# The effects of humanure and ecofert (urine) on soil fertility and physical properties

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**Abstract**

In recent diagnostic survey of smallholder agricultural sector in the Manyame catchments of Zimbabwe it was revealed that exhausted soils depleted of their natural mineral and organic constituents by years of cropping with little fertilization or manuring were the major problems contributing to low yields and poor food security in this sector in Zimbabwe. The low organic matter content of the exhausted sandy soils in the smallholder sector in Zimbabwe predisposes them to the rampant soil erosion and land degradation that is characteristic of the communal areas today. Cheap and readily available sources of plant nutrients and organic amendments are therefore urgently required to turn around the deterioration in soil fertility, to improve crop yields and ensure food security

The aim of the study was to promote the use of human excreta to rehabilitate soils and improve agricultural production for the smallholder farmers in Manyame Catchment. It was hypothesised that use of compost human excreta can improve soil fertility as well as water retention capacity of soil. The study investigated the effect of using composted human excreta and urine on soil fertility and physical properties. Samples of urine used in the study were taken and analyzed in the laboratory to determine the amount of crop nutrients available in the urine. The main nutrients that were assessed were nitrogen in the form of ammonia, potassium, phosphorus and other trace elements such as calcium and magnesium. Soil samples were taken to determine nutrient content of the soil before the application of the urine and composted feacal matter. Repeat soil samples were taken four weeks (4wks) after the application of the nutrients to ascertain any change in the fertility of the soil. After 10wks weeks of planting the crops bulk soil samples to determine the effect of using human excreta on soil physical properties such as water holding capacity, organic carbon content and particle distribution. The study concluded that using human excreta particularly humanure improves the soil water holding capacity making moisture available to crops especially during midseason dry spell which has become a common phenomenon in Zimbabwe and other tropical regions.

***Keyword**s* Soil fertility, permanent wilting point, water holding capacity, humanure, and ecofert

**1.0 Introduction**

Low soil fertility is one of the major environmental constraint to optimum crop yields (DRSS ,2001) and there is strong evidence showing that soil fertility deficiencies often is a more serious constraint for crop growth and productivity than soil water deficiencies in the Sub –Sahara Africa. This suggests that significant crop yields can be achieved through a major soil fertility enhancement (Rockstrom, 1999). A deliberate and concerted effort to develop and disseminate improved and appropriate soil fertility management techniques offers the best possibility for increased crop productivity (DRSS, 2001).

Some work on manure and fertilizer combinations in vegetables was done in the 1990s on farm location in Chiota and major benefits of using fertilizer and manure combinations on vegetable included a reduction in mineral fertilizer rates for combining with manure hence the reduction in cost and better plant growth and higher yields of vegetables due to synergistic effects between fertilizer and manure. (DRSS, 2001) .

The depression in crop yields when soil pH values were below 6.0 was attributed to nutrient imbalances characteristic of weakly buffered sandy soils when high doses of lime are applied at once (DRSS,2001). The Agronomy Research Institute’s Weed Research Team (ARIWRT) has shown that soil pH has an influence on weed species distribution. Results from work on soil acidity imply that regular use of lime on sandy soils must be an integral part of soil fertility management, this however might prove impossible where farmer can’t even afford the basic crop nutrients like AN and compound D (ARIWRT,2000).

Current fertilizer guidelines place emphasis on the application of macro-nutrients such as N, P and K. The continued mining of micronutrients from the soil through harvested grain has resulted in decline in yields even where N, P and K are adequate (DRSS,2001). A study to determine the effects of cattle manure aggregates on soil aggregate stability and water retention capacity of sand soils showed that manure application improves soil organic carbon C by (10-38%) in the (0-10cm) layer. The Readily Available Water (RAW) capacity of the soil was significantly increased by manure additions whereas the increase in AWC was not significant (Gotosa, 2001)

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### 2.0 Methodology

**The study was carried out in lower part of the Manyame catchment at Muzika Primary School near Guruve growth point about 150km from Harare. This site was chosen for soil analysis because ecosan has been practiced for about four years. It was assumed by the study that such prolonged nutrient amendment could have affected the soil physical structure by now.**

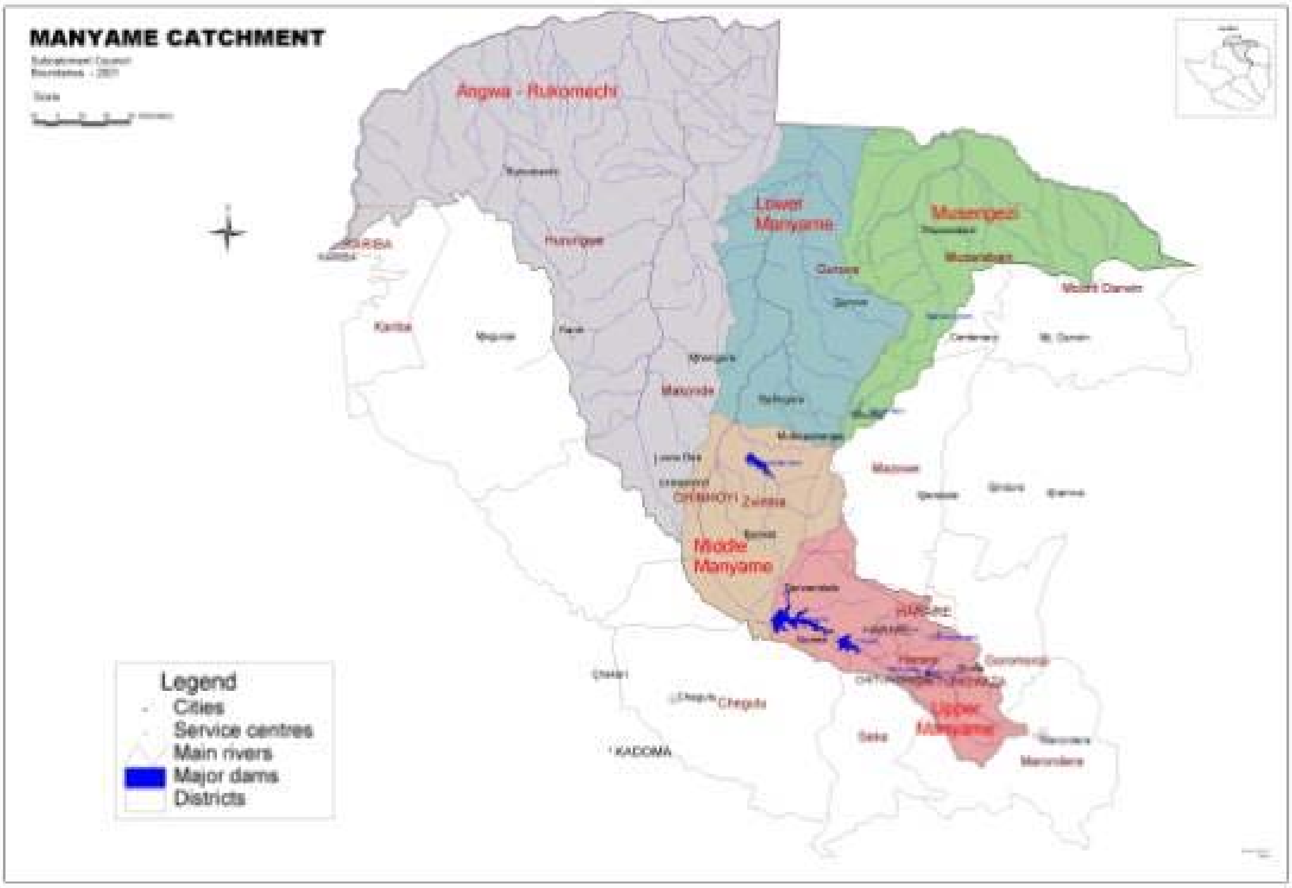


Figure 2.1 Map of Manyame Catchment

Lower Manyame Catchment has grey loamy sand soils of granite origin these soils have been worked on for more than 100 years and have become easily readable because of intense animal and human activities that are taking place in the area

Temperature ranges from warm to very cold during winter with minimum temperature going as low as 20 degrees Celsius. The area, like other parts of the country experiences winter as from May up to July. Summer starts in October up to March maximum summer temperatures may go as high as 22degree Celsius. The study area falls under natural region 2 and 3 characterized by high to moderate rainfall with average rainfall ranging between 600 mm – 1200 mm. In the 2003/2004 cropping season however the average rainfall was about 630mm The rainfall comes around the 15 of October, but is highly variable with mid season droughts very common especially around January. Cropping season faces high rainfall variability with midseason dry spells extending to as long as three weeks. In some bad seasons the midseason dry spells causes complete crop failure. Ground water table ranges from 3m on average to about 15m. Guruve communal area is a shallow well area, deep well are found in some dry parts of the area.

### 2.1 Soil assessments

Soil samples to determine the full soil fertility and soil physical properties for the control and treated plots at each of the participating household and school were taken from 5cm to 20cm depth range then send to the Department of Research and Specialist Services (DRSS) for analysis. Before each sample was taken 5cm clearance of residue organic matter was done. Intact soil cores of $200cm^3$ capacity were collected in triplicates from the soil sub-surface for water retention and bulk density measurement. In addition about 2kg composite soil samples (4-sub-samples per plot) were collected from the top 10 cm of soil for organic carbon and particle size distribution. Because of the resource constraints no follow up samples were taken to determine the nutrient content after the harvest.

### 2.2 Soil fertility
In order to determine soil pH 5 grams of 0.01M Calcium Chloride was added into a 25 ml soil water solution. The solution was shaken for 30 minutes allowed to settle for about five minutes. A digital pH meter was used to measure the pH after standardization using buffer pH of 4 and 7. Nitrogen determination was done by examining ammonium, nitrogen itself could not be determined. Nitrogen was determined as initial nitrogen in its inorganic form and organic nitrogen after two weeks incubation. Ammonium nitrogen was extracted using the Potassium Chloride $K_2CL$ extraction method. The Ammonium Nitrate is measured as mg/kg soil and usually below 20 is considered low, 20-30 mg/kg is considered medium, 30-40 mg /kg is adequate and anything above 40 mg/kg of soil is higher or rich under such conditions minimum or no addition of urine is recommended. Phosphorous was measured as available phosphorous using the resign extraction methods. The following are the ranges used for recommendations below 7 very low, 7-15 deficient, 15-30 moderately deficient, 30-50 adequate and above 50 is considered high and such soil may not require further nutrient addition. The base metals potassium magnesium and calcium were determined using the Ammonium Acetate method. Calcium and magnesium were measured using the Atomic Absorption Spectrometer (AAS) and potassium and sodium were measured using the flame photometer. The units for the base metals are usually 1 mg/100g of soil. Usually the general fertilizer recommendations for the study area were given by the (DRSS) as AN 200kg/ha, D 350kg/ha.

### 2.3 Soil organic carbon
The modified Walkey-black method determined soil organic carbon (Houba ***et al.***1989). This method entails complete oxidation of soil organic carbon by heat with a solution of potassium dichromate and sulphuric acid. The excess dichromate is determined calorimetrically.

### 2.4 Particle size distribution
The air dry samples were dispersed in calgon solution by an electric stirrer and the particle size distribution of the soil was determined by sieving and sedimentation (hydrometer method) (Bouyoucos, 1950).

### 2.4 Measurement of soil water ‘constants’

### 2.5 Field Capacity FC
Field capacity is the amount of water retained by an initial saturated soil, which has been allowed to drain under gravity in the absence of evaporation; this is the upper limit of plant available water. Water retained at field capacity (FC) was measured in the lab on intact soil cores using the hanging water column technique (water manometer). The determination entailed saturating the soil cores by capillarity and draining under gravity in the absence of evaporation. Saturated soil cores were transferred to a sandbox (suction table) at a pressure of 5kPa (under pressure). A hanging water column set the pressure. Loss in weight of the soil cores was monitored at 48-hour intervals. The cores were declared to have equilibrated, when the weight loss between consecutive weighing was negligible (<0.1 g). After equilibration, the soil water content was then determined at this pressure (equivalent to field capacity).

### 2.7 Permanent Wilting Point (PWP)
This is the soil water content beyond which a plant growing in the soil wilts irreversibly. In the lab water content retained at suction 15bars constitute PWP and the pressure membrane apparatus obtained it. The PWP corresponds to the lower limit of available water. The permanent wilting point was obtained by the pressure membrane extraction method (Klute, 1986). Saturated soil samples were subjected to a constant pressure of 1500 kPa in a pressure chamber until equilibration. The volume of water extracted from the soil samples was monitored in a burette until equilibration. After equilibration, the soil water content was then determined at this pressure (equivalent to wilting point).

Available water capacity (AWC) The AWC or (water holding capacity) is the volume of water retained between FC and PWP. It is a concept applicable to freely draining soils.

**AWC = QvFC – Qv pwp in w** **(2.1)**

Where AWC is the Available Water Capacity
Qv is the quantity x flow velocity
FC is the Field Capacity
PWP is the Permanent Wilting Point

Available water capacity was computed as the difference between the water contents at field capacity and permanent wilting point.

### 3.0 Discussion and results

### 3.1Fertility and nutrient variations in soils

It has been found in the study that the soils in the project area have acidic level ranging from pH 4.1 – 5 which was considered inappropriate for crop production. It has also been shown that human excreta contain crop nutrients and their application to the soils improves fertility as well as pH of the soils improving the productivity of the land.

### 3.2 Urine analysis

The urine that was used in the study was taken for analysis at the Soil Science and Civil Engineering laboratories at the UZ to ascertain the amount of nutrients in the form of Nitrogen Ammonium ( $NO_3NH_4$) Phosphorous (P), Potassium (K) and Calcium (C). The table below shows the results of the analysis

Table 3.1 Nutrient content of Urine

| Sample ID | Ammonia ($NH_3$) in 100ml of urine (mg) | Phosphorus (P) in 100ml (mg) | Potassium (K) in 100ml of urine (mg) | Calcium in 100ml of urine (mg) |
|---|---|---|---|---|
| Farmer 1 (OM) | 240 | 12.7 | 91 | 0.02 |
| Farmer 4 (MM) | 350 | 12.07 | 85 | 0 |
| Farmer 2 (GM) | 200 | 3.7 | 86 | 0 |
| Farmer 5 (SM) | 200 | 9.45 | 58 | 0 |
| Farmer 3 (EM) | 190 | 12.4 | 79 | 0.08 |
| Farmer 6 (CT) | 280 | 3.0 | 88 | 0.17 |

The above results indicate that urine does contain nutrients required by the crops; nitrogen is contained as Nitrogen Ammonium $NO_{3.}HN^4$. Table 3.1 above shows the nutrient content in 100 ml of urine collected from different households. Nitrogen content in a sample of urine differs from household to household. It was not clear why nutrient content differs from one household to the other may be further studies are required in this respect. On seeing some differences in the nutrient content of urine from different household an investigation was carried out into other possible causes and some clue were given. The urine from different household and sources was thoroughly mixed before application. Socio economic analysis revealed that nutrient content in urine may be linked to the family diet and the amount of fluids intake by a particular individual. It appears that families with a higher intake of meat for example Farmers MM, CT and OM had relatively higher Ammonia content in their urine ranging between 240, 350 and 280 mg per 100 ml respectively. These families had higher incomes compared to other households in the study who had relatively low Ammonium Nitrogen content in their urine ranging from 200, 200 and 190 mg/100 ml of urine for the low income farmers namely farmers GM, SM and EM respectively. Further investigations into the diet of the individual families indicated that relatively higher income families eat meat or beans five days a week while the relatively low income families eat meat and or beans three times a month. The same relationship was observed with respect to phosphorous (P), the urine from higher income families had higher phosphorous content compared to the urine from lower income families. For example urine from MM, OM, and CT had on average Phosphorous (P) content of 12 mg per 100 ml compared to an average of 5.5 mg per 100 ml for farmers GM, EM and SM whom we consider to be of lower incomes than the trio above. There was however no marked variations in Potassium (K) content in all the urine collected from the different urine samples probably because Potassium is a vital element required in the body for membrane formation hence it is not excreted in large amounts. What is of more interest is the fact that urine from excessive fluid consumers has fewer nutrients than “normal” urine. For example urine collected from a beer-hall has fewer nutrients than urine collected from all the six households. Calcium (C) is in minute quantities in all samples the samples irrespective of income level or diet of a household.

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Soil samples were taken from different plots treated with the following different nutrients commercial fertiliser compound (D) and Ammonium Nitrate (AN), humanure + ecofert and ecofert only and the Control plot where no nutrients were added. The Fig 2.2 below shows nutrient levels in soils taken from different plots after treatment the control represents the scenario before addition of nutrients. Shows nutrient levels in soils taken from different plots after treatment the control represents the scenario before addition of nutrients.

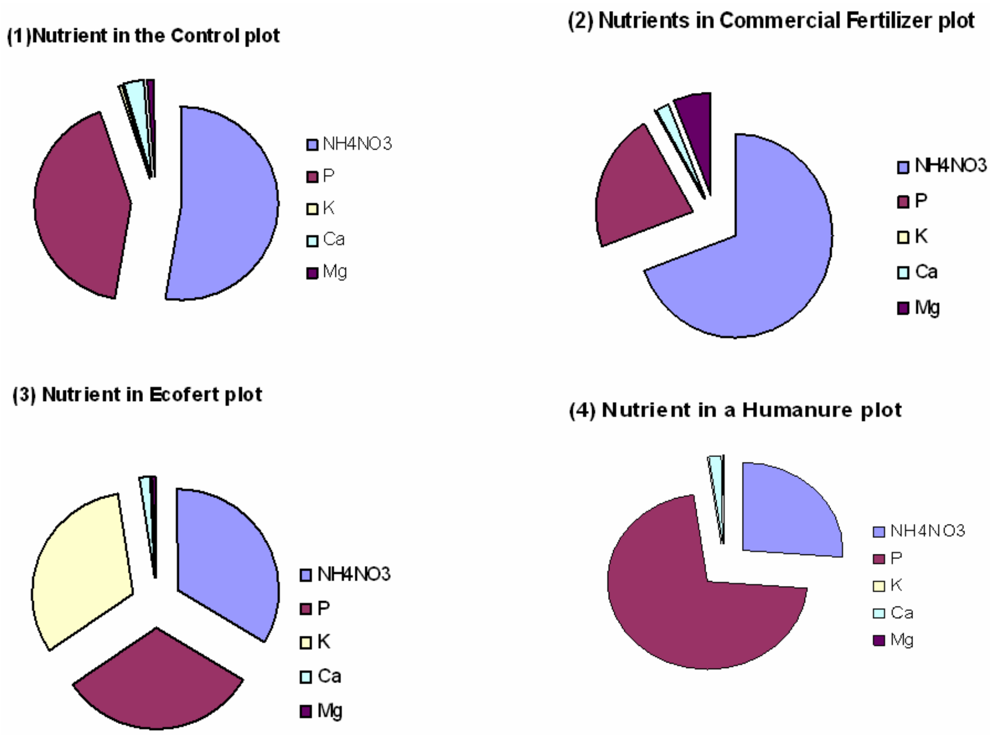


Figure 3.1 Levels of nutrients in plots treated with different nutrients and the control

From the above analysis using the pie charts on figure 3.1 above, the study shows a significant increase in phosphorus (P) from an initial 43% in the control plot to 72% in the humanure plot after the addition of humanure. What is not very clear is the decrease in phosphates from the initial 43% in the control plot down to 32%. One supposition may be that because of well developed root system the plants in the ecofert plots have absorbed most of the phosphorous. If this is the case it may suggest that what is being observed in the humanure plot is the residual phosphorous or humanure slowly releases nutrients to the plants. A marked increase of potassium (K) was observed in humanure plot compared to all other plots from negligible levels to 33%. With respect to nitrogen it is observed that nitrogen levels in the control plot increased from 53% to 70% in the commercial fertiliser plots and diminishing values of 26% and 32% respectively were observed in the humanure and ecofert plots

The findings on the effect of adding nutrients in the form of human excreta or commercial fertilizer seems to indicate that treating soils with human excreta has the effect of improving soil fertility and raising pH to levels conducive for maize production. For example soils treated with ecofert (urine) had pH raised from an average of 4.6 to an average of 5.5 for the three sample farmers. Soil treated with humanure (faecal matter) had pH raised from an average of 4.6 to an average of 6.7 indicating that humanure is more effective in neutralising the acidity of soils when compared to ecofert. This is probably due to high wood ash content that is added by the users as part of the preliminary treatment process of the faecal matter while it is still in the toilet vault.

It has been observed that potential increase of nitrates available to plants is higher in soils treated with humanure than both the control and ecofert treated soils for example for farmer 2 GM initial Ammonium Nitrogen was 9 ppm and this increased to 62 ppm upon incubation representing a 530% increase. For ecofert treated plot the increase was from initial 19 ppm to 65 ppm which is 230% increase. For the control the Ammonium Nitrogen increased from 12 ppm to 68 ppm which is a 462% increase. Increase in available phosphates and potash was observed in soils treated with humanure and urine respectively indicating the effectiveness of these nutrients in improving soil fertility. For example in Farmer 3 SM plots soils treated with humanure had phosphates of up to 244 ppm which is higher than the phosphates levels in ecofert treated soil with 28 ppm but all these figures reflected a marked increase in phosphorous levels when compared to 15 ppm found in the control in the field of the same farmer. The same pattern was observed for both Farmer 2 (GM) and 5 (EM). What is suggested by the findings is that treating soils with human excreta has the effect of improving soil fertility. Calcium, magnesium and potassium are low in the soil this is due to these nutrients being trace elements and as a result are very important in the human body hence less is being excreted by the human body. Magnesium is mainly essential for energy transformation in the body as result very little quantities are released into the soil; it can also be assumed that these elements exist in minute quantities in sandy soils as they easily leached. Potassium is also very little in the soil and this is probably due to the fact that it is an essential nutrient used for maintaining membrane potential difference in the body thus we can safely conclude that this is the reason why at all the farmers plots the content of K is minimal. The large quantities of phosphorus (P) are in humanure plots which we have assumed to be linked to the diet of the farmers; it is most likely that most of their diet has high phosphorus content. Further research may be needed to ascertain exactly what it is that determines nutrient elements content in an individual.

### 3.2 Soil physical properties

Bulk samples of soils were taken from fours treatments at two different fields and were analyzed by the (DRSS) to determine the comparative effects of applying ecofert only, humanure + ecofert, commercial fertilizer on the soil physical properties compared with a scenario where nothing was applied. The table below summarizes the results and findings of the analysis. Additional bulk samples were also taken for particle distribution and table 3.3 shows the results as indicated below.

Table 3.2: Effect of humanure, ecofert and fertilizer on water retention capacity of sandy soils in Lower Manyame Catchment (Guruve district)

| Site | Lab No. | Treatment | Sample Reference | No of samples | FC (% v/v) Ave. | PWP (%v/v) Ave. | AWC (%v/v) Ave. | Bulk density Ave. |
|---|---|---|---|---|---|---|---|---|
| Muzika primary sch | A | Commercial fertilizer | MZF a | 4 | 21.0 | 8.9 | 12.4 | 1.39 |
| | B | Humanure | MZH b | 4 | 26.0 | 11.8 | 14.5 | 1.29 |
| | C | Ecofert (E) | MZE c | 4 | 21.0 | 7.6 | 13.4 | 1.42 |
| | D | Control | MZC d | 4 | 20.0 | 9.4 | 10.6 | 1.46 |
| Kutadzaushe (KT) | 1 | Commercial fertilizer | KTF | 4 | 21.0 | 10.5 | 10.5 | 1.51 |
| | 2 | Humanure | KTH | 4 | 26.0 | 8.5 | 17.5 | 1.38 |
| | 3 | Ecofert | KTE | 4 | 24.0 | 12.6 | 11.4 | 1.48 |
| | 4 | Control | KTC | 4 | 21.0 | 10.7 | 10.3 | 1.51 |

Table 3.3 Particle size distribution and organic carbon content of soils at study sites

| *Site* | *No of samples* | *Ref* | *Particle* | *Size* | *Distri-bution* | | | *Texture class* | *Organic carbon (%)* |
|---|---|---|---|---|---|---|---|---|---|
| | | | %clay | %silt | %fine sand | Medium sand | %course sand | Medium loamy sand | |
| Muzika primary school (MZ) | 4 | MZF | 5 | 11 | 42 | 22 | 20 | Coarse loamy Sandy | 1.06 |
| | 4 | MZH | 4 | 8 | 34 | 29 | 25 | Coarse loamy Sandy | 1.02 |
| | 4 | MZE | 4 | 7 | 38 | 26 | 25 | Coarse loamy Sandy | 1.00 |
| | 4 | MZC | 3 | 9 | 36 | 27 | 24 | Coarse loamy Sandy | 0.63 |
| Kutadzaushe (KT) | 4 | KTF | 8 | 6 | 41 | 22 | 23 | Coarse loamy Sandy | 0.89 |
| | 4 | KTH | 6 | 10 | 38 | 23 | 24 | Medium loamy Sand | 1.13 |
| | 4 | KTE | 8 | 10 | 44 | 20 | 19 | Medium loamy Sand | 0.95 |
| | 4 | KTC | 8 | 10 | 43 | 19 | 19 | Medium loamy Sand | 0.97 |

Table 3.3 above shows that feacal matter (humanure) treatment improved the amount of soil water held at field capacity (FC) more than any other treatment. At Muzika primary school, feacal matter (humanure) plus urine (ecofert) fertilization (H+ EF) increased the FC by 6% whilst the commercial fertilizer and urine (ecofert) treatments marginally increase by (1%) this parameter. The feacal (humanure) is hypothesised to increase soil organic carbon content and soil structure which enhances water retention at low soil suction such as Field Capacity (FC). This study also revealed that humanure treatment increased the AWC of the soil by 4% to 15% at Muzika primary when compared to the control treatments. Better increases (+ 2.8% for ecofertilisation, 1.8% for commercial fertilizer, table3.2) in AWC of the soil were observed than FC at the site.

The organic carbon status under the humanure (H) treatment is consistently higher it both sites, though the values are low (<2%) for all treatment (table 3.2) probable due to rapid decomposition rates under these tropical climatic conditions.

At Kutadzaushe site similar trends were observed by the response variables (FC, AWC), Humanure application increased the AWC by 7.2% to 17.5% when compared with the control when compared with the control (table 3.2). Commercial fertilization (KFT) and ecofertilisation (KTE) marginally increased available water capacity of the soils. These two soil amendments are basically inorganic in nature and they have minimal effect on water retention.

What is clear from the study is that humanure and ecofert treatment response is dependent on soil texture. It has been shown in this study that the treatment response is more pronounced at the Kutadzaushe site due to disparities in soil texture. At the KT site, the soils are heavier (medium sandy loam) than at the MZ site where the soils are sand. The heavier soils at the KT site interact with organic carbon and promote build up of organic matter in the soil system, which in turn improve soil aggregation (structure). Consequently, the soil organic carbon organic carbon contents are higher at this site.

The bulk density of the soil is a coarse measure of the soil structure. High values imply poor soil aggregation and low organic carbon content. In this study, the average soil bulk densities at both sites were lowest under humanure treatment (1.29 $cm^3$ at Muzika and 1.38 $g/cm^3$ at Kutadzaushe). This testifies that soil structure and water retention were improved by humanure treatment. Higher bulk densities values (1.40-1.52g $cm^3$) were obtained under humanure sites of the treatments where organic carbon was relatively high at both sites. Findings of this study agrees very well with what Johnsson 1999 found in study done by Uppsala University at on farm experiments in Sweden.

The study also revealed that some of the soils in Manyame Catchment have lost their natural fertility as a result of several years of cultivation without proper soil fertility or adequate nutrient addition. The above development has resulted in farmers in Manyame Catchment realizing deteriorating crop yields year in year out without a solution being visible in the near future. Soil pH has fallen to unprecedented levels with some fields recording a pH as low as 4.2 such low pH is not conducive for maize production. Maize requires a pH of about 6.3 to 7.0 for viable production. This finding agrees very well with results of a study done by Department of Research and Specialist Services (DRSS) in the Ministry of Agriculture. Alternative sources of crop nutrients are definitely needed to turn around the fortunes of smallholder farmers. The use of humanure and ecofert is a promising option for a readily available cost effective source of crop nutrients.

**Conclusion**

Higher bulk densities values (1.40-1.52g $cm^3$) were obtained under humanure sites of the treatments where organic carbon was relatively high at both sites. Humanure application increased the (available water capacity) AWC by 7.2% to 17.5% when compared with the control his study also revealed that humanure treatment increased the AWC of the soil by 4% to 15% at Muzika primary when compared to the control treatments. Nutrient levels increased remarkable for example it has been shown that Phosphorous which is an important nutrient for maize growth increased from 43% by volume to 72% while nitrogen increased from 53% in the control to 72% in the humanure + ecofert treatment. It can safely be concluded that treating soils with humanure and ecofert improves the nutrient and organic carbon content of soils considerable and increase soil pH to levels conducive for maize production, this was more pronounced where humanure + ecofert nutrient strategy was employed. Soil structure and water retention were improved by humanure treatment.

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