Decomposition Dynamics and Inorganic Fertilizer Equivalency Values of Compost Prepared from Different Plant Residues

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Abstract

A study was conducted for two years (2005-2006) at Adet to estimate the inorganic fertilizer equivalency values of compost prepared from different plant materials; recommend the appropriate plant materials composition in compost; and measure the optimal duration required for compost formation. The experiment was sub divided into pit and pot sub experiments. The pit experiment included of 5 treatments that included different proportions of composting materials (100% dry cereals stubble, 75% dry cereals stubble + 25% of dry legumes stubble, 50% dry cereals stubble + 50% dry legumes stubble, 25% dry cereals stubble + 75% dry legumes stubble and 100% dry legumes stubble). The pot experiment included growing of tef in pots that contained all treatments in the pit experiment and one control treatment. Similarly a pot experiment on mineral N was conducted side by side with the compost experiment to compare the effects of mineral N fertilizer and compost. All the experiments were arranged in randomized complete block design with three replications. Results of the experiment revealed that the organic carbon content did not have a wide difference among composting plant materials. Nevertheless, all the cereal residues contained lower total N content than the legume residues. During the 8 months of the composting period, organic carbon content showed a reduction trend while total N and inorganic N contents showed increasing trend. Increasing legume contents in composting materials increased yield and yield components of tef. A ratio of 75% legume and 25% cereal was found to be optimal one. Composting upto 7.5 months generally improved inorganic N release and yield and yield components of the test crop. From the experiment it was possible to recommend that since huge amount of compost is required to satisfy the nutrient demand of crops, compost should be applied in combination with mineral fertilizers for commercial purposes. However, for small plot agriculture of Ethiopian farmers, compost remains to be very useful low cost organic fertilizer.

Key Words: C/N ratio, inorganic N, organic carbon, total N, yield and yield components

Introduction

Composting is the practice of creating humus like organic materials outside the soil by mixing, piling, or otherwise organic materials under conditions conducive to aerobic decomposition and nutrient conservation (Brady and Weil, 2002). During the composting process, the C/N ratio of organic materials in the pile decreases until a fairly stable ratio in the range of 14:1 to 20:1 is achieved. Achieving this ratio is possible by selecting appropriate combinations of cereal and legume plant materials, adjusting the composting time and selecting appropriate composting period.

The finished product, compost, is popular as a mulching material, as an ingredient for potting mixes, as an organic soil conditioner, and as slow-release fertilizer. Compost as a fertilizer has a lot of potentials in boosting land productivity. It is less costly, can be prepared from locally available materials and significantly improves soil physical as well as chemical properties. The Amhara Regional State extension endeavors are now pushing compost application for crop production. Therefore, composting has become an urgent priority.

It is apparent that the rates of compost applications are not known. Unlike chemical fertilizers, determination of nutrient rate of application from compost is quite difficult. This is mainly related to the unavailability of information on the inorganic fertilizer equivalency values of compost prepared from different plant materials. Once these values are known, it will be possible to estimate fertilizer rate recommendations using compost as a source of nutrients. The objectives of the study were to determine the inorganic fertilizer equivalency values of compost prepared from different plant materials; identify the appropriate plant materials composition in compost; and estimate the optimal duration for compost formation.

Materials and Methods

Location and Climatic conditions

The experiment was conducted at Adet Agricultural Research Center, located at an altitude of 2240.0 meters above sea level and geographic position of 11^{o}17.2'N latitude and 37^{o}28.9' longitude. The mean monthly temperature and total monthly and annual rainfall data of the experimental site during the experimental period are presented on Table 1.

Experimental design and field layout

Composting experiment

The composting experiment had five treatments that were

1) 100% dry cereals stubble
2) 75% dry cereals stubble + 25% of dry legumes stubble
3) 50% dry cereals stubble + 50% dry legumes stubble
4) 25% dry cereals stubble + 75% dry legumes stubble
5) 100% dry legumes stubble

Similarly a pot experiment on mineral N was conducted side by side to compare the effects of mineral N fertilizer and compost on grain yield, fresh biomass yield, dry biomass yield and plant height of tef. The treatments for the mineral fertilizer rate experiment included 0, 30, 60, 90, 150, 210 and 270 kg N ha^{-1}.

Results and Discussion

Composting

Chemical composition of the compost materials

The chemical analysis of the plant materials revealed that the organic carbon content did not have a wide difference among them (Table 2). It ranged from 43.1% in *S. Sesban* to 49.3% in wheat. Nevertheless, the cereal plant materials contained relatively higher organic carbon content than the legume plant materials. Regarding total N, all the cereal residues contained total N content of less than 1% (0.71-0.75%). However, the legumes had total N content of above 1.9% (1.9-3.31%). Eventually, the C/N ratio was higher for cereals than the legumes. This parameter was affected more by total N content of the materials than their organic carbon content.

Table 2. Chemical composition of the plant residues used for composting

Plant residues used for composting	Organic carbon content (%)	Total N (%)	C/N ratio
Tef	46.6	0.74	63.0
Finger millet	47.2	0.71	66.5
Wheat	49.3	0.75	65.7
Faba bean	44.2	1.90	23.3
Field pea	43.2	1.97	21.9
Sesbania sesban	43.1	3.31	13.0

Dynamics of organic carbon, total N and inorganic N contents in the compost during composting period

Organic Carbon

Results of the composting experiment which was conducted for 8.5 months (Table 3) revealed that the organic carbon content in the initial composting material ranged from 44% (100% legume) to 47.2% (100% cereal). It was apparent that as the legume content in the composting material increased, the organic carbon content relatively decreased. Nevertheless, there was no wide difference among treatments in their organic carbon content.

As the composting time increased, the organic matter content in all treatments decreased. The loss of organic carbon could be attributed to the mineralization process which causes loss of CO_2. The loss of carbon during the composting time was the highest for the 100%

legume compost and was the lowest for the 100% cereal compost. This indicates that the former was much easier for the microorganisms to decompose it than the later.

Total N

The initial total nitrogen content in the composting material ranged from 0.71% (100% cereal) to 2.03% (100% legume). The total nitrogen content in the compost generally increased as the legume content increased (Table 3). In the course of composting time, the total nitrogen content generally increased. The increase in total N content could be due to the decrease in OC content of the biomass which eventually increased the concentration of nitrogen in the compost.

Carbon-to-nitrogen ration (C/N ratio)

The C/N ratio in the initial composting material ranged from 66.5 (100% cereal) to 21.7 (100% legume). Generally, as legume content in the composting material increased, the C/N ratio linearly decreased (Table 3). With regard to the dynamics of C/N ratio with increase in time of composting, the C/N ratio generally decreased as the composting time increased. However, the C/N ratio in the cereal compost did not decrease too much during the composting period to obtain matured compost. The 100% cereal compost after 8.5 months of decomposition had a C/N ratio of 37.9 which is not still too suitable for application to the soil. The same phenomenon was observed for the treatment with 75% cereal + 25% legume compost.

As the proportion of legume was raised to 50% and the proportion of cereal straw was lowered to 50%, the C/N ratio also dropped below 20 after 7.5 months of composting. As the proportion of legume was further raised to 75%, the C/N ratio dropped below 20 just after 4.5 months of composting. After 8.5 months, the C/N ratio of this treatment was only 12.8. Composting of 100 % legume stover alone gave the lowest levels of C/N ratio at all composting periods and the desirable level of C/N ratio for application to the soil (below 20) was obtained after 3.5 months of composting.

The C/N ratio determines how long decomposition will take. For rapid composting, the initial C/N ratio of composting material should be in the range of 25 to 30. If the C/N ratio is above 35, the process will be considerably slower and if the C/N ratio is less than 20, nitrogen tends to be released than tied up (Biochemical and Microbiological Aspects of Composting, 1974). Compost that is immature or not well decomposed should be used primarily as mulch. Incorporation of immature compost into the soil may result in nitrogen deficiency and poor plant growth (Schumacher et al., 1987).

Inorganic N release

The inorganic N release was the lowest for 100% cereal compost and was the highest for 25% cereal + 75% legume compost. The N release from 100% legume compost was second next to the above treatment but was much better than other treatments which have higher cereal plant material composition. Inorganic nitrogen release increased as the time of composting increased up to the 7.5 months time. After this time all treatments showed a down turn in mineralization of nitrogen. The mean inorganic N release after 8.5 months of composting was 4.0, 6.0, 9.1, 10.1 and 9.7% of the total N for treatments 1, 2, 3, 4 and 5, respectively (Table 3).

Table 3. Dynamics of OC, total N and inorganic N contents in the compost during 8.5 months of composting

Treatment	Compost composition	Parameters	Composting time (months)					
			Initial	3.5	4.5	6.5	7.5	8.5

of the soil. Water holding capacity increased with increase in decomposition rate and legume content in the compost.

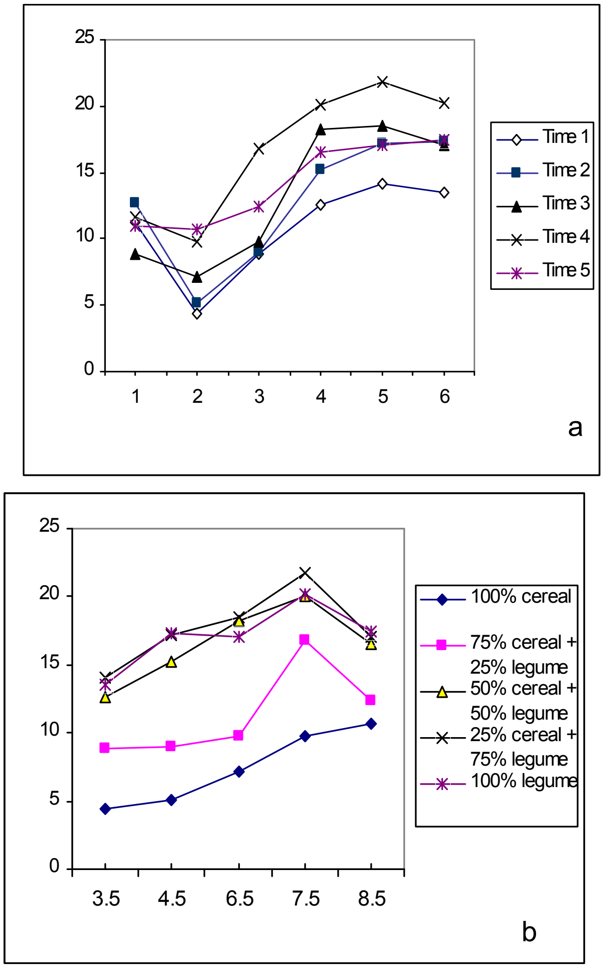

Figure 1. The effect of compost composition and composting time on fresh biomass yield of tef

However, as the cereal content in compost composition decreased and the legume content increased, fresh biomass yield also demonstrated an increasing trend. The increase was more linear up to the treatment containing 50% cereal and 50% compost. The increase showed a curvilinear trend beyond this treatment.

Almost for all treatments, fresh biomass yield increased up to composting time of 7.5 months (Figure 1b). As composting was proceeded further to 8.5 months, the compost from the same composting time gave diminished fresh biomass yield for all compost compositions except the 100% cereal compost. This particular treatment gave increased fresh biomass yield with increase in time of composting.

Dry biomass yield

Dry biomass yield exhibited similar response trend with the fresh biomass yield of tef (Figure 2a). The soil amended with 100% cereal compost gave lower dry biomass yield than the soil which did not receive any compost. As the legume level increased in the composting material, the dry biomass yield response showed a curvilinear increase up to treatment 5 which received compost with 25% cereal + 75% legume plant material. The treatment which received compost with 100% legume material (treatment 6) exhibited a diminished response than treatment 5 but was better than other treatments. Dry biomass yield as affected by composting time also exhibited similar trend with dry biomass yield (Figure 2b). It increased up to 7.5 months of composting and dropped beyond this time.

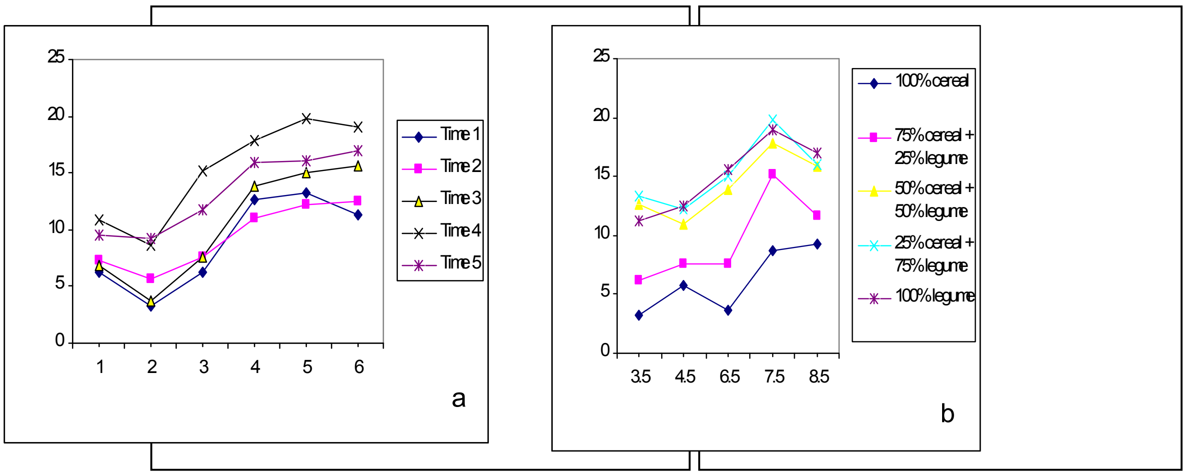

Figure 2. The effect of compost composition and composting time on dry biomass yield of tef

Grain yield

The treatments supplemented with compost containing 100% cereal straw gave lower grain yield values compared to the treatment which did not receive compost (Figure 3a). Other treatments, however, were better than the control treatment at all times of composting. The treatment with 25% cereal + 75% legume compost gave the highest yield almost at all times of composting followed by the treatment with 100% legume compost.

For all compost compositions, except the 100% cereal compost, composting time linearly increased grain yield of tef up to the 7.5 months of composting (Figure 3b). As composting time increased further to 8.5 months, grain yield declined. However, the 100% cereal compost exhibited an increase in grain yield as the time of composting extended.

Plant height

The treatment with 100% cereal compost gave lower plant height value than the treatment which did not receive compost at all (Figure 4a). However, the control treatment exhibited lower plant height value as compared to other treatments. As the legume composition was increased in the compost, plant height also increased.

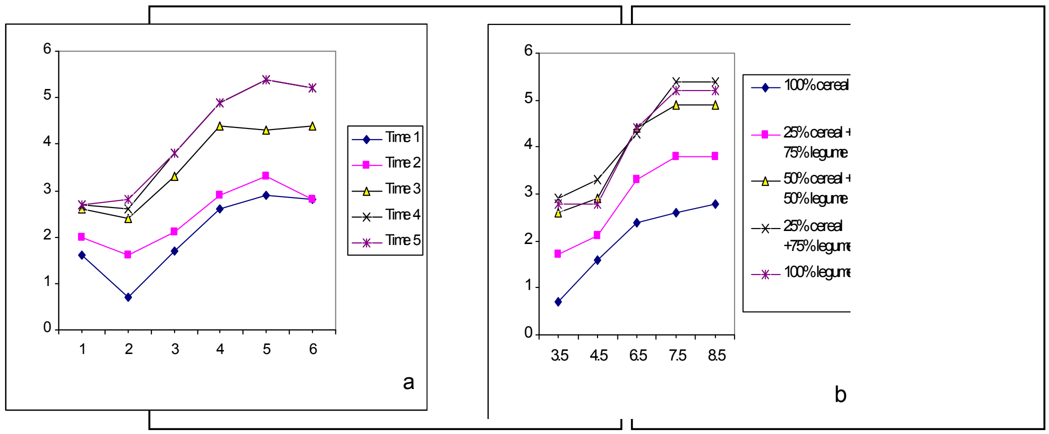

Figure 3. The effect of compost composition and composting time on grain yield of tef

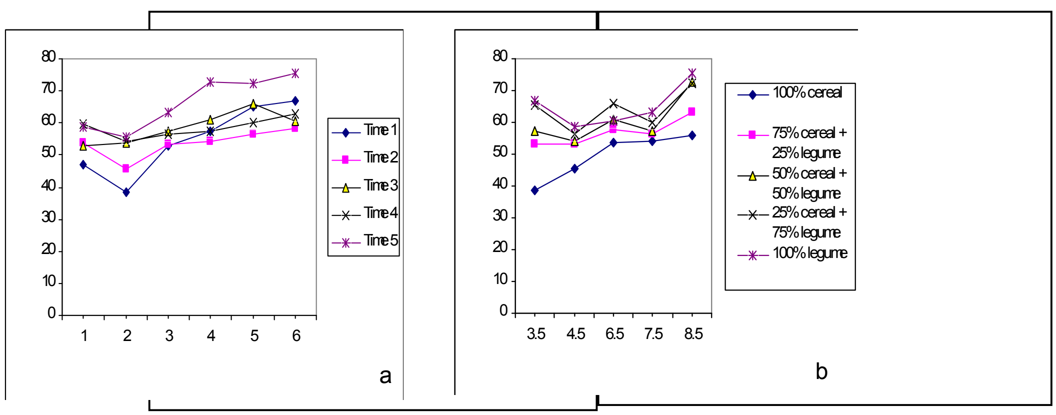

Figure 4. The effect of compost composition and composting time on plant height of tef

Plant height did not show a clear trend for composting time. However, it exhibited slightly linear trend with increase in time of composting (Figure 4b). The linearity of the trend was more superior for the 100% cereal compost than other combinations It was also noted that pots which received row compost were thinner and taller for most compost compositions. It was also clearly seen that pots which received 8.5 months old compost also tend to show increasing trend contrary to yield and yield components measured.

Comparison between mineral N fertilizer and compost

Pot experiment was also carried out to compare the effects of five rates of mineral fertilizer (0, 30, 60, 90, 150, 210 and 270 kg N ha-1) and the compost with the highest mineral nitrogen release (25% cereal + 75% legume) composted for 5 different durations, i.e., 3.5(T1), 4.5(T2), 6.5(T3), 7.5(T4) and 8.5 (T5) months. A rate of 90kg/ha mineral nitrogen gave the highest fresh biomass yield (51.7 gm/pot) among the mineral fertilizer treatments (Figure 5). When we compare the fresh biomass yield from this fertilizer rate with a 25% cereal + 75% legume compost composted for T1, T2, T3, T4 and T5 months, it was clearly seen that the mineral fertilizer gave more than a double fresh biomass yield advantage over the compost treatments. The compost composted for T4 months gave only 21.8 gm/pot fresh biomass yield.

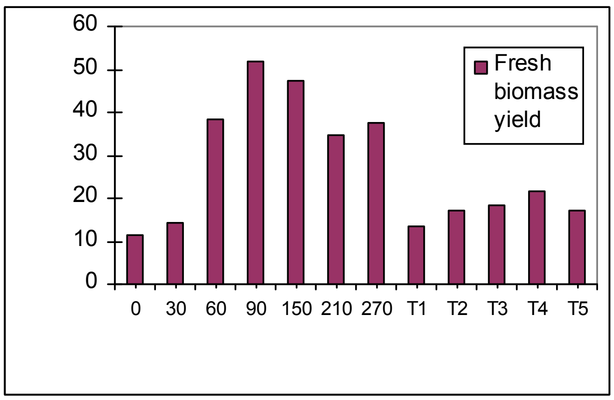

Figure 5. Comparison between fresh biomass yields of treatments that received different rates of mineral nitrogen and 10 tons of 25% cereal+75% legume compost composted for 5 different durations

The rate of 90kg ha^{-1} mineral fertilizer rate also gave the highest dry biomass yield (Figure 6). The yield was 34.5 gm/pot which is a 14.7gm/pot dry biomass yield advantage over the 25% cereal + 75% legume compost with T4 composting time that gave the highest mineral fertilizer release.

Figure 6. Comparison between dry biomass yields of treatments that received different rates of mineral nitrogen and 10 tons of 25% cereal+75% legume compost composted for 5 different durations

From the mineral fertilizer treatments, the highest plant height value (87.7cm) was registered from application of 90kg/ha mineral fertilizer. From the compost treatments, however, the highest plant height value was obtained from composting time of 8.5 months (72.1cm) (Figure 8). It is important to note that the differences in plant height among treatments were not wide enough as compared to the differences among treatments in fresh biomass, dry biomass and grain yields.

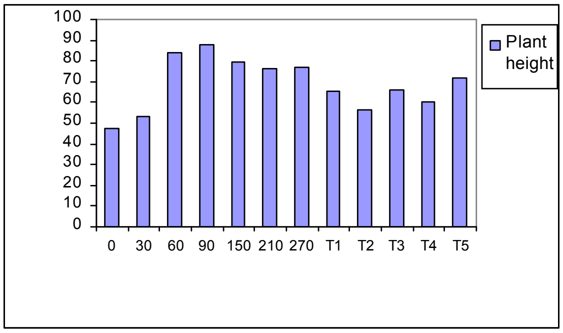

Figure 8. Comparison between plant height of treatments that received different rates mineral nitrogen and 10 tons of 25% cereal+75% legume compost composted for 5 different durations

Determination of inorganic fertilizer equivalency values of compost

The amount of available nitrogen release from the total N in the compost ranged from 3.76% in 100% cereal compost to 10.82% in the 25% cereal + 75%legume compost (Table 4). The amount of available N release demonstrated a curvilinear increase as the amount of legume in the compost composition increased. The amount of compost required to obtain 100kg of available nitrogen generally varied very widely. It ranged from 316.46 tons for the 100% cereal compost to 36.23 tons for the 25% cereal + 75% legume compost. This shows a negative correlation between cereal content in the compost and nitrogen release. As the composting time increased up to 7.5 months, the amount of nitrogen release increased and the amount of compost required to satisfy the inorganic nitrogen demand decreased.

Table 4. Determination of the amount compost required to obtain required available nitrogen content

Treat-ments	Composting time (Months)	Total N (%)	Available N (%)	Nitrogen release (%)	Compost to obtain 1kg available N (ton)	Compost to obtain 100kg available N (ton)
1	3.5	0.79	0.0316	4.00	3.16	316.46
	4.5	0.94	0.0353	3.76	2.83	283.29
	6.5	1.24	0.0496	4.00	2.02	201.61
	7.5	1.53	0.0614	4.01	1.63	162.87
	8.5	1.52	0.0603	3.97	1.66	165.84
2	3.5	1.06	0.0636	6.00	1.57	157.23
	4.5	1.09	0.0653	5.99	1.53	153.14
	6.5	1.32	0.0793	6.01	1.26	126.10
	7.5	1.6	0.0960	6.00	1.04	104.17
	8.5	1.58	0.0943	5.97	1.06	106.04
3	3.5	1.45	0.1454	10.03	0.69	68.78
	4.5	1.51	0.1498	9.92	0.67	66.76
	6.5	1.57	0.1544	9.83	0.65	64.77
	7.5	1.64	0.1682	10.26	0.59	59.45
	8.5	1.64	0.1497	9.13	0.67	66.80
4	3.5	2.01	0.2030	10.10	0.49	49.26
	4.5	2.39	0.2587	10.82	0.39	38.65
	6.5	2.59	0.2672	10.32	0.37	37.43
	7.5	2.67	0.2760	10.34	0.36	36.23
	8.5	2.68	0.2717	10.14	0.37	36.81
5	3.5	2.37	0.1949	8.22	0.51	51.31
	4.5	2.59	0.2582	9.97	0.39	38.73
	6.5	2.67	0.2617	9.80	0.38	38.21
	7.5	2.76	0.2757	9.99	0.36	36.27
	8.5	2.77	0.2683	9.69	0.37	37.27

Conclusions and Recommendations

From the results of the experiment it is possible to conclude the following;

1) The organic carbon contents in cereal and legume plant materials do not significantly vary among each other;
2) Legume plant materials have higher total nitrogen content and lower C/N ratios as compared to cereal plant materials;
3) As the composting time increases, the organic matter content and C/N ratio in compost materials decreases while the total N content and inorganic nitrogen release increases;
4) As the legume content in compost materials increases, the response of tef in fresh biomass, dry biomass, grain yield and plant height increases;
5) As composting time increases up to 7.5 months fresh biomass, the response of tef in dry biomass, and grain yield increases while there was no clear response in plant height.

6) The experiment clearly indicated that a huge amount of compost is required to obtain equivalent amount of nitrogen that could be obtained from mineral fertilizers.

From the results of the experiment it is possible to recommend the following:

1) The plant materials composition in compost need to be 25% cereals' and 75% legumes' stubbles. Increasing the proportion of cereal material above 50% could cause nitrate depression in the soil and subsequent yield reduction.
2) The optimum composting time for 100% cereal compost and 75% cereal + 25% legume is >8.5 months; for 50% cereal + 50% legume compost is 7.5 months; for 25% cereal + 75% legume compost is 4 months; and for 100% legume compost is 3 months. However, it is recommended that further study on nitrogen release dynamics of compost over years is required.
3) Since huge amount of compost is required to satisfy the nutrient demand of crops, compost should be applied in combination with mineral fertilizers for commercial purposes. This procedure will supply effectively the crop nutrient requirement as well as will improve the organic matter content and physical properties of the soil. However, for the subsistence type agriculture of Ethiopian farmers, compost remains to be very useful low cost organic fertilizer.

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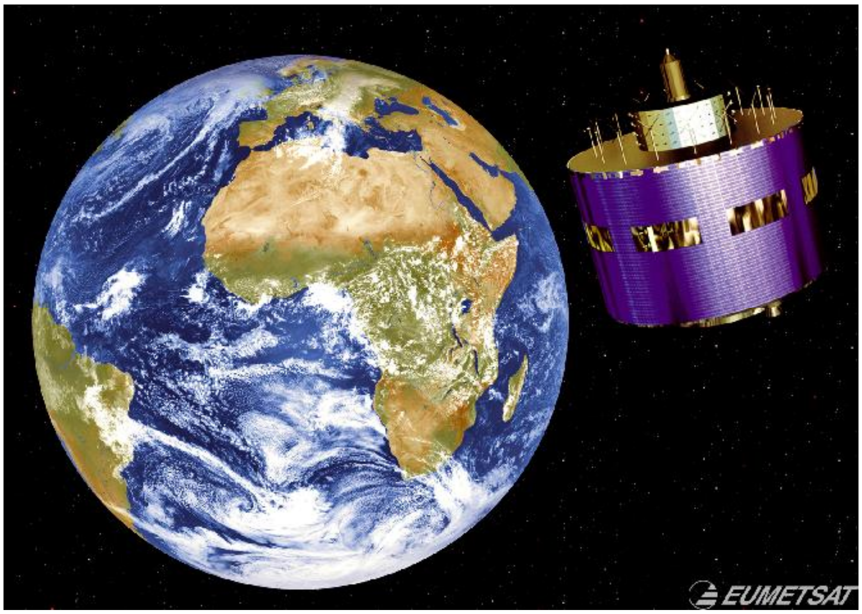

III) GIS and Remote Sensing Based Land Resource Studies