 17 and 33 % over the respective fert. And Or.Input(Chivenge et al., 2011)
- application N fertilizer with manure/compost + hybrid maize variety have significantly increased the N-AE from 23 kg/kg N in the sole fert. treatment to 36 kg/kg of N applied in Fert. + Organics (Vanlauwe et al., 2011).

Interaction effect of organic-inorganic sources

Figure 5 **Interactive Effects - Concept**



	Input	Yield
■	Soil	500
◆	Residue	1000
●	Fertilizer	1500
x	Fertilizer+Residue	2500

Interaction = Fertilizer+Residue - Soil - (Fertilizer - Soil) - (Residue - Soil)

Interaction = 2500 - 500 - (1500 - 500) - (1000 - 500)

Interaction = 500

Source: Vanauwe (2011)

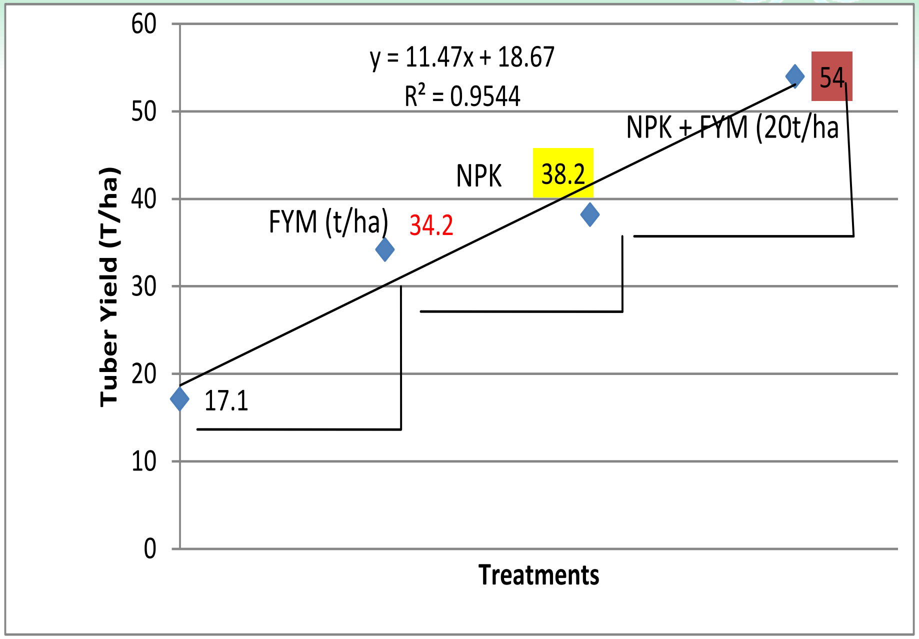


Figure. 6. The effect of organic, inorganic fertilizers and their combination on the yield of potato at acidic soil of Chencha, South Ethiopia, 2007

Source: wassie, unpublished

Mechanism of by which of organic input in ISFM system

Benefit better crop performace

-Reduction of toxic effect of cations such as Al through complexation in acidic soils

-Decreasing P-fixation/sorption in p-fixing soils (malic acid, citrate etc..)

-Increase microbial activity (eg release chelates

-Increased –availability and better synchrony of N was achieved with urea + FYM or Leucaena

-Decreased nitrate leaching when urea was appl. with FYM (Taye, 1996), increased synchrony (Vanlauwe et al, 2002)

Research and extension experiences on ISMF in Ethiopia

Soil degradation/soil fertility decline is a major challenge to agricultural production in Ethiopia like any other sub-Saharan African countries.

-soil acidity and salinity

-Due attention have been given to reverse soil fert. By govt.

-ISMF is taken as a key approach to solve

Table .3 Summary of yield response of crops to ISFM trials conducted across different location of Ethiopia

No	Treatment	% Yield increase			Crop type	Location	Year	Reference
		Control	Fertilizer	Organic source				
1	2Mg ha^{-1} FYM + 61kgN ha^{-1} +31kgP ha^{-1}	90.9	8.5	28.5	Potato	Central Ethiopia		Teklu et al., 2004
2	10 t/ha FYM + 75% RDF	186	10	52	Potato	Western Ethiopia	2005	Daniel et al., 2008
3	Compost + fertilizer treatment	97	46	16	maize	South Ethiopia	200-10	2011
4	4 t/ha *C. cajan*+ half RD Fertilizer	110	equal	23	maize	Western Ethiopia		Abebe&Diriba, 2003
6	23/10 kg NP + 10 t/ha E. bruci biomass	173	11	20	wheat	Kokat, South Ethiopia		Wassie 2012

Table 4. Mean Potato tuber yield as affected by organic-inorganic amendments

NP app. Did not affect tuber yld In both years

But sign. Increased With 15 t/ha FYM by 394%
Further increased When K was applied Indicating that K from FYM was not sufficient

Treatment	Total Potato Tuber Yield (t/ha)		Mean	% increase over the control
	2006	2007		
1. Control	6.33 d	6.16 d	6.27 d	-
2. NP (110:40 kgha-1)	8.82d	8.60d	8.09 d	29
3. NPK (110:40:100 kgha^{-1})	31.09 b	31.70b	30.88 b	393
4. NP+15t FYM	31.74 b	31.60 b	30.96 b	394
5. NPK+15tFYM	42.59a	40.55a	41.88a	568
6. 15 ton FYM	16.47 c	16.38 c	16.43 c	162
LSD (0.05)	**6.08**	**6.56**	**4.47**	
CV(%)	**21**	**24**	**23**	

Source: Wassie and Shiferaw, 2009

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The effect of integrated NP/NPK + FYM on Potato studied at Chencha 2007 (Fig. 1).

- FYM sig. increased the tuber yld

- Both rates of NP did not increase Yld. But NP + FYM sig increased yld
- also The inclusion of K with NP has also sig. increased yld.
- The highest yld was obtained from integrated app. of half and full rate of NPK + 10/20 t/ha FYM

Thus half of NP/NPK + 10 t/ha FYM is Recommended

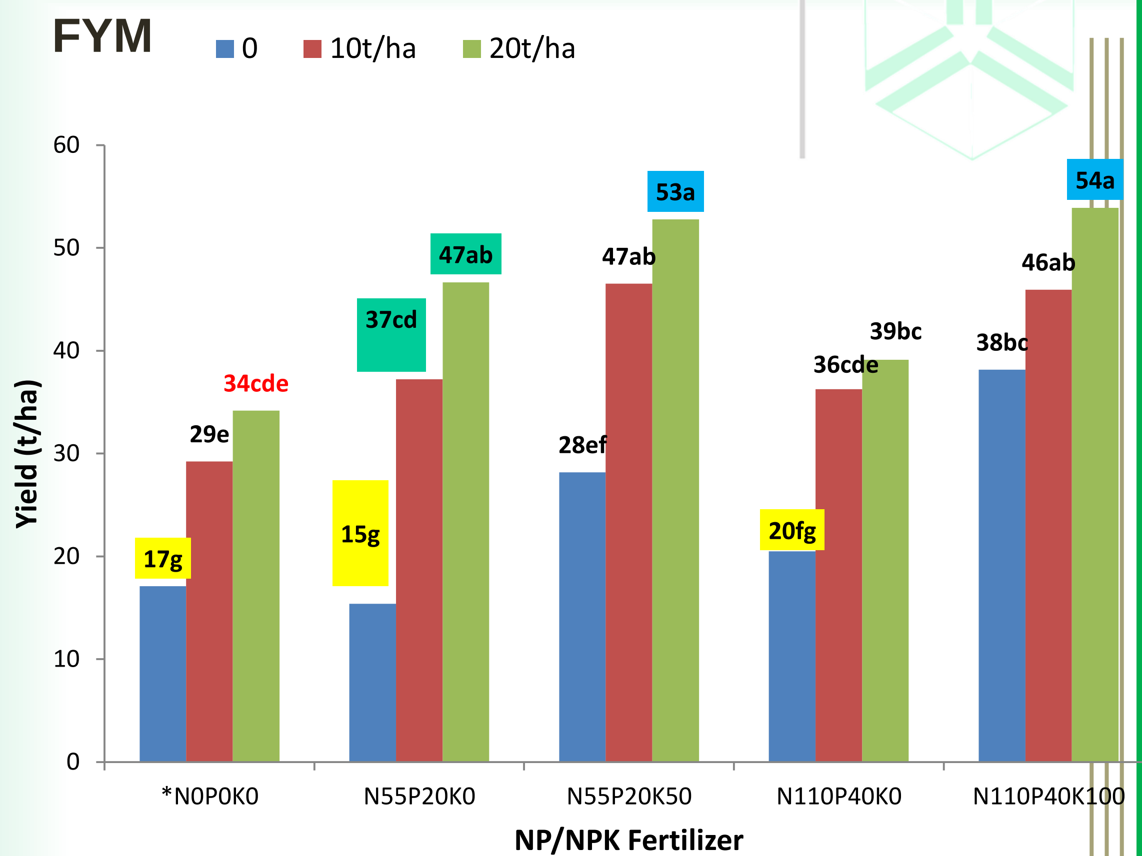

Figure 4.The effect of integrated app. of FYM and NP/NPK fertilizes on the tuber yield of potato at Chencha in 2007

Effect on Agronomic efficiency

AE was found to be
-ve or not affect by
NP fertilizers
But sig. increased
When applied with
10 & 20 t/ha FYM

The AE was high

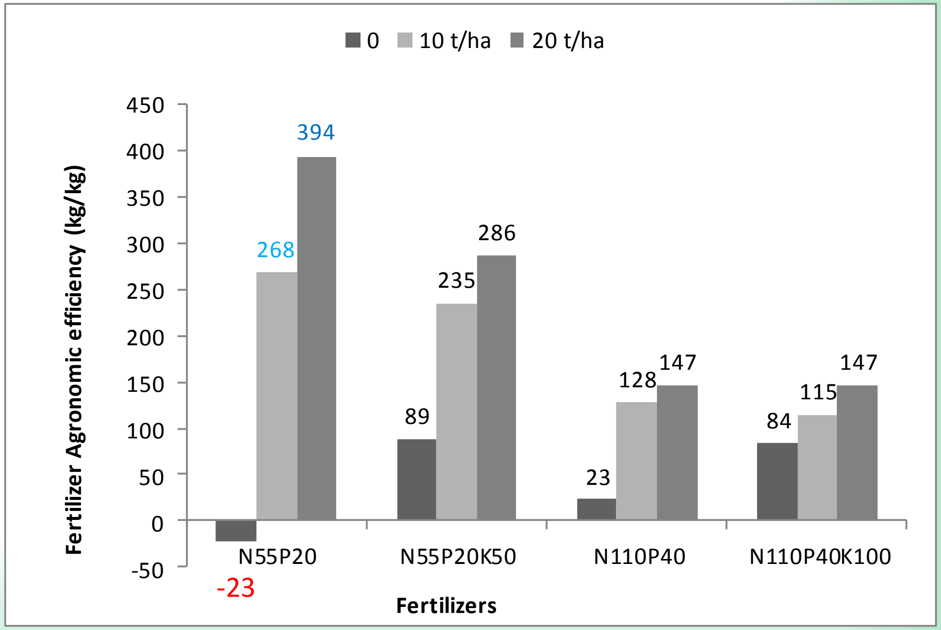

Figure 7. The effect of combined application of fertilizers and Farm yard manure (FYM) on the agronomic use efficiency of potato, Chencha, southern Ethiopia 2007 (Wassie Unpublished).


NP Treated


NP + FYM


Untreated Control


NPK + FYM

Result of ISMF with E. bruci biomass on wheat

E. bruci identified to be nutrient Rich N-fixing endemic tree to Ethiopia

N= 4.83, P = 0.38% and K= 2.24%
Richest and untapped resource

Fast growing , high biomass Producing, easy to propagate

It was studied as integral Component of ISMF(2007-08

The results is shown in Fig

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Fig. 1: *E. bruci* leaf showing N-fixing nodule, near Soddo town, 170 km south west of Addis Ababa, Ethiopia

N-fixing nodules on leaves of *E. bruci*

Plate A

Plate B

5 & 10 t/h E bruci biomass
Increased grain yld by 82
& 127 % respectively

46/40 kg/ha NP produced
Same yld as 10 t/ha E bruci

Highest yld was obtained
With half or full NP + Biomass
Half recommended NP + 10t/ha
Increased the grain yld 173 %
Over the control
-20 and 11% over biomass
And fert. respectively

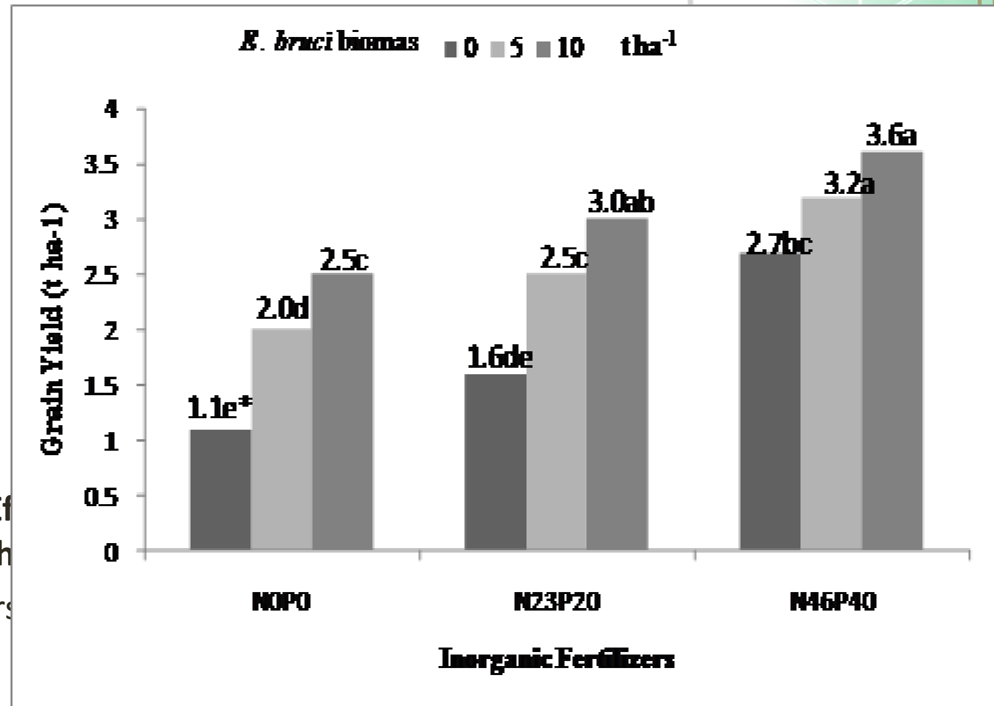

Figure 8. Ef… grain
yield of wh… 2012)
*Bars … each
other.

Result with Delicos lablab

Field grown Delicos lablab Immediately before incorporation (2007)

Table 5. The effect of *Delicos lablab* as Green Manure (GM) on Wheat at Kokate and Hossana, Southern Ethiopia (Wassie & Shiferaw, 2009)

Gm + 23 kg N/ha
Produced significantly
Higher yield in
both location compared
with control

Treatment	Mean Grain Yield (kgha^{-1})	
	Kokate	Hossana
Control	2011c	1443b
GM + ON	3282ab	2857a
GM0 + 23N	2926b	2956a
GM + 23N	3417ab	3141a
GM0 +46N	3329ab	3392a
GM + 46N	3529a	2954a
lGM0 + 69N	3502a	3267a
GM + 69N	3630a	3130a
LSD().05)	**327**	**365**
CV(%)	**10.7**	**13.3**

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ISFM: Effect on Soil Responsiveness

Both NP rates did not
Sig. increased the yld
Relative to the control
At acid soils of chencha
In 2007 (Fig. 6)

But with 10 & 20 t/ha Fym
Yld was dramatically
increased

This means that FYM
Made none responsive
Soil to be responsive
Against the claim that none
Responsive soils be first
Rehabilitated for 3 yrs with
om

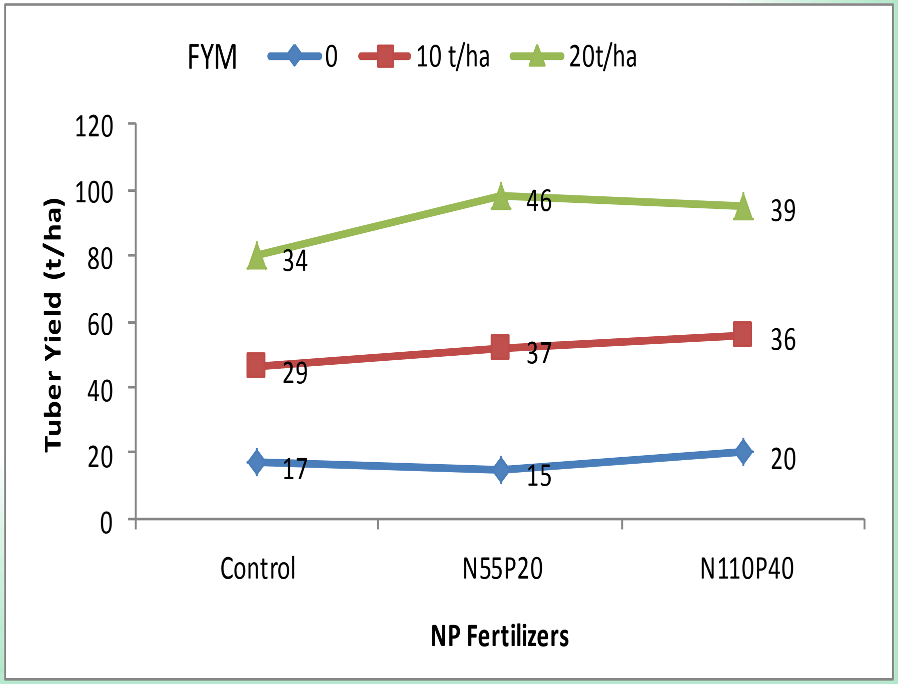


Figure 9. The effect of NP fertilizer applied alone and in combination with FYM on the tuber yield of potato at Chencha, southern Ethiopia, 2007

Only
The residue of
FYM at 20 t/ha
Along N55P20
increased yld sig.
In 2008

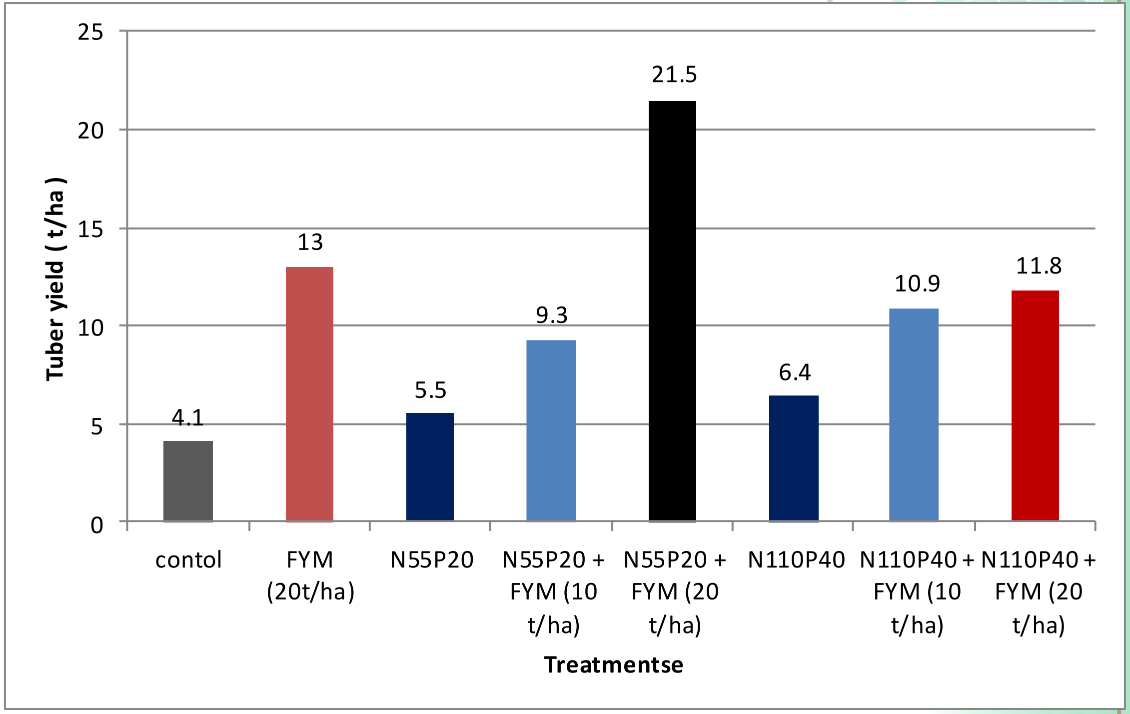


Figure 10. The effect of continuous application of NP fertilizers and residue of FYM on the yield of potato in 2008.

Fig 8. shows that
Yld was sig increased
With NP + FYM
But further increased
With NPK + FYM
Suggesting that all the
K requirement
cannot be met with
Supplementation
FYM alone.

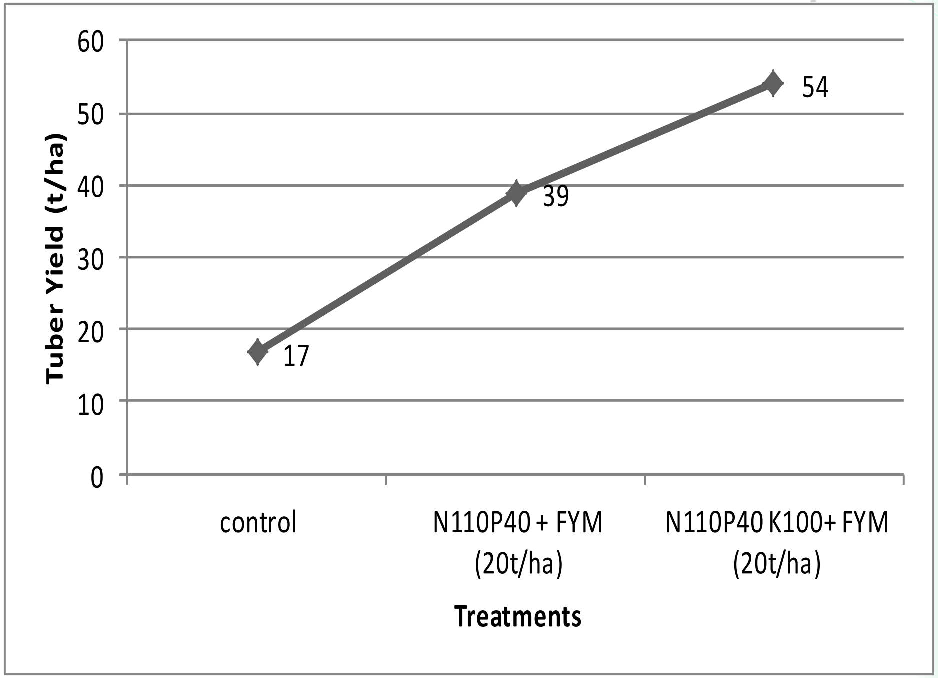


Figure 11. The effect of integrated application of NP, NPK and FYM on the tuber yield of potato at Chencha, Southern Ethiopia, 2007.

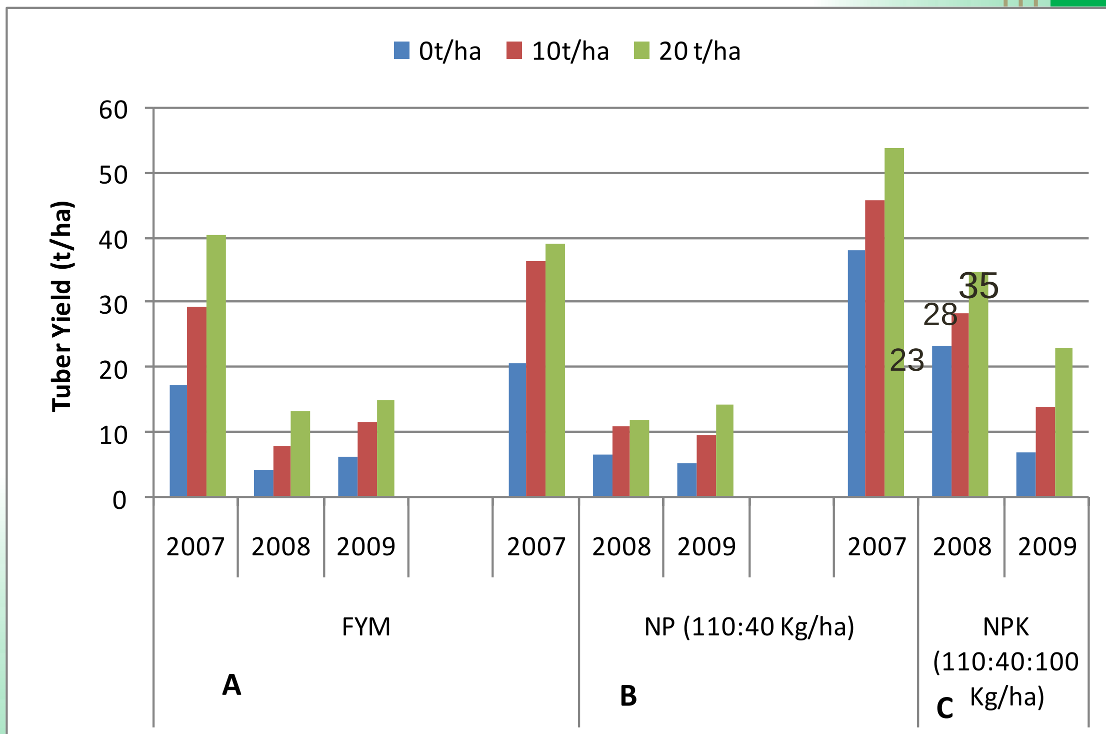
Effect on Land sustainable Productivity

Fig 12. direct
And residue effect
Of FYM & continuous
App. Of NP/NPK
On potato

-only residue high rate
Of 20t/ha FYM sig.
Increased yld
In 2008

-NP + FYM residue
Did not improve yld

But NPK + residue
Of FYM sig. increased
Tuber yld sig. in both 08-09 years



The residue helps
In sustaining land
Productivity provided
hat balanced application
Of fert. Is there

Extension dissemination of ISFM technology in Ethiopia

Limited use by farmers

Reasons:

-only recently recognized advance soil fertility mgt technology so not well known by stake holders

-needs to be tested in a wide agro ecologies

-Should be demonstrated to farmers

But recently national strategy have already been designed to promote and scale up ISFM across the country headed by MOA

-implementation is started

Summary of Lesson from ISMF research in Ethiopia

- Strengthened the claim that ISFM is advanced soil fertility management technology that produce higher yield, increased AE and reduces fertilizer costs
- We have identified *E. bruci* to be nutrient rich N-fixing tree widely available but untapped resource that can be used as organic fertilizer alone but with higher benefit with application along with inorganic fertilize
- None responsive soils to NP mainly due to soil acidity or OM depletion, made responsive with combined application of NP with FYM, without prior rehabilitation OM
- Benefit from continuous application of NP/NPK in same land is unsustainable, but NPK receiving soil can be sustainably productive with the residue of FYM, implying that Organics are beyond source of nutrient in crop prn.

Overall advantage of ISFM

-increased yield

-decrease the cost of inorganic fertilizers (contributes to farmers saving, cuts nations spending for fertilizer import)

-Increase agronomic use efficiency of fertilizers

-increase nutrient use efficiency

-increase water use efficiency

-maintains/enhance s sustainable land productivity

-flexible (applicable in a wide environment, can be adapted local condition/enables the use of local available organic nutrient sources as integral component of ISMF)

-Deceased damage to the environment

Challenges and opportunities with ISFM in Africa

Challenges

-Poor enabling environment

-poor coordination among stakeholders

-lack of investment

-shortage of trained manpower

Opportunities

-high food price in the world market

-plenty of untapped organic nutrient sources

-presence of international organization that can provide technical backstopping like UNU-INRA, TSBF-CIAT etc..

Soil is Our Soul

So Let Us Save

Our Soil !!!

THANK YOU

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