Soil Water Erosion Research

Application of green manure to annual crops to reduce erosion and increase yields

Introduction

Water erosion is the detachment and transport of soil by the energy contained in moving water, particularly raindrop impact and surface runoff. Water erosion results in the loss of the fertile topsoil required for healthy plant growth. Water erosion is particularly severe in sloping upland areas of Vietnam due to farming methods, steep slopes, shallow poorly structured soil and heavy rainfall[1]. Green manure (green plant material) contains more nutrients then dry plant material, potentially increasing plant growth while providing erosion control[2].

Local sources of green manure are readily available in the upland areas of Vietnam. These sources can be weeds, remains of a previous crop or a poorly utilised waste product from other processes e.g. leaves from forest trees and elephant grass stalks. In locations where sources of green manure are poorly available, strategic planting of a source with increase the availability, such as hedgerows or cover crops, resulting in minor reductions in productive area. Local field trials need to show it is possible to offset the reduction in productive area by the increase in productivity in the crop.

Not all green manures are the same. Using a simple field trial different green manures can be assessed to determine there respective effectiveness at reducing erosion and increasing plant yield.

The structure of this report focuses on relatively simple and universal methods and considerations to conduct a field trial. The methods assess soil erosion by raindrop impact, mulch decomposition rate, plant biomass productivity, plant yield, weed growth, soil moisture. It is not essential to use all of the methods below together. In addition, most methods will need customisation to fit the situation. Make the trial as simple and efficient by only concentrating on the important issues. For example to assess the affect of time of application of the same green manure additions there is little need to assess decomposition rate.

Literature review

1) Only use research which from credible sources
2) Look for similar studies
3) Identify most suitable method for the situation
4) Identify what issues needs to be considered for the trial to be successful.
5) Identify the expected results

Applied research is about suitable solutions

1) Ensure the solutions are feasible for the audience
    a) The solution needs to be relatively simple
    b) The solution needs to be available to the target audience
    c) The site needs to be similar to the target audience

    d) The farming system needs to be similar to the target audience

Ensure the results can be communicated to the audience

1) Include management practices typical of the audience as a treatment
    a) This allow direct assessment if the treatment is better then their current management practices
2) The key difference between treatments need to be simple
    a) Complex difference between of treatment will be hard for the audience to understand
3) Measure meaningful properties which are understood by the audience
4) Only communicate the most important and interesting findings.
    a) Too much information will confuse people and dilute the main points

Experimental design

1) Try to choose a location where you would expect crop growth and erosion to be uniform between plots without the treatments applied. Ideally, the only difference between the plots is the treatment applied.
2) Keep the number and spacing of plants relatively similar between treatments.
3) Stick to typical field conditions. Avoid extremes of plant growths, or erosion. For example, locate plots around, but not in areas prone to water logging and avoid edges of the field.
4) The larger the plot the more they will represent erosion typical of the field. However, larger plots will need larger containers to catch all the runoff and sediment.
5) Greater replication allows a more accurate description of the variation and reduces the bias of toward treatment located is naturally better areas. Where large natural variation is expected more replication is required to gain confidence in the results

Materials

1) For the erosion trial
    a) Plastic pipe
        i) Directs runoff into container
        ii) Gutter when cut in 1/2 length ways
    b) Elbow joints
        i) Allows connection of gutter and pipe
    c) Physical barriers
        i) Material not critical but needs to be durable and impervious to water.
    d) Large container with lid
        i) Allows capture runoff from large erosion events.
                (a) 1mm of rain per m^2 = 1L
            (2) As a very rough guide for poorly structured soil assume ½ rainfall will runoff
                (a) Container size (L) = ½ maximum rainfall expected in a day multiplied by the plot size m^2
        ii) Lid prevents direct rainfall filling container
    e) Small container
        i) Allows easier measurement of small erosion events

f) Plumbers glue
    i) Seals plastic pipe and gutter to elbow

2) For litter bags
    a) 3mm nylon net
    b) String
    c) Needle
3) Turbidity tube
    a) 40-50mm diameter 1.2 m long transparent pipe
    b) White plug with a black line or cross on the bottom
4) Universal
    a) Numerous smaller containers
        i) Which do not melt at 150°C
        ii) Sized to fit on the small scale and in oven
    b) Oven
        i) Capable of maintaining low temperature 60-70ºC
        ii) Used for obtaining dry weights of plants and soil
    c) Small scale
        i) Weight up to at least 200g
        ii) Accurate to 0.2 g
    d) Large scale
        i) Weight up to at least 5kg
        ii) Accurate to 20g
    e) Tape measure
    f) Rain gauge

Method

1) Set up plots
    a) Minimise the impact of water from outside the plot by using barriers to direct water around the plot.
    b) Dig the gutter into the soil such that the top of the gutter is equal or slightly below the soil surface.
        i) Minimise soil disturbance within plot, as will cause erosion
        ii) Ensure there is no gap for the water to leak into before the gutter
        iii) Ensure there is sufficient slope on gutter to allow water to flow towards elbow.

2) Large container
   a) Place the container down slope such that there is sufficient slope to allow the water to flow through pipe into container.
   b) If necessary, dig containers into the ground and increase the length of pipe so the water will flow into the container.
   c) Put the smaller container inside to catch water flowing from pipe
      i) Allows easier and more accurate measurement
   d) The large container will need a large rock to prevent it floating or being blown away
   e) Another rock will help keep the lid in place

3) Make litter bags (not essential, but allows a measurement of the litter decomposition rate)
   a) The size should be large enough to fit a representative sample which can be weighted (suggestion: 25 by 30cm will fit approximately 200g of fresh leaves)
   b) Sow bags with needle and string so will not fall apart in use
   c) How many will need to make?
      i) number of treatments
      ii) Multiplied by number of times measured in time (Suggestion: at least 3)
      iii) Multiplied by the number of replicates (Suggestion: at least 3)

4) Apply a measured amount of mulch to each plot.
   a) Record
      i) Application details
         (1) Fresh weight applied (kg per m^2)
         (2) Ground cover estimate or measure %

(3) Date applied
(4) Growth stage of crop or weeks since planting

ii) Mulch properties
(1) Calculate moisture content of a representative sample
(a) Record the sample fresh weight
(i) Ensure the sample is not wet with rainwater
(ii) Remember to take the container weight from the sample
(b) Dry at 70ºC until the weight change over time is very small typically 2 days, but can be longer.
(c) Record the dry weight of the same sample
(i) Remember to take the container weight from the sample
(d) Moisture content (%) = ((fresh weight-dry weight)/dry weight)X 100
(2) Growth stage of mulch plant (pictures will help)
(a) Before or after flowering
(b) If the twigs are woody
(c) How green the leaves are
(3) Estimate or measure the composition (on a dry weight basis)
(a) % Sticks
(b) % Twigs
(c) % Leaves
(4) Measure or estimate decomposition rate
(a) Observe the time taken for the amount of ground cover to ½
(b) Measure the decomposition rate using litter bags
(i) Place a measured amount of mulch in each bag
1. Calculate the original weight of dry mater
a. Dry weight = Fresh weight X (1-(Moisture content (%)/100))
2. Place litter bags in field
3. Measure the change in dry weight over time
a. Remove 3 replicates of each treatment from the field at set days since application
i. The spacing of day should get longer with time
ii. Recommended spacing 0, 2 , 4, 8, 16, 32 weeks
iii. Fast decomposition mulch will need closer spacing
b. Record observations of decomposition (photos help) eg mulch colour change, insect activity, fungal growth, composition changes etc
c. Brush off excess dirt
d. Dry in oven and measure dry weight (as stated before)
i. Ensure to all dirt is removed before weighing (it is easier to remove when dry)

5) Measure plant height, weed height and ground cover numerous times through season
a) Plant height
(1) Ground to top of plants leaves fully erect

ii) Repeat for all corn in plot
(1) Measure each corn in the same order i.e. right to left and bottom to top

iii) Count the plants in plot
iv) Average height = sum of all heights/ number of plants

b) Weed cover
   i) Typical weed height
   ii) Estimate weed ground cover (%)

c) Ground cover
   i) Include anything which is not soil up to 20-30cm above the surface. Include weeds, fallen leaves, stones
      (1) Measure (time consuming to get an accurate result)
         (a) Lay a tape measure on the ground
         (b) Count the number of mm or cm marks laying over cover only on one edge of the tape.
         (c) Total number of mm or cm measurement taken /count
         (d) Repeat in around 10 times to get an accurate result
         (e) Best to complete half replicates up and down plot the other half left to right, to remove bias.
      (2) Estimate when you know % groundcovers looks like

6) Record daily rainfall
   a) Using rain gauge record daily rainfall events
   b) Rainfall will help interpret data

7) Measuring runoff and sediment
   a) Check small and big container for water
   b) If the water is clear
      i) Empty without measurement
      ii) Ensure the clear water is tipped out daily
   c) If water is dirty
      i) Wait for runoff to stop
      ii) Weigh the amount of water with the large scale
         (1) Remove container weight from measurement
         (2) If the large container fills add up use several measurements of the smaller container, transferring to another container after each weighing
         (3) Do not discard the water
      iii) Let the water and sediment settle for at least a day
      iv) With minimal disturbance, tip only the water into another container leaving the muddy sediment.
      v) Weight and record water removed
      vi) Mix thoroughly and take a measured representative sample
      vii) Slowly tip into turbidity tube until you can only just see the black line
      viii) Record the height of water in tube where this occurs
      ix) If the measurement is lest than 10cm, dilute the sample by a known amount and repeat measurement.
         (1) To dilute by a factor of 1/10 add 100ml to a litre container and fill with very clear water until made up to a litre.
         (2) If still too dirty dilute again.
         (3) Record the height and dilution factor (Sediment concentration can be calculated later)

x) Place muddy sediment in to a smaller container to fit the oven
xi) Dry at 70°C (105°C is have a metal container) until stops losing weight
xii) Weigh and record dry sediment weight.

8) Measure weed biomass at harvest
   a) Cut plants (weeds) in plot off at soil surface
   b) Put all weeds in a bag weight and record fresh weight for each plot.
   c) Measure moisture content (same as mulch)
      i) If weed composition quite different calculate a moisture content to represent each composition
      ii) Replication will give confidence to moisture contents
   d) Calculate dry matter (same as mulch)
   e) Calculate dry matter
      i) Weed biomass (kg/m^2) = Dry matter per plot (Kg)/ area of plot (m^2)
      ii) Weed biomass (t/ha) = (Weed biomass (kg/m^2)/1000)X10000

9) Measure plant yield
   a) Count the number of plants
   b) Remove fruit/ seeds from plant
   c) Count and record the number of fruit/ heads of seeds
   d) Weigh and record fresh weight for each plot
      i) Corn
         (1) Remove husk
         (2) Weight and record cob weight without husk
         (3) Dry cobs in oven at 70°C until stop losing weight
            (a) If there is not many cobs dry all (keep each plots separate)
               (i) Remove seeds from cob, weight and record for each plot
            (b) If too many dry 3 or 4 replicates of representative samples
               (i) Work out moisture content of cobs
               (ii) Work out seeds weight as a percentage of cob dry weight
               (iii) Calculate seed yield from fresh weights
      ii) Root crops
         (1) Remove root from ground
         (2) Clean off dirt
         (3) Cut root from above ground parts of the plant
         (4) Weigh and record fresh weight
         (5) Use 3 or 4 replicates of representative samples
         (6) Weight fresh weight of each representative sample
            (a) Cut into smaller pieces to allow quicker drying
            (b) Dry in oven at 70°C until stop losing weight
            (c) Work out moisture content
            (d) Use moisture content to workout dry weight
   e) Calculate yield (dry weight)
      i) Yield (kg/m^2) = Dry weight per plot (Kg)/ area of plot (m^2)
      ii) Yield (g/plant) = Dry weight per plot (Kg)*1000/plants per plot
      iii) Yield (t/ha) = (Yield (kg/m^2)/1000)X10000
   f) Yields of juicy fruit and vegetables are typically not dried and only recorded as fresh weight.

10) Measure plant biomass at harvest
   a) Cut plants in plot off at soil surface
   b) Put all plants in a bag weight and record fresh weight for each plot.
   c) Measure moisture content (same as mulch)
      i) If plant health is quite different calculate a moisture content to represent each group of plant with similar health (e.g. Poor group, Medium group, Good group)
      ii) Replication will give confidence to the moisture content results.
   d) Calculate dry matter (same as mulch)
   e) Calculate dry matter
      i) Plant biomass (kg/m^2) = Dry matter per plot (Kg)/ area of plot (m^2)
      ii) Plant Biomass (g/plant) = Dry matter per plot (Kg)*1000/plants per plot
      iii) Plant biomass (t/ha) = (Plant biomass (kg/m^2)/1000)X10000

Analysis of data

1) Look at the data and understand how the process works
   a) Generally, simple relationships will fit into one of the following 3 categories.
   b) A causes B to change
      i) E.g. Higher soil fertility causes higher yield
   c) B changes because the change in A
      i) E.g. Yield is higher because soil fertility is higher
      ii) E.g. Running rivers doesn't cause rain but rain causes rivers to run
   d) C causes both A and B to change
      i) E.g. Location in landscape causes both soil fertility and yield to change
      ii) E.g. Higher soil fertility causes better weed growth and plants growth. Higher plant growth doesn't cause better weed growth
2) For communication purposes, it is preferable to graph and describe the relationships as A cause B, with A on the x axis (horizontal axis) and B on the y axis (vertical axis)
3) Transform the data to display causation, minimising any confounding factors.
   a) E.g. If there is an uneven numbers of plants, the number of plants is a confounding factor. Displaying the yield as weight per plant (Figure 5) instead of yield per area (Figure 3). This will massively reduces the affect of the confounding factor.
4) Avoid removing data points from the analysis, but sometimes it is necessary to obtain reliable results.
   a) Removal of data points needs to be well justified. (Figure 1)

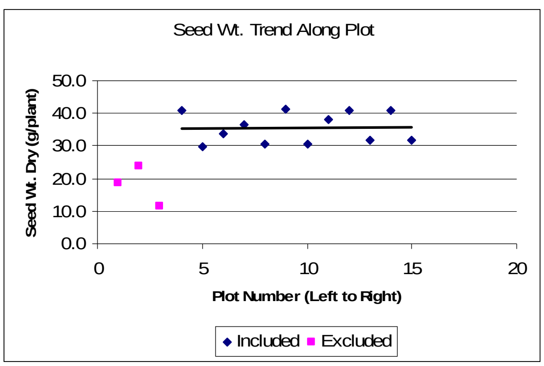

Figure 1 The 3 most left plots in the field where severely affected by water logging and damage from buffaloes. Leaving these plots in the analysis massively increase the standard error around the mean. These plots are not typical of the rest of the field.

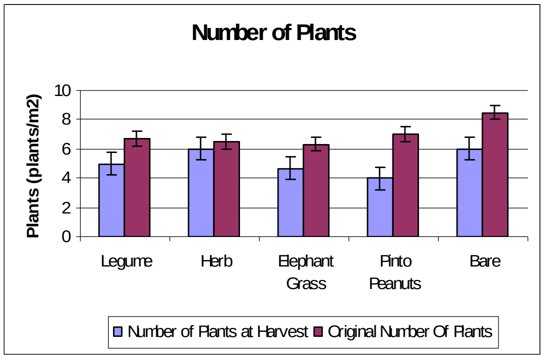

Figure 2 Average number of plants originally and later at harvest. The error bars represent the standard error of the mean.

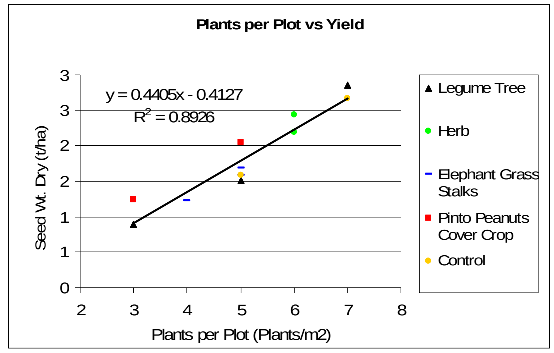

Figure 3 Correlation between number of plants per plot and seed yield, expressed on a per area basis.

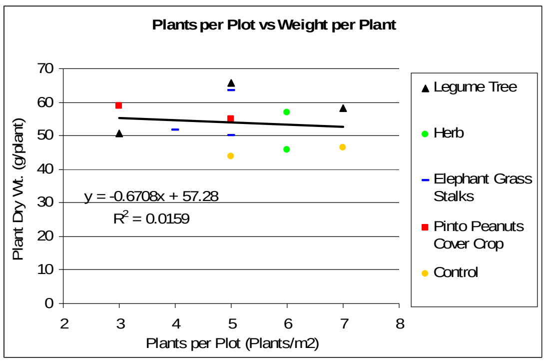

Figure 4 Correlation between number of plants per plot and plant dry weight, expressed on a per plant basis.

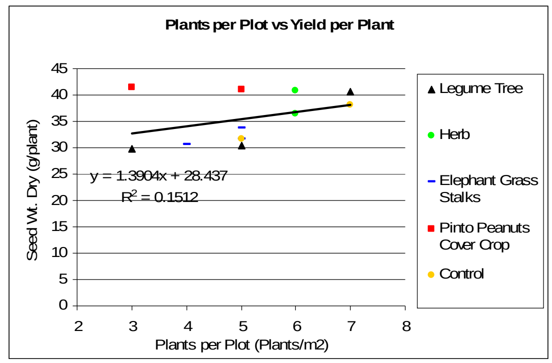

Figure 5 Correlation between number of plants per plot and seed yield, expressed on a per plant basis.

Uneven plants at harvest caused problems with identifying causation.

Shortly after flowering the some of the corn were cut to feed to the animals. The cutting was not done methodically to each treatment making analysis difficult. Plants assumed to have no or only small corns were cut. It is hard identify if selective culling of plants favoured treatment or the culled plants genuinely would have no corn due to the treatment. There is a strong correlation between the number of plants in each plot with yield per plot r^2=0.89 (excluding waterlog affected plots) (Figure 2 and Figure 3). Expressing the yield per plants at harvest reduced the correlation with a factor which is not the treatment (Figure 4 and Figure 5).

Expressing the yield per plant results in a lot less variation so a better indicator of growth.

Statistics

3 replicates of the same treatment are used in the same field to account for and describe the variation observed in this field in this season. These treatment replicates are randomly assigned to locations the field trial to reduce the chances of bias of some treatments towards favourably conditions in the field. The variation between fields and seasons is typically estimated, as it is very time consuming to complete numerous trials. To describe the variation between seasons or fields you with need to repeat the experiment in different field or seasons.

When you measure a sample of a treatment, you are unsure if that sample represents the mean of the entire treatment or differences between samples mainly due to chance.

Standard Error of Mean (SEM) describes the uncertainty of mean based on the difference between numerous replicates of the same treatment.

Error Bars on graphs represent: SEM
SEM = Standard Deviation/√number of treatment replicates
In Excel Standard Deviation = formula STDEV

≈1 SEM bars above and ≈1 SEM bars below describes a 68% chance of containing the mean
≈2 times SEM bars above and ≈2 times SEM bars below describes a 95% chance of containing the mean

When reading a graph, the error bars help communicate if the difference between the treatments is large enough to overcome the uncertainty of the measurement. As a guide if the error bars of 2 treatments overlap the treatments are too similar to comment that there is a difference between treatments. The smaller the error bars are, compared to the difference between treatments the more confident you can be that the treatments are different.

Results

Site Details

The field is a bench terraced hill slope (10-15% slope) on poorly structured Clay Loam soil. The bench terrace beds are at around 5% slope and have the crop planted on contour. Despite the numerous erosion control methods used, erosion remains a major issue under the organically grown annual crops with frequent cultivation and long periods of unprotected soil. The typical rotation of corn-peanut-beans concentrates on annual legumes as they obtain a satisfactory yield in the low fertility soil.

	Bulk surface area (cm^2/g dry mater)	Bulk moisture content (%)	Composition dry weight basis (Average diameter (mm))			Growth stage of green manure plant when cut
			Leaves	Twigs	Sticks	
Herb	760	77%	25%	56% (2.4)	18% (5.9)	Early flowing
Legume	224	60%	26%	27% (4.2)	47% (10.5)	At flowing some green seed pods formed
Elephant Grass Stalks	1	83%	0%	0%	100% (13.2)	Plant 1.5-2m high well before flowering

Table 1 Properties of green manure when first cut and applied.

Application	Date applied	Weeks since corn planted	% Ground cover	Green manure addition fresh (g/plot)			Green manure addition equivalent dry (g/plot)		
				Herb	Legume	Elephant grass stalks	Herb	Legume	Elephant grass stalks
1st	23/11/08	8	20-30%	300	150	2000	69	60	335
2nd	11/12/08	11	90%	600	600	600 (Hoang xa)	138	238	138

Table 2 Green manure application details

Green Manure Decomposition

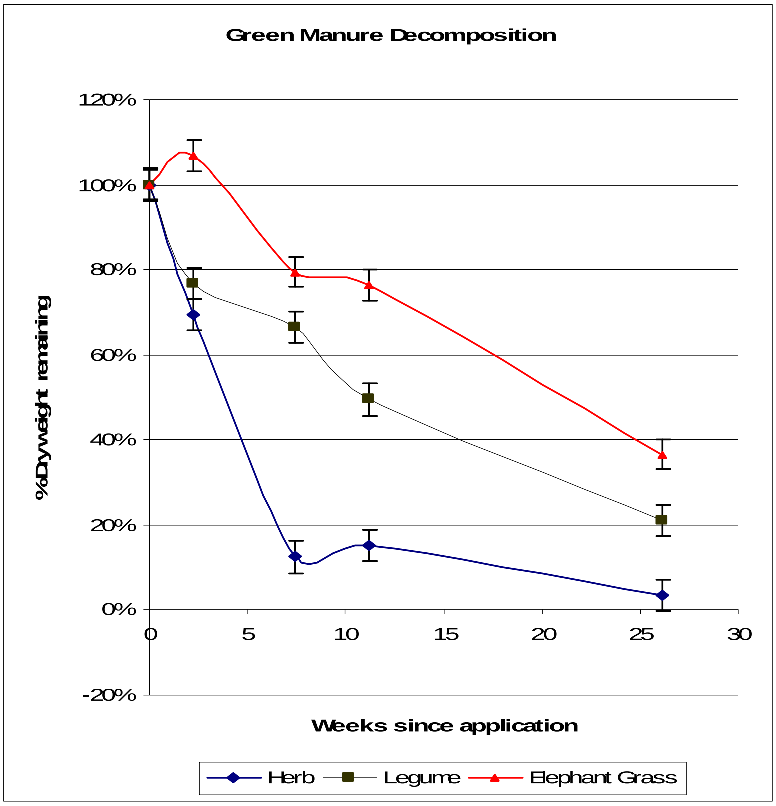

Figure 6 Green manure decomposition rates as measured by litterbags. The error bars represent the standard error of the mean.

Herb

The decomposition rate of herb was rapid, taking only 4 weeks to reduce the weight of dry mater to half the original amount applied (Figure 6). The herb material has the highest surface area per dry weight 760cm^2/g dry mater and has low lignin content in sticks, both leading to high decomposition rates (Table 1). Lignin makes the plant parts rigid and woody but reduces rate of decomposition[2]. Termite activity further contributed to accelerated decomposition in 2 ways. The first way is by directly by consuming the larger sticks but the termite activity also by broke up and mixed soil into the mulch, modifying the microclimate around the mulch.

Legume

The decomposition rate of the legume tree (Tephrosia sp.) was slower then originally assumed, taking 11 weeks to reduce the weight of dry mater to half the original amount applied. The legume material has a surface area of 224cm^2/g dry mater and has a high proportion of sticks with high lignin content. The sticks accounted for a high proportion of the dry weight (Table 1). The leaves persisted on the soil surface until the corn was harvested and the soil cultivated. The persistence of the Legume tree is partly due to Tephrosia species containing high concentrations of the natural pesticide compound Rotenone[3]

Elephant Grass Stalks

Elephant grass stalks took the longest to decompose. Taking 20 weeks to reduce the weight of dry mater to half the original amount applied. Elephant grass stalks had a very low starting surface area of $1cm^2$ /g dry mater but the stalks decomposed from the inside first. Meaning the outside surface area poorly describe the decomposition rate. The initial increase in dry weight is due to the stalks sprouting and possibly sampling error.

Ground cover and weed

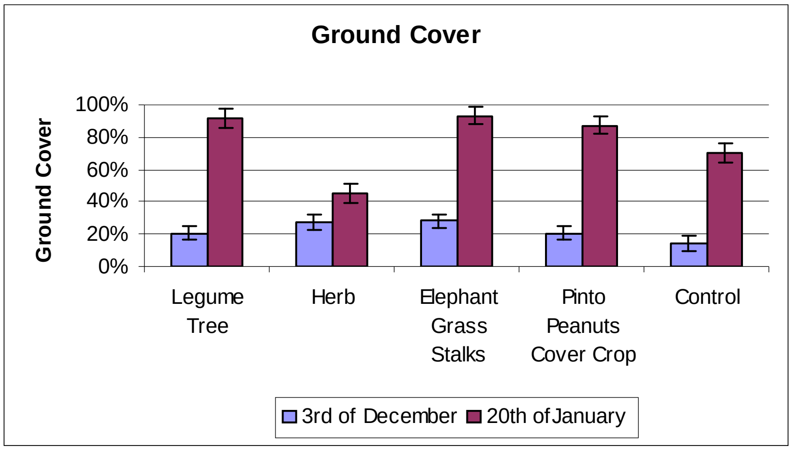

Figure 7 Ground cover under the corn canopy through the season. Ground cover describes all materials covering the soil within 30cm of soil surface, including weeds. Application groundcover targeted 20-30% on the 23rd of November and 90% on the 11th of December. The error bars represent the standard error of the mean.

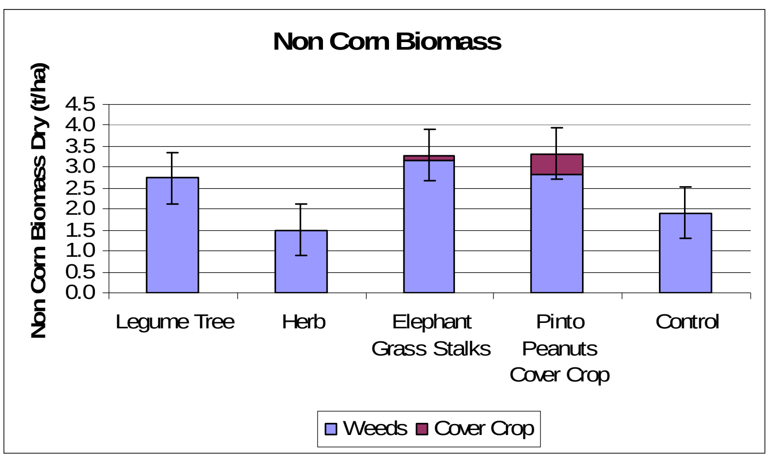

Figure 8 Non corn biomass includes all live plant material in the plot which is not corn including weeds and cover crops, planted or sprouted from the green manure. The error bars represent the standard error of the mean of the sum of weeds and cover crop.

Pinto Peanut and legume leaves groundcovers measurement on the 3rd of December (10 days after application) are only slightly different to the control (Figure 7). Shortly after application, the legume leaves additions dried and curled up, significantly reducing its contribution to the groundcover measurement. Doubling the weight of legume leaves in the second addition counteracted this issue. Groundcover of the control is greater then zero due to contribution of some small weeds and to a lesser extent previous crop residue.

Except for Herb, the additions of green manure and cover crop increased weed growth and ground cover over the control (Figure 7 and Figure 8). Herb green manure additions suppressed weed growth as show in ground cover (Figure 7) and in weed biomass (Figure 8).

The Pinto Peanuts where planted a week before the application of green manure, but the cuttings require time to establish and cover the soil. When the Pinto Peanuts were planted, many small weeds had germinated. In the more fertile areas of the trial, weeds out competed the Pinto Peanut and the weed growth increased, while in the less fertile plots the Pinto Peanut effectively suppressed the weeds. Overall, the average for the Pinto Peanut treatment was greater due to the enhancements being greater then the suppressed areas (Figure 8). The suppression was very effective in the waterlogged area but these plots were removed from the analysis as do not represent typical field conditions.

The biomass production of the Pinto Peanut cover crop and the sprouts from the elephant grass are very small in comparison to the weeds. Mature Pinto Peanut plants remain a low ground hugging plant and will unlikely compete with an established corn plant for light but would restrict weeds from establishing. While elephant grass is an aggressive plant and given time would definitely compete strongly with the crop for water, nutrients and light.

Productivity

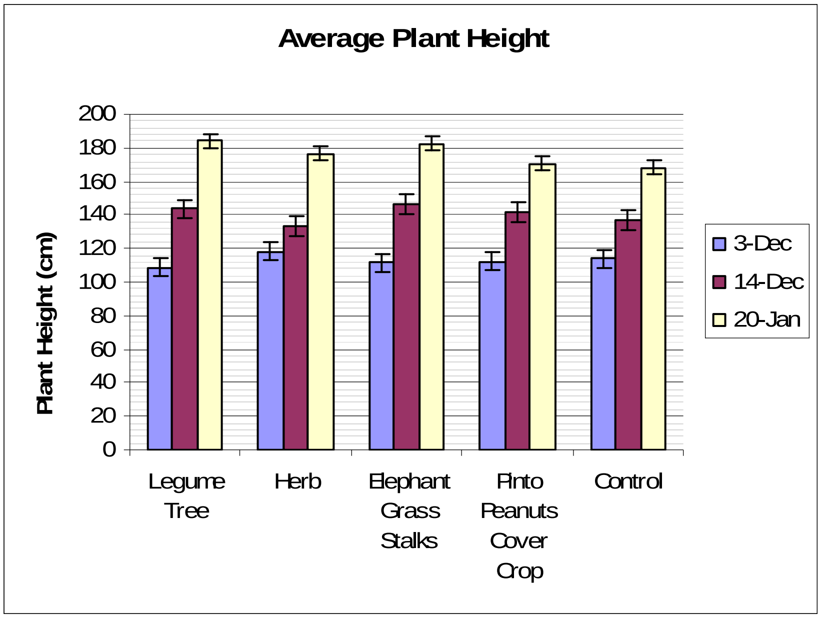

Figure 9 The average plants height is the distance from the soil surface to the leaves fully erect. The error bars represent the standard error of the mean.

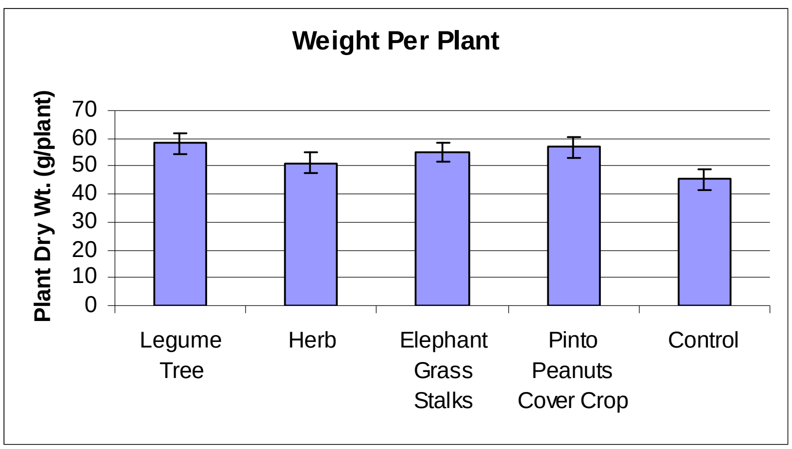

Figure 10 Weight per plant represents the total biomass produced by the plant. The material is dried to remove the affect of moisture that accounts for the bulk of the fresh plant weight. The error bars represent the standard error of the mean.

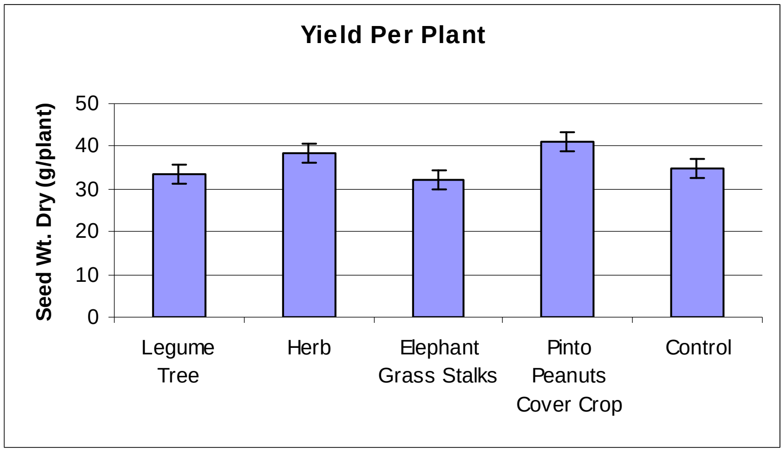

Figure 11 Yield per plant only includes the dry corn seeds (without the cob). The error bars represent the standard error of the mean.

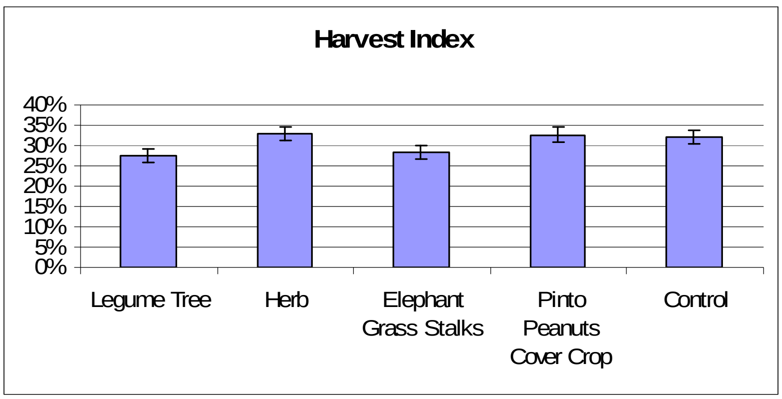

Figure 12 Harvest index indicates the % dry weight the harvestable portion of the plant accounts for of plant total dry weight. The larger the harvest index the more efficient the plant is at producing a yield. The error bars represent the standard error of the mean.

All treatments increased plant growth but interestingly this increase in plant growth did not always translated into an increase in plant yield. Pinto Peanut is the only treatment which significantly increased yield per plant (18% above control) (Figure 11), but this treatment had the most plants removed when the plants were cut within trial (Figure 2). The low density of plants may contribute to larger yields in the remaining plants or it may be due to the effect of the treatment. Herb shows an 11% improvement in yield over the control but this is similar to the standard error of the measurements. Additions of legume tree and elephant grass stalk green manures only resulted in more vegetative growth (Figure 10) and taller plants (Figure 9), generally reducing the efficiency of producing a yield indicated by the harvest index (Figure 12). Within the treatments that received green manure, the yields (Figure 11) and harvest indexes (Figure 12) are higher where the plants remained shorter (Figure 9).

Soil moisture and soil erosion

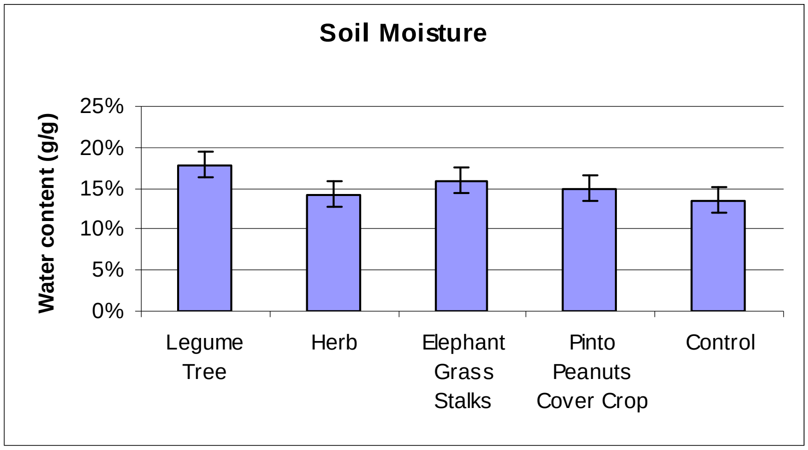

Figure 13 Soil moisture of the soil surface (0-2cm). The measurement was taken after several warm dry days on the 20th of January when the corn was ripening in. The error bars represent the standard error of the mean.

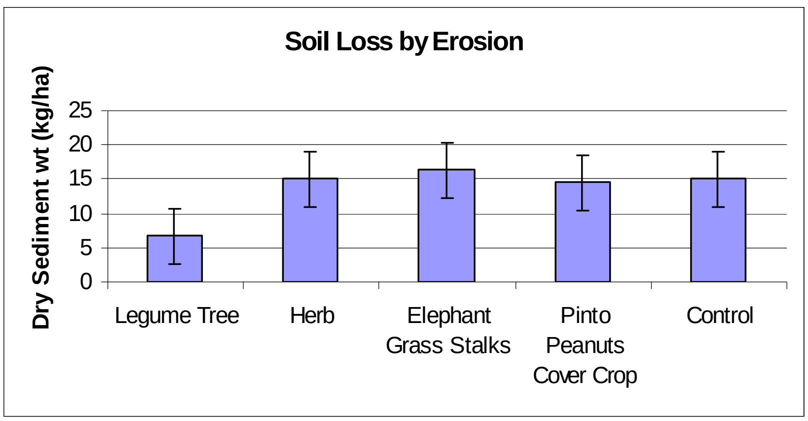

Figure 14 Soil loss by erosion represent the erosion occurring before the formation of rills, mostly raindrop impact erosion. The error bars represent the standard error of the mean.

Additions of green manure and cover crops treatments all increased the surface soil moisture, although Legume Tree was the only treatment to show a significant increase compared to the control (Figure 13). Through most of the growing season it rained most days, too much soil moisture (water logging) would be more of a problem, than not enough water.

Only one small, but intense rainfall event of 32mm resulted in soil erosion within the plots after the treatment where applied. This rainfall event occurred on the 22nd of December, 2 weeks after the second green manure application. The soil erosion measured was very small and does not represent the erosion expected through the entire season but does indicate the relative effectiveness of different green manures at reducing erosion.

Far more damaging rains occur between cultivation and when the treatments where applied, reducing the remaining soil vulnerability to further erosion. With the small rainfall event, only the Legume tree green manure treatment showed a reduction in erosion compared to the control (Figure 14).

It is important to understand that the trial was only designed to measure erosion before the formation of rills, mostly raindrop impact erosion. Linearly extrapolation of the results observed in this trial will not represent the erosion at the landscape scale. In a normal sized field within a landscape other erosion processes will occur altering the results such as the concentration of water flow and the formation of rills.

Discussion

Green manure decomposition rate describes how long the material remain intact on the soil surface and how quickly the material release nutrients. Slow decomposition rates, seen in the Legume tree treatment, are good for erosion control and soil moisture conservation as protects the soil surface for longer[2]. Fast decomposition rates, such as the herb treatment, are desired for supply of nutrients to the plant when they need it, such as plant establishment.

The suppression effect of herb additions on weed growth cannot be explained by smothering effect alone, as elephant grass stalks and legumes leaves have similar % cover. Possible explanations are termite activity, chemicals released in the process of decomposition or the physical barrier created when the leaves collapse in decomposition. Termite activity was observed on the plot and contributed to the rapid and more complete decomposition in litterbags. The soil disturbance by termite activity could prevent small weeds from establishing.

The persistence of the Tephrosia sp. Legume tree is due to the high proportion of woody stick and the chemical compounds of lignin and rotenone. Other Legume species with less lignin and rotenone would likely have faster decomposition rates. Legumes commonly have high nitrogen content that contributes to a faster decomposition rate[2].

The poor performance of elephant grass stalks at preventing erosion can be explained by the size of the fragments. Fewer larger fragments are less effective at reducing erosion then many small fragments for equivalent percentage groundcover. Drop drops impacts retain more energy when they hit the soil directly, without partially hitting a fragment of mulch. Many small fragments result in more raindrop interception before hitting the soil.

Poor translation of increased plant growth into higher yield is assumed to be due to the timing of nutrients release. All green manure treatment would be more effective if added earlier with slow decomposing material added the earliest as feasible without reducing seedling emergence. Adding the green manure earlier should protect the soil when barest and the nutrients will be released at a better time to produce a stronger higher yielding plant.

Another issue is the persistence of the mulches after the crop is harvested and the field need to be cultivated to plant the next crop. Structurally stable residues will make cultivation difficult by preventing the plough working effectively. Elephant grass and the woody part of Legume tree additions persist well past harvest while, there are very little structurally stable residues from the herb addition.

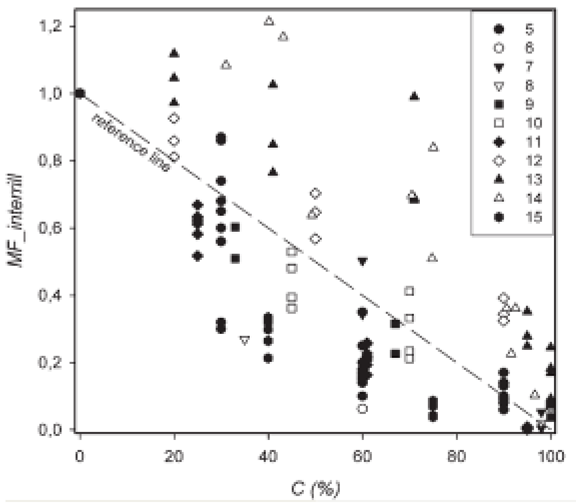

Figure 15 Inter rill erosion study review. MF_interrill = proportion of erosion from dominantly interrill processes relative to bare soil control. C(%) = percentage ground cover. Numbers in key refer to the study where observed. Interrill erosion refers erosion occurring before water flows into rills including raindrop impacts. Numbers equal to 1 have the same amount of erosion as the control. Numbers greater then 1 have higher erosion then the control[5].

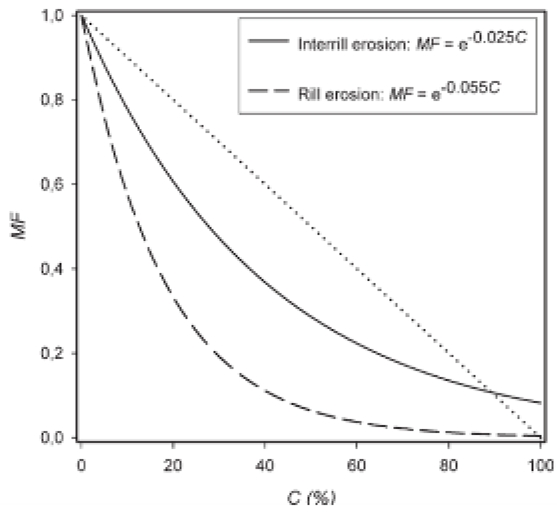

Figure 16 Interrill and rill erosion according to the revised universal soil loss equation (RUSLE2). MF = proportion of erosion relative to bare soil control. C(%) = percentage ground cover. Interrill erosion refers erosion occurring before water flows into rills including raindrop impacts. Numbers equal to 1 have the same amount of erosion as the control. Numbers greater then 1 have higher erosion then the control[4].

Only small reductions or even small increases in erosion rates (compared to the unmulched control) were observed in a review of other studies with similarly low mulch covers (Figure 15)[5]. The Revised Universal Soil Loss Equation (RUSLE2) does not explain these results under light mulch cover. The RUSLE2 model indicates light mulch cover is effective at reducing erosion. Increasing the mulch cover the effectiveness of additional cover has diminishing efficiency (Figure 16)[4]. The fact that only one very small erosion event occurred in the trial after the soil surface was well eroded from previous heavy rain severely reduced the erosion off the plots. With the low erosion rates, the differences are difficult to measure and result in large sampling errors, indicated by the large standard error. If the entire growing season was captured the erosion rate is expected to follow the RUSLE2 model, with all treatments showing some reduction in erosion compared to the control.

Conclusion

The herb green manure additions show promise at suppressing weed growth and rapid supply of nutrients to increase yield while Legume tree green manure additions are the most effective at controlling erosion and increasing soil moisture. Elephant grass stalks appear to cause more problems with plant competition then giving any advantage in erosion control or higher plant yield. Pinto Peanut cover crops are slow at establishing an effective cover to outcompete weeds and prevent erosion before an effective corn canopy is established, although the Pinto Peanut treatment shows the largest increase in plant yield.

Further research needs to investigate the influence of the timing of green manure additions, the feasibility of higher mulching rates as well as investigate the performance of other green manure addition. The feasibility needs to include ways to overcome the availability of green manure sources and prove the additions of green manure are worth the investment of time, labour, money and area set aside to produce the green manure crop.

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