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Understanding the Dynamics of Soil Nutrient Balance and Its Management Option of a Common Bean Farm: The Case of West Arsi, Ethiopia

Diriba Megersa Soboka[1, *], Mekin Mohammed[2]

[1]Ethiopian Institute of Agricultural Research, Ambo Agricultural Research Center, Ambo, Ethiopia

[2]Ethiopian Institute of Agricultural Research, Fogera Agricultural Research Center, Fogera, Ethiopia

Email address:

dmegersa81@gmail.com (D. M. Soboka)

[*]Corresponding author

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Abstract: The yield of Common bean [Phaseolus vulgaris], the important legume crop for large percentage of the world's population is challenged by soil fertility declining in the most growing regions. The survey was conducted in Goto Onomo kebele, West Arsi Zone, Ethiopia during June 15, 2017 to understand the dynamic of soil nutrient balance in common bean farm and its management option. The Combinations of field observation and semi-structure interview data collection methods and NUTMON [nutrient monitoring for tropical farming systems] method of FAO data analysis in micro level approach were applied. Accordingly, a total of 10kg/day of cow dung was recorded. Total inputs of 45.75kg/season was recorded as Nitrogen sources from different inputs. Additionally, 48.83kg/season of nutrient out flow was recorded. As a result, negative nutrient balance [-3.08kg/season] was exhibited due to the high nutrient removal rates by harvested biomass that leads to poor nutrient management and low use efficiency. Hence, the farm has been exposed for nutrient deficiency by -3.08kg/season that farm level nutrient management such as crop residue management, addition of farmyard manure, and inorganic fertilizer sources are recommended as better alternative management options for legume crop production.

Keywords: Common Bean, Goto Onomo, Nutrient Balance, West Arsi

1. Introduction

Nutrient balance in the soil is the key component of enhancing crop production. The exploitative agriculture for the centuries has reducing the fertility status of the soil to a level that even the application of inorganic fertilizers at higher rates is not able to sustain the productivity of soil [12]. Nutrients have four basic chances in the soil: 1] they are imported to the farm in purchased products, like chemical fertilizer and manmade organic fertilizer, 2] they are exported from the farm in products sold; 3] they remain on the farm to be recycled; and 4] they are lost to the environment. A well-organized nutrient management plan may reduce purchased inputs, improve nutrient cycling, and reduce the potential for nutrient loss [11]. Each farm should be seen as a complete system or cycle with inputs, outputs, storage, losses and recycling all taking place [14].

According to Stoorvogel, J. J., and E. M. A., the cultivation farms are subject to severe losses of nutrients through soil erosion and by removal of dung and crop residue for fuel [13]. Ethiopia was among the country with the highest rates of net nutrient losses. Soil nutrients like N, P, K, and OC are mainly obtained from manure, leftover feed of animals from around the houses and homestead refuse. Unlikely, mineral fertilizer [Diammonium phosphate DAP and Urea] were the main sources of nutrient addition to the distance fields [10]. Our field of common bean has the same history i.e. it is at distant from homestead that diammonium phosphate or urea fertilizers are the only alternative nutrient input for this field.

While common bean is an important legume crop for a large percentage of the world's population [15]; its actual yield is relatively low in most of the regions where this crop is grown. Both biotic and abiotic limitations are responsible for reduced yields [2, 5]. Low soil fertility is the major yield-limiting factor in most of the common bean-producing regions [3, 4, 15]. That is why this survey was designed to understand the dynamic of soil nutrient balance in common bean farm and its management option.

2. Methodologies

2.1. The Study Area

The study was conducted in Oromia Regional State, West Arsi Zone Goto Onomo kebele which is lies approximately between 7°0’N-7°10’N and 38°30’E-38°40’0’E latitude and longitude respectively [Figure 1] and covers a catchment area of 755ha. Its elevation ranges is 1783 masl.

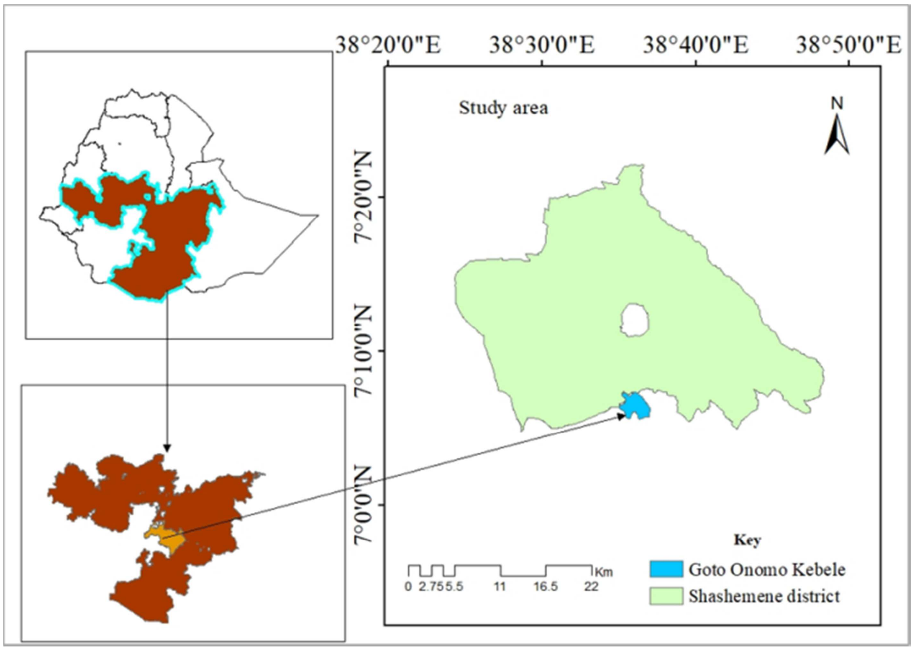

Figure 1. *Map of the study site.*

The average annual rain fall of the area is 1123mm. The kebele has the major food crops: - Maize, Teff, Wheat, potato, Haricot-bean and Common bean. Hence, Common bean was the target crop of the study for data collection to explain the nutrient in and outflow in the farm or pilot.

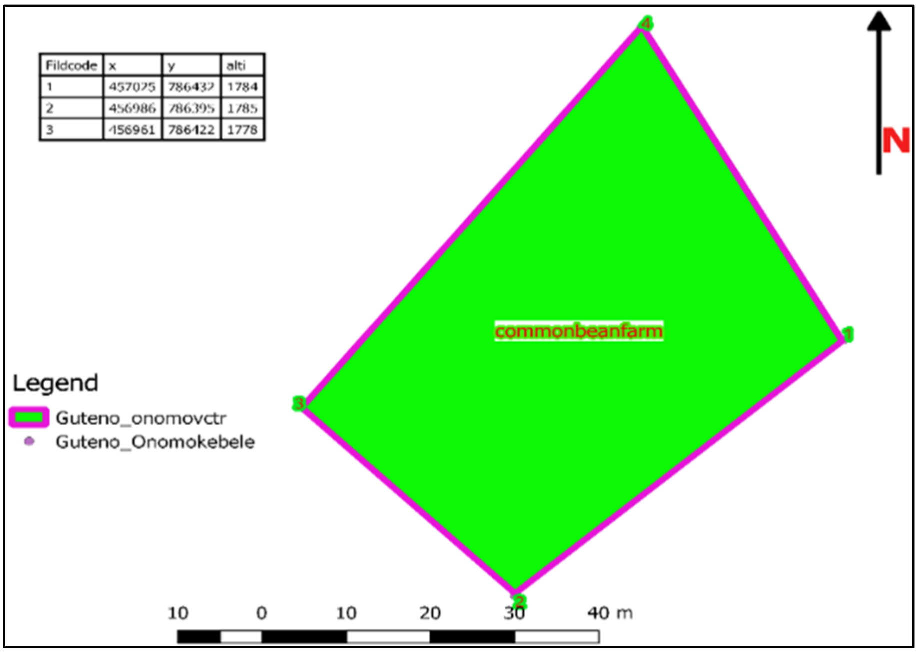

Figure 2. *Map of the Study Farm/Plot.*

2.2. Data Collection and Analysis

2.2.1. Data Collection

The data was collected by field observation and semi-structure interview. The area of the farm [Figure 2] was converted from GPS and satellite photo of the kebele [Figure 3] was taken from Google earth by print screen.

Source: - Google Earth snapshoot

Figure 3. *Goto Onomo Kebele satellite image.*

Meteorological data were obtained from local meteorological station. Common bean has been selected deliberately and interview was made with farm owner [Figure 4] on the nutrient in-flow and out-flow. Questioners were used for the interview and attached at appendix page.

Figure 4. *Photos during farmer's interviews.*

2.2.2. Data Analysis

The data was analyzed by using NUTMON [nutrient monitoring for tropical farming systems] in micro level approach which was suggested by FAO report [2003]. Accordingly, the following formulas and procedures were applied.

2.2.3. Formulas for the Data Analysis and Procedure Followed

Based on the formulas, the nutrient flow calculation was carried out one by one as follows.

Step 1. Nutrient input calculation

a. Biological Nitrogen Fixation [Inflow 1]

The total N demand of leguminous crops [soybean, groundnuts and pulses], 60 percent is supplied through symbiotic Nitrogen fixation [Rhizobia]. Nitrogen fixation was calculated as, 60% * total Nitrogen demanded. Common bean [*Phaseolus vulgaris*] is less efficient in fixing N than other legumes, but is reported to have fixed up to 125 kg N/ha. It can nodulated with several rhizobia [Wortmann, 2006].

So, in our trial farm, Nitrogen deposition from fixation = 125kg/ha *0.255hac

=31.875kg

b. Atmospheric Deposition [Inflow 2], was calculated as, Deposition =0.14*[rainfall]$^{1/2}$

using three transfer functions:

$$\text{Inflow} = 0.14\times P$$

annual rain fall of wondo genet =1123mm/y

1year=1123mm

1/4year =?

We use 1/4year because, we perform for only the current cropping season. The Farmer has told us that, He will cultivate or sow teff after harvesting the Common bean on the same plot. So that, it is impossible to calculate the nutrient flow for the whole months of the year.

Inflow =1/4year*

=280.8mm

$$\text{Inflow} = 0.14\times \sqrt{P}$$

$$=0.14* \sqrt{280.8mm} = 2.35 \text{ kg of N}$$

Where P = annual precipitation [mm/year].

c. Sedimentation [Inflow 3]

FAO Sedimentation for nitrogen N=10Kg/ha/year this was converted to our plot area [0.255 ha]. But, since the field is surrounded by ridge, no sedimentation come to the plot from elsewhere by erosion and irrigation.

d. Manure [Inflow 4]

Inflow 4 [organic inputs] was determined by asking the farmer and combining the applied quantities with the nutrient contents from the background database.

N_2 [organic manure applied by farmers] =zero, since there is no addition of manure and no interference of cattle [the area was fenced] and the farmer did not add any manure on the targeted plot due to the location of the common bean farm from the homestead. Therefore, the manure inflow was zero.

e. Crop residue [Inflow 5]

Inflow from crop residue was zero, due to complete removal or harvest of the crop from the farm for cattle feed.

f. Mineral Fertilizer Urea fertilizer [inflow 6], = 25 Kg of urea was added.

This mineral fertilizer was determined by asking the farmer and combining the applied quantities with the nutrient contents from the background database as suggested in [6].

Urea added by the Farmer =25Kg, 100 kg of Urea contain 46 kg of Nitrogen. Based on this, the amount of Nitrogen found in 25kg of urea was converted.

100kg urea=46kgN

25Kg=?

[25kg*46kg]/100kg

= 11.5kg mineral nitrogen

Step 2. Nutrient output calculation

Harvested product was calculated by the following formula of FAO report on [7]

a. Crop residues [OUT 2]

$$\text{OUT2} = \frac{\sum[Area*Content*Yield]}{Total\ Area} * Removal\ factor$$

1) Removal factor in our case is 100% =1, i.e. total removal of residue for livestock feed, no fraction of residue return to the plot.
2) Content is the concentration amount of N in crop.

Nitrogen concentration in the common bean shoot and grain was calculated from [1], table 1 below.

***Table 1.** Nitrogen concentration and uptake of common bean.*

Nitrogen concentration [kg/ha/y]		Nitrogen up take [kg/ha/y]	
shoot	**grain**	**shoot**	**grain**
6.3	32	16.9	124.1
38.3		141	
38kg/h/y*1/4y=9.58kg/ha		141kg/ha/y*1/4y=35.25kg/ha	
[9.5kg/ha*0.255ha]=		[35.25kg/ha*0.255]/1ha=	
Total	2.42kg	Total	8.99kg

1) ➔Now, the output from crop residue = OUT2 = $\frac{\sum[Area*Content*Yield]}{Total\ Area} * Removal\ factor$

$$\text{OUT2} = \frac{\sum 0.255\text{ha} * 2.42\text{kg} * 200}{0.255ha} /10 * 1$$

2) ➔ = 48.4kg, this shows that, 48.4 kg of Nitrogen is removed from the farm plot per one season.

b. Leaching [OUT3]

$$\text{Out 3} = 2.3 + [0.0021+0.0007*F] * R + 0.3*[N_1+N_2] - 0.1*UN$$

1) F= Fertility level, it is medium from expert wise observation. So, its value should be 2 based on FAO recommendation.
2) R= Rain fall, which is 1123mm/year from local meteorological data.
3) N_1 = Mineral fertilizer, which is 25 kg of Urea [11.5 kg of N].
4) N_2= Manure, which is zero in our target plot=0.
5) UN= Uptake of Nitrogen=8.99kgN.

➔Leaching= 2.3 + [0.0021+0.0007*2]*280.7mm+0.3*[11.5kg+0] -0.1*8.99kg = 5.83kg

c. Gaseous losses [OUT 4]

$$\text{OUT 4} = \text{'Base'} + 2.5 \times F + 0.3 \times [IN_1 + IN_2] - 0.1 \times UN$$

Even if this formula is works to calculate the gaseous losses, it is difficult to calculate it by only field survey. It needs laboratory analysis. Therefore, in this case, the value become zero.

d. Erosion [OUT5] = as discussed above, since the farm were surrounded by ridge, the erosion effect is nearly negligible, the value of erosion output become zero.

3. Results and Discussions

3.1. Results

3.1.1. Field Survey Results

From the field survey and semi-structured interview, the size of farms belongs to the farmer [1 hectare] of which 0.255 hectare is cultivated common bean that season and his livestock data was recorded. Table 2 below presents the data of manure from livestock.

***Table 2.** Livestock and cow dung data.*

Types of Animals	Amount	Average Dung kg/day/livestock	Total Dung Kg/day
Oxen	1	4	4
Cows	2	3	6
Heifer	--		
Goat and Sheep	--		
Others	--		
Total	--		10

***Table 3.** Nutrient in and output for common bean farm.*

No	Input	Amount added in Kg/season 4month
1	Biological N fixation	31.9
2	Deposition	2.35
3	Sedimentation	0
4	Manure	0
5	Crop residue	0
6	Urea fertilizer	11.5
	Total	45.75
	Output	
1	Harvested product	48.4
2	Leaching	5.83
3	Gaseous losses	0
4	Erosion	0
	Total	48.83

3.1.2. The Nutrient Balance of the Farm for One Season [4 Months]

The partial nutrient balance analysis of the study site has been considered only the most important inputs and outputs flow. The inputs include mineral fertilizer, organic inputs while the output harvest products or grain and residues removed. It calculated as the difference between sum of inputs and sum of outputs. Based on the partial input-output nutrient balance analysis, the study area shows the following result.

Nutrient Balance = Input –Out put

Here, from table 3 above, the sum of input and output were. Total Input =45.75 kg, Total output =48.83 kg. Therefore, Final Nutrient Balance [NB] = 45.75 – 48.83 = -3.08kg. Figure 5 below, shows the brief nutrient flow of the common bean farm at 2017 cropping season from the farmer's field.

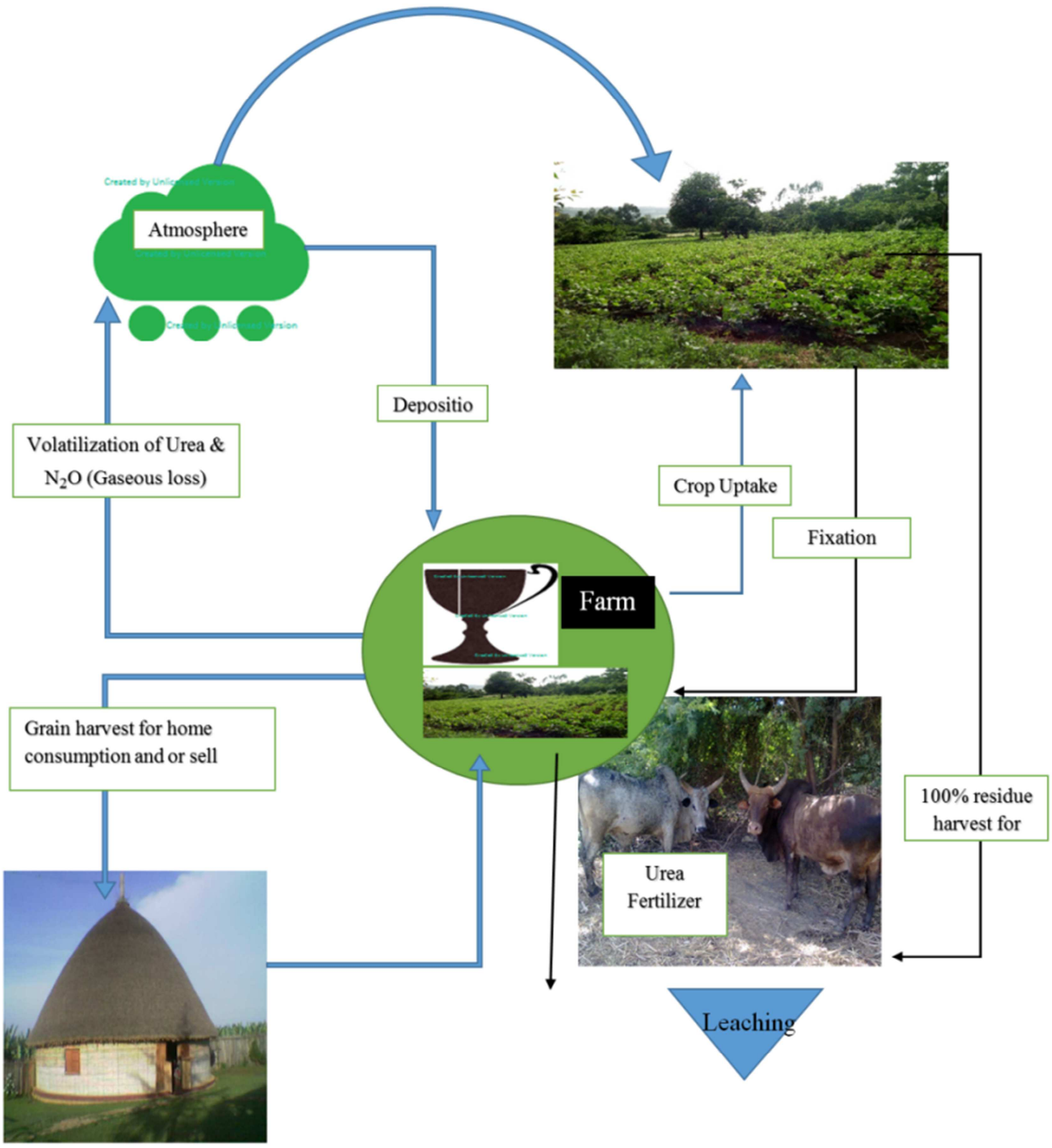

Figure 5. *Nutrient in and outflow in the common bean farm at 2017 cropping season.*

3.2. Discussions

The cow dung result shows that, the addition of manure to the farm, even though, the farmer has been applied any cow dung. As the interview result revealed, the manure has been used for sugarcane farm rather than food crops farms. This was due to two reasons: - a] due to the high price of sugarcane when compared to other crops [Common bean in this case] and b] due to the distant location of common bean farm from the residence, transportation of manure to the farm become labor consuming. Likewise, the fence to the farm in order to protect the crop from beast damage has excludes cattle from interference to farm which become another obstacle for cow dung substruction from the farm, and constructed ridge for protection of erosion has been played indirect role in preventing addition of manure and sedimentation from elsewhere.

The result of interview indicated that the crop residue had been removed completely from the farm and took to home for livestock feed. The farmyard manure also applied to nearby farm not to the common bean plot. Both the absence of Manure and complete removal of the crop residue and harvested product from the farm aggravates the nutrient outflow from the farm; which is cause for the deficiency.

The Nitrogen fixing capacity of legume crop [Common bean] is better than other non-legume crops. In this case, the nutrient [Nitrogen] input by the crop is 31.9 kg. The nutrient lost by erosion, gaseous loss and leaching are negligible. The cumulative effect of these factors [Nitrogen fixed by the crop and those negligible losses] had saved the farm from serious nutrient deficiency. Even if different scholars [9] vetoes the application of Urea fertilizer on legumes fields; the farmer we had interviewed has used 25Kg of urea fertilizer for the common bean farm. This is another input that adds some nitrogen to the farm. The Nutrient balance become negative from the above calculation. This negative result shows that how much the farm exposed to nutrient deficiency.

4. Conclusion

The output of this project work concludes that there is higher nutrient removal rate, particularly for Nitrogen in the farm level, primarily due to complete removal of nutrients in harvested output and residue as a result of poor nutrient management, leading to low nutrient use efficiency. The use and management of specific source of soil nutrients like application of mineral fertilizer and organic inputs are poor and nutrient depletion is high. Generally, the farm has exposed for Nitrogen nutrient deficiency [-3.08kg]. Consequently, farm level nutrient management such as on farm crop residue retention, addition of farm yard manure and compost are immediate remedy for the farm to balance the deficiency problem. Moreover, application of commercial fertilizer other than Urea might be another management option for leguminous target crop farms. Likewise, Crop rotation is another agronomic solution not only for the nutrient balance, also for the mitigation of crop failure risk due to disease and drought.

Appendix

Data collection questionnaires: -

1. Do you own land? Yes ☐ No ☐

If yes, how much in hector? _____________

2. Do you have Livestock? Yes ☐ No ☐

If yes, would you indicate types and number of the livestock? And also, can you estimate amount of dung or wests you obtain from them per day?

Types of Animals	Number	Average Dung kg/day/livestock	Total Dung Kg/day
Oxen			
Cows			
Heifer			
Calf			
Goat			
Sheep			
Others			
Total			

3. For what purpose you do use their dung?

A. Fire wood____________________

B. Manure______________________

C. Compost_____________________

D. Others_______________________

4. Do you cultivate common bean on your farm?

Yes ☐ No ☐

A. If yes, how much in hectors? ______________

B. How you do harvest the crop?

a] Complete removal

b] Harvest at certain height from the ground_________

C. How much yields you do expect from it?

a] Grain_________________ ☐

b] Residues______________ ☐

5. For what purpose you do use the:-

A. Grain?

a] Sell____________

b] Home consumption_________

B. Residue?

a] For sell______________

b] For compost____________

c] Leave on the field____________

d] For cattle feed_____________

e] Others, if there_____________

6. Did/do you use other commercial fertilizers on the farm?

A. DAP_________________

B. Urea_________________

C. TSP_________________

D. Others, if there______________

7. Their application method

A. Top dressing ☐

B. Broadcasting ☐

C. Fertigation, if there ☐

8. Did the field exposed to different type of erosion?

A. Yes ☐

B. No ☐

9. If yes, what are they?

A. Rill ☐

B. Sheet ☐

C. Gully ☐

10. Is that is possible to define their status as the following?

A. Serious ☐

B. Medium ☐

C. Low ☐

D. Deposition from else-where ☐

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