COVER CROPS FOR SOIL EROSION AND RUNOFF CONTROL IN FORAGE MAIZE

PROGRESS REPORT

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EXECUTIVE SUMMARY

This report contains the results obtained from Phase 1 of a 3 year PhD. The first part of the report will cover the background to the project and a summary of the literature review undertaken. This will lead on to a discussion around the methods used to assess soil loss and runoff and the Phase 1 results. Conclusions and future directions of the project close the report. Cover crops have been evaluated as soil erosion control measures and compared to the conventional practices of leaving the soil bare overwinter. The treatments tested were: i) Italian ryegrass undersown [broadcast], ii) Italian ryegrass undersown [drilled], iii) Forage rye drilled post-harvest, and the controls: iv) bare soil with strips tilled across slope [ripvator cultivator], v) bare soil tilled prior maize drilling [disc plough], vi) bare soil tilled prior maize drilling [mouldboard plough]. It was hypothesised that cover crops would reduce erosion and runoff as compared with the controls. The hypothesis was tested through a field experiment and the application the Modified Morgan Morgan and Finney (MMF) soil erosion model (Morgan and Duzant, 2008). The field experiment was carried out from December 2014 to March 2015. Runoff and sediment from enclosed erosion sub-plots (15m x 1.5m) were collected via Gerlach troughs to instrumented storage tanks. The erosion model predicted soil erosion taking into account the effects of vegetation cover on soil loss. The input parameters used in the MMF model are specific to the field and cover crops used in this project.

Due to limited number of runoff generating rainfall events no significant differences in soil loss or runoff were observed between treatments. Therefore, the hypothesis that cover crops would reduce erosion and runoff as compared with the controls could not be tested. Consequently, a second field experiment (Phase 2) will be undertaken during 2015-16. The erosion model predicted that the presence of cover crops significantly reduces soil erosion. Italian ryegrass performed the best, having almost 100% runoff reduction and 85% soil loss reduction compared to the bare soil treatments. The MMF model outputs and the trends from the field experiment will be validated in the Phase 2 field trials.

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1 Introduction

1.1 Project background

The river Wye and its tributaries (e.g. river Lugg and Clun) form a large catchment located across the border between Wales and England. The catchment is important for salmon and brown trout and many parts of the rivers are classified as Special Areas of Conservation and Sites of Special Scientific Interest (CaBA). The river Wye is designated as a Special Area of Conservation because of its high ecological status (Jarvie et al., 2003; Wye and Usk foundation).

Forage maize is known to increase soil erosion (Morgan, 2005). This can result is an accumulation of sediments in receiving water bodies and subsequently eutrophication, endangering trout and salmon spawning areas (Mainstone & Parr, 2002). The Wye catchment is currently failing to meet the required water quality standard of the European Water Framework Directive (WFD) (Wye and Usk foundation, 2014). Phosphate levels have been found to be high in the river Wye (Jarvie et al., 2005), for this reason reduction of soil erosion and prevention of phosphate contamination via runoff are focal points of the River Wye SAC Nutrient Management Plan Action Plan (Environment Agency & Natural England, 2014).

This research aims to manage runoff and subsequently optimise erosion control in areas of forage maize production. Cover crops (CC) are being evaluated as a soil erosion control measure and will be compared to conventional practices, such as cross slope chisel ploughing, chisel plough and disc plough. CAP reform ‘Greening Rules’ (2014) require growers to; maintain minimum soil cover; minimise land management to limit erosion and maintain soil organic matter levels through appropriate practices. Further, in Ecological Focus Areas (EFAs) growers ‘must’ use a sown mix of at least two different species from a choice of rye, vetch, phacelia, barley, mustard, oats and lucerne. The optimization of cover crop mixes provides a unique opportunity to simultaneously address the key degradation threats facing UK agriculture namely soil compaction, soil erosion and loss of soil organic matter. CC have successfully been used to control soil erosion in maize, and are known to have additional beneficial effects such as increased soil organic matter and overwinter ground cover. Italian ryegrass (*Lolium multiflorum*) and forage rye (*Secale cereale*) are the main choice of cover crops for this first part of the project because Italian ryegrass is known to provide fast ground cover and both species can produce an economically valuable yield.

2 Summary of the literature review

Soil erosion is the detachment, entertainment, transport and deposition of soil particles by rainfall, wind and surface run off (Morgan, 2005). It is a natural process, exponentially exacerbated by human activities, such as deforestation and agriculture, leaving the soil bare (Weggel & Rustom, 1992; Wali et al., 1999; Montgomery, 2007). Soil erosion and runoff in agriculture represent a serious threat to the environment and to agricultural productivity (Bakker et al., 2004). The impact of agricultural soil erosion is both onsite and offsite. On site, the breakdown and rearrangement of soil micro and macro-aggregates leads to degradation of soil structure, capping, and loss of organic matter, plant nutrients and soil carbon. Consequently, the soil loses its fertility, with reduced cultivable depth and water holding capacity (Crosson, 1997*;* Morgan, 2005). Off-site, runoff enters surface waters, consequently, carbon, pollutants such as P and N concentrate in the water bodies causing contamination and eutrophication (Morgan, 2005). Sediments accumulate in rivers, which can increase floods, block canals, endangered spawn areas and threaten reservoirs (Haregeweyn et al., 2012). Suspended particles cause water turbidity, which can lead to an increase in water temperature, decrease of oxygen dissolution and light penetration in water.

Several key UK crops are associated with high soil erosion and runoff risk. For example crops planted into ridges and furrows (e.g. potatoes) concentrate runoff flow into the furrows (Vinten et al., 2014), crops harvested in late autumn (e.g. maize) leave the soil bare over winter, and winter crops planted into rows (e.g. winter wheat) have reduced development during periods of high rainfall (Watson & Evans; 2007; Morgan, 2005).

Conventional maize cultivation in a region with high precipitation, even on a gentle slope, can have serious erosion issues (Morgan, 2005). The soil is left fallow over winter until late in spring when the maize is planted. Hence, the soil remains exposed to intense rainfall events (Tuan et al., 2014) and so is vulnerable to erosion for long periods.

Cover crops (CC) that provide ground cover over winter and early spring can be an effective way of controlling erosion and runoff (Langdale et al., 1991). They have multiple effects on the environment and on the following crop, depending on the species of cover crop planted, and on crop management. In general CC's decrease soil detachment by rainfall. They protect the soil from the direct impact of rain drops, dissipating raindrop kinetic energy (Liedgens et al., 2004), while the density of crop stems reduces runoff velocity, and enhances sediment deposition over detachment. CC roots increase soil aggregate stability (Roberson et al., 1991; Perin et al., 2002), increase water infiltration and decrease soil compaction (Newman et al., 2007; Pratt et al., 2014). They decrease deep percolations of P and N because they are assimilated as nutrients; for example vetch, winter rape, oilseed rape, alfalfa limit nutrient loss overwinter (Rasse et al., 1999; Salmerón et al., 2011). Roots exudates of CC's increase soil organic matter (soil C and N) (Carter, 2002; Gabriel & Quemada, 2011) and therefore water holding capacity, soil structure (Duda et al., 2003) and soil fertility (Hubbard et al., 2013) are effectively improved over time.

Aggregate stability and soil erosion are correlated, as good aggregate stability often corresponds to low soil erosion risk (Le Bissonnais, 1996; An et al., 2013). Plant roots, fungal hyphae and bacteria exudates act as bonding agent that holds soil aggregate together (Tang et al., 2011). In particular fungal activity is related to soil macro-aggregates, because of the production of polysaccharides, the physical bounding of soil particles by fungal hyphae and the production of hydrophobic compound that decrease aggregate permeability (Ternan et al., 1996; Le Guillou et al., 2011). Soil micro-aggregates formed by the combination of bacterial colonies and clay particles, glue together by bacterial exudates and polysaccharide capsules (Schutter & Dick, 2002).

Soil aggregates are in continuous evolution, forming or being disrupted as the soil organic carbon is used by the microbial activity. Hence, aggregate stability is highly correlated to soil organic carbon, and microbial activity (Rillig, 2002) and microbial carbon (Sparling et al., 1992).

3 Objectives and research hypotheses

Objectives:

1. Critically evaluate and quantify the role of companion and cover cropping to reduce runoff, soil loss and hence offsite environmental impacts associated with forage maize cultivation.
   1.1. Quantify the capacity of companion and cover cropping towards reducing the environmental impact of Maize cultivation through reducing runoff, soil and nutrient loss (particularly nitrogen and phosphorus) compared to current practices.
   1.2. Evaluate the impact of companion and cover cropping on soil susceptibility to erosion and runoff, through determining any interactions with biological, chemical and physical indicators (not covered in this report).
   1.3. Evaluate and quantify the role of soil microbiology towards controlling soil erosion (not covered in this report).
2. Critically evaluate the economic viability and practicality of companion and cover cropping (not covered in this report).

Objective 1 hypotheses:

i) Italian ryegrass will reduce soil loss and water runoff compared to the current practices or leaving the soil fallow overwinter.

ii) Under-sowing of Italian ryegrass will reduce soil loss compared to direct drilling,

iii) Among the controls, cross slope chisel ploughing will reduce runoff compared to the controls with only tilled bare soil [mouldboard plough and disc plough].

4 Methodology

4.1 The experimental design

Six treatment variables were established in blocks (12.0 m wide x 200m length) in May 2014 at Wallend Farm, Leominster, Herefordshire.

1. Italian ryegrass (*Lolium multiflorum*) undersown broadcast approx. 6-weeks after maize drilling (**IRB**).

2. Italian ryegrass undersown drilled approx. 6-weeks after maize drilling (**IRD**).

3. Forage rye (*Secale cereale*) drilled post-harvest (**RPH**).

Controls:

4. Bare soil with strips tilled post-harvest across slope (ripvator cultivator) (**PHC**).

5. Bare soil tilled prior maize drilling (disc plough) (**CSD**).

6. Bare soil tilled prior maize drilling (mouldboard plough) (**CP**).

Three fully instrumented erosion sub-plots where placed inside each treatment block to collect runoff and sediments. Hence the experimental design comprised of six treatment variables, each with three replicate erosion sub-plots that were established within each of the six main blocks.

4.1.1 Erosion sub-plots

The erosion sub-plots (Figure 1) were 12m x 1.5m, bordered by soffit boards dug into the soil on all sides to avoid water entering or departing the plot. Runoff and sediments were collected by a stainless steel gerlach trough placed at the bottom of the plot (Figure 2), connected with a pipe to a storage tank (Figure 3). Pre-calibrated linear level sensors were placed inside the storage tanks to monitor water at 30 minute intervals, or five minute intervals if more than 0.2 mm of rainfall had fallen. The sensors were connected to a tipping bucket rain gauge via a DT80/2 data logger, which was linked to a weather station placed in the field.

The tanks will be sampled to collect the sediments transported by the runoff. After sampling the tanks were emptied, into a drainage ditch (Figure 4).

To ensure that the gradient of the erosion sub-plots was comparable the experimental field was surveyed and a Digital Terrain Model generated in ArcGIS (Figure 5). This method was considered the most appropriate way of allocating sub-plot location as a random allocation across the field was not possible, due to the already fixed location of the different treatment blocks and the fact the treatments blocks were not replicated across the field.

Figure 1. Erosion Plot.

Figure 2. Gerlach trough.

Figure 3. Storage tank.

Figure 4. Instrumented storage tank and drain ditch.

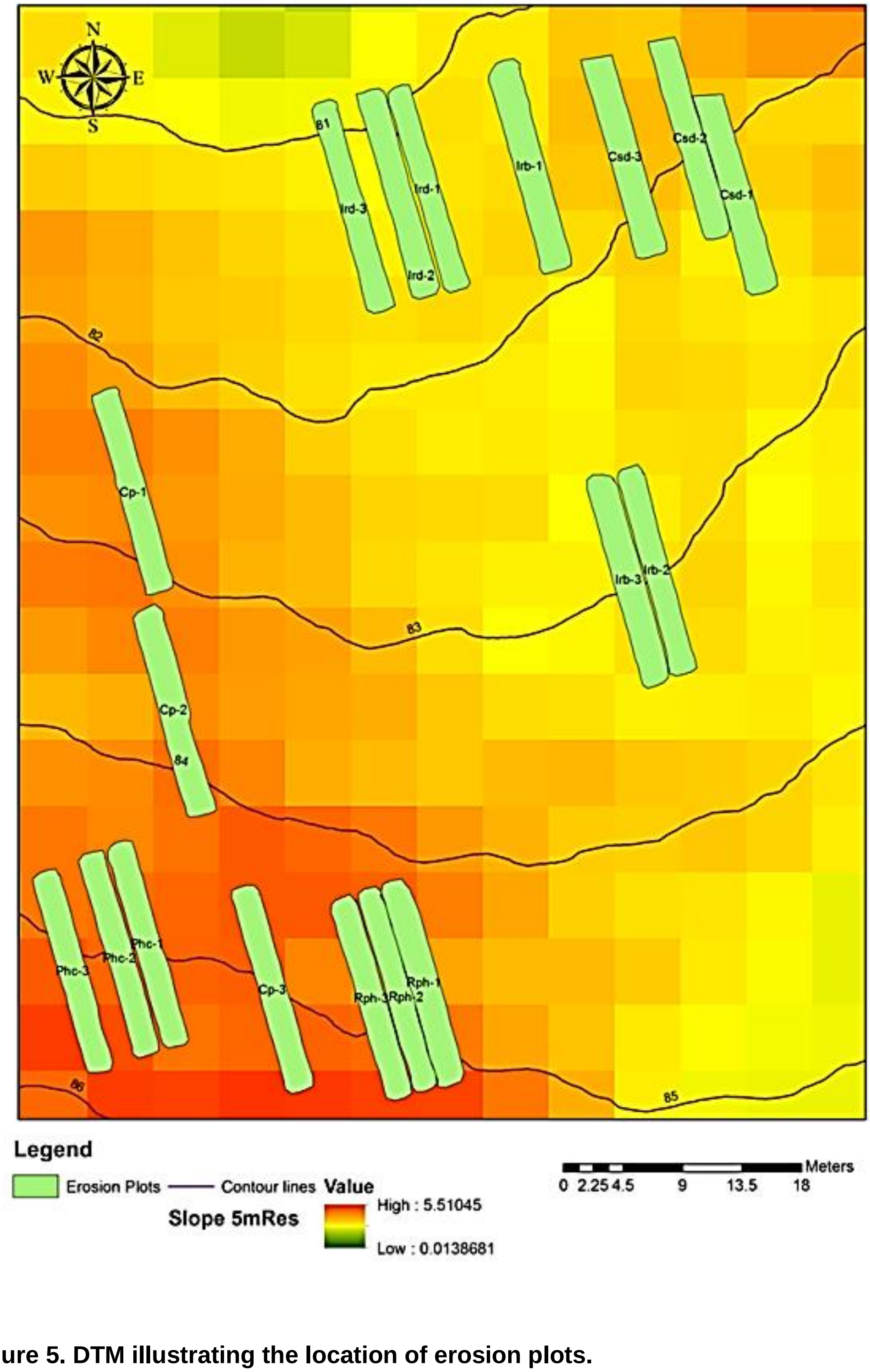

Figure 5. DTM illustrating the location of erosion plots.

The erosion plots installation ended on the 28th of November 2014. Two interventions of maintenance were necessary, due to a combination of extreme weather, soil type (slumping), causing the tanks to move from their previous position. The first intervention was carried out before Christmas. The storage tanks were secured in the soil by compacting the soil around them. A second intervention was carried out after Christmas on the 22nd of January, to stabilise 6 tanks, and this time they were fixed supporting them with wooden shuttering (Figure 6 and 7). Because of these unforeseen events, all data collected before the 22nd of January was not statistically robust. However, the results were indicative of the erosion processes operating.

4.1.2 Runoff sampling and runoff analysis

Runoff hydrographs were collected by a data logger powered by a solar panel and an 80Ah professional gel cell battery and can be visualised online on a webserver. Samples of runoff were collected manually from the tanks on the 16th of March. The runoff samples were used to determine, runoff volume, total soil loss and nutrient (N and P) concentrations in runoff.

5 MMF model

After the problems that were encountered in monitoring soil erosion and runoff overwinter, it was necessary to apply to the MMF model to predict erosion. This was undertaken in order to obtain an indication of the predicted soil loss and runoff generated by the different treatments from November to March. The MMF model predicts annual soil loss on hillslopes and is divided into two parts, a water phase and a sediment phase. The water phase determines runoff production based on total rainfall, number of raining days, rainfall intensity and soil condition (cover, texture, bulk density etc.). The sediment phase estimates soil loss as the difference between the total sediment detached by raindrop impacts and by overland flow and the percentage of sediments which deposit; the flowchart of the model can be found in the Appendix (Figure_A 1). The Morgan and Duzant (2008) revision of the model takes into account the effects of vegetation cover on soil loss, using specific and measurable plant parameters. For this reason, we chose it to predict soil loss and runoff for this project. Input parameters used in the model are specific to the field and cover crops used in the project. The parameters have been derived from the weather station present on site, from analysis of the experimental soil and from crop factors measured in the field. The results from the MMF model are presented for each month of the experiment. Details of the model inputs are presented in the Appendix.

5.1 Statistical analysis

Kruskal-Wallis ANOVA for non-parametric statistic was used to access significant differences between the treatments. It was also use to establish if differences in slope inclination, location (top, middle, bottom part) and presence of cover crops were affecting the results.

6 Results

6.1 Field experiment

Runoff and soil loss in both periods (from the 18th of December to the 13th of January and from the 22nd of January to the 15th of March) was greatest in the bare soil tilled (mouldboard plough) (CP). However, due to high variability within treatments, differences between the treatments were not significant ($p > 0.05$) (Figures 6, 7 and 8). Further, although there are clear trends in the performance of treatments, due to variability within treatments, no significant difference in runoff or soil loss was observed.

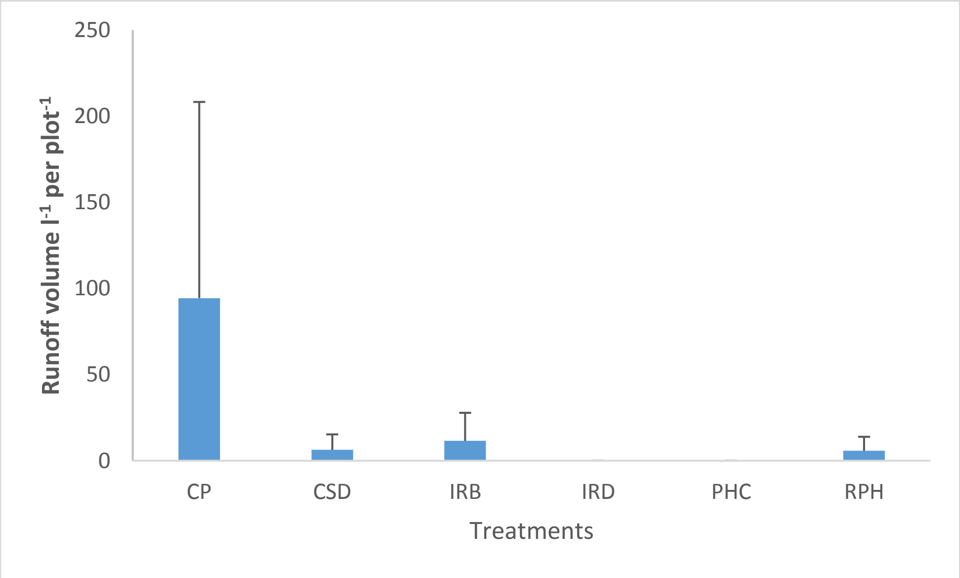

Figure 6. Runoff collected between 18th December to13th January. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m^2. Treatments: Italian ryegrass broadcast (IRB). Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC)

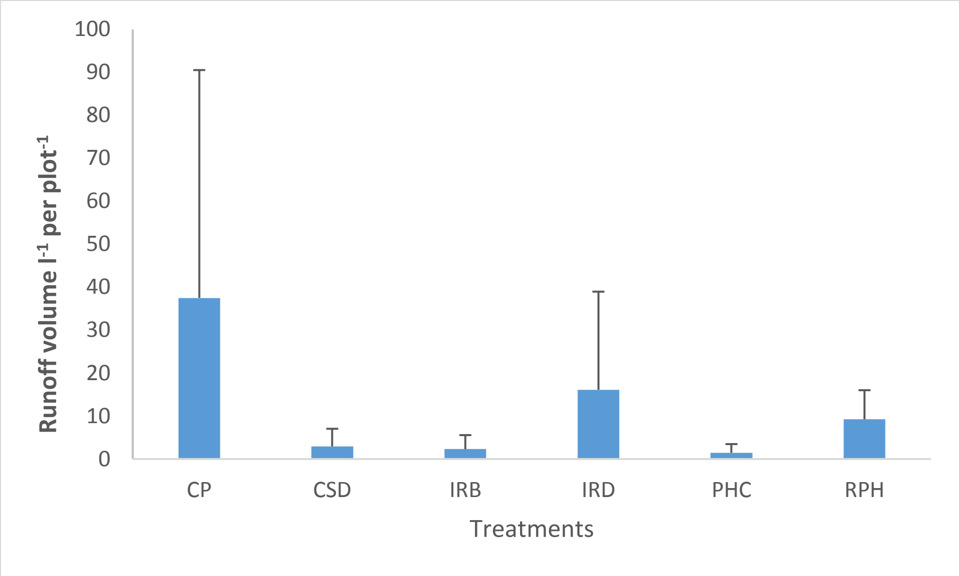

Figure 7. Runoff collected between 22nd of January to 15th of March. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m^2. Treatments: Italian ryegrass broadcast (IRB). Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough) (CSD). Bare soil tilled (mouldboard plough) (CP).

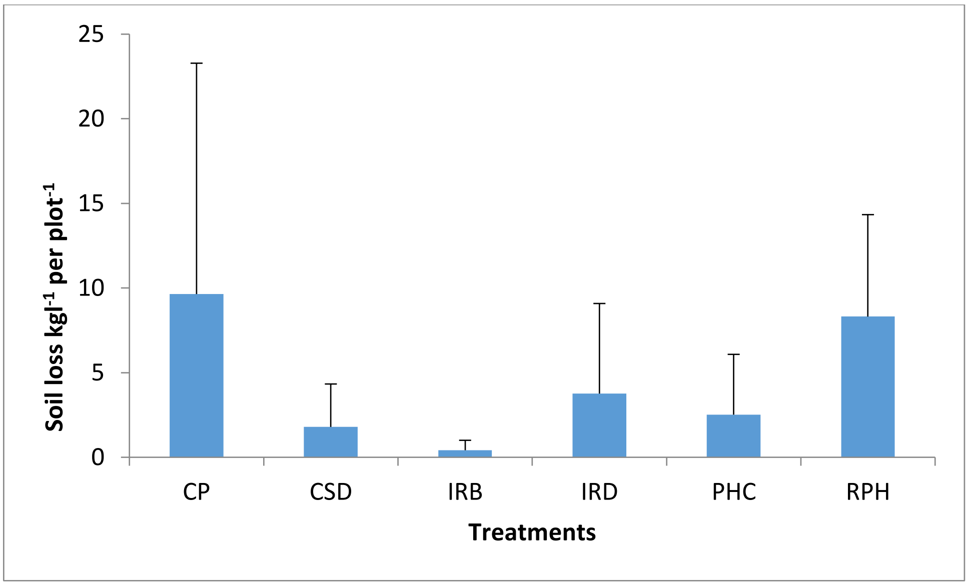

Figure 8. Soil loss between 22nd January to 15th March. Error bars represent standard deviation. Italian ryegrass broadcast (IRB). Erosion sub-plot area is 22.5 m^2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough) (CSD). Bare soil tilled (mouldboard plough) (CP).

6.2 MMF model

The MMF model runoff and soil loss results demonstrated significantly different between treatments. The presence of cover crops significantly reduced runoff and soil loss results for each month and the differences in slope and in location did not affect the results.

Runoff and soil loss prediction differ between months, but the trend over time remains the same. For runoff, Italian ryegrass, both broadcast and drilled (IRB, IRD), had the smallest runoff production, followed by forage rye (RPH) (Figure 9, 10, 11, 12, 13). This reflects the trends observed in the field trial runoff data (Figures 6-7). The greatest runoff was produced by the controls bare soil with strips (ripvator cultivator) (PHC), bare soil tilled (disc plough) (CSD) bare soil tilled (mouldboard plough) (CP) (Figure 9, 10, 11, 12, 13).

Soil loss was smallest in the plots with Italian ryegrass (IRB, IRD) (Figure 14, 15, 16, 17, 18). Soil loss from plots with bare soil with strips tilled across slope (PHC) resulted higher than from bare soil tilled (disc plough) (CSD) for each month except for February (Figure 14, 15, 16, 17). Again, this reflects the trends observed in the field soil loss data (Figure 8) particularly for IRB. Bare soil tilled (mouldboard plough) (CP) had the highest soil loss in each month (Figure 14, 15, 16, 17, 18).

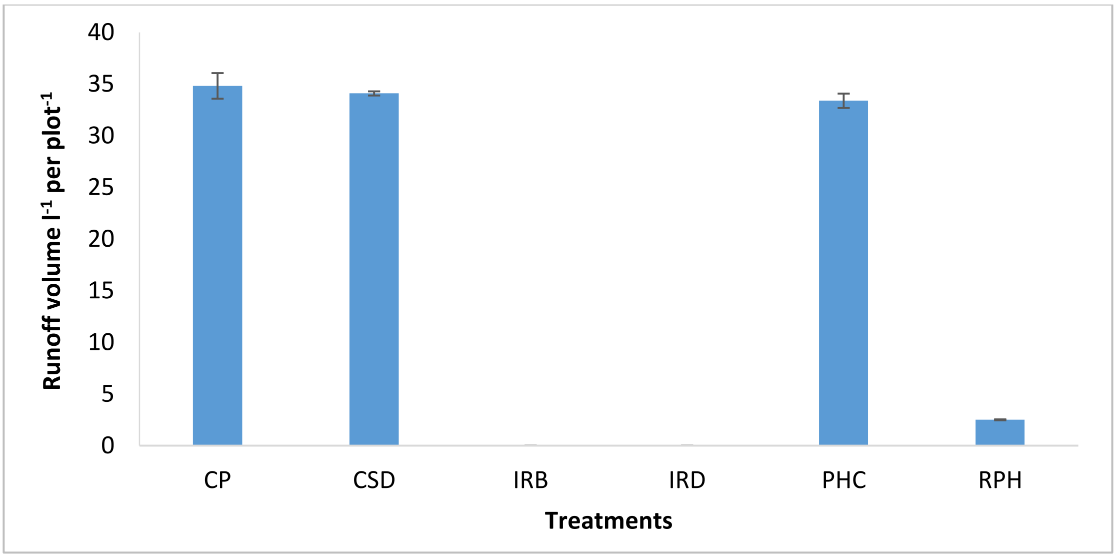

Figure 9. Runoff from the 22nd of January to the 15th of March. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m^2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough) (CSD). Bare soil tilled (mouldboard plough) (CP).

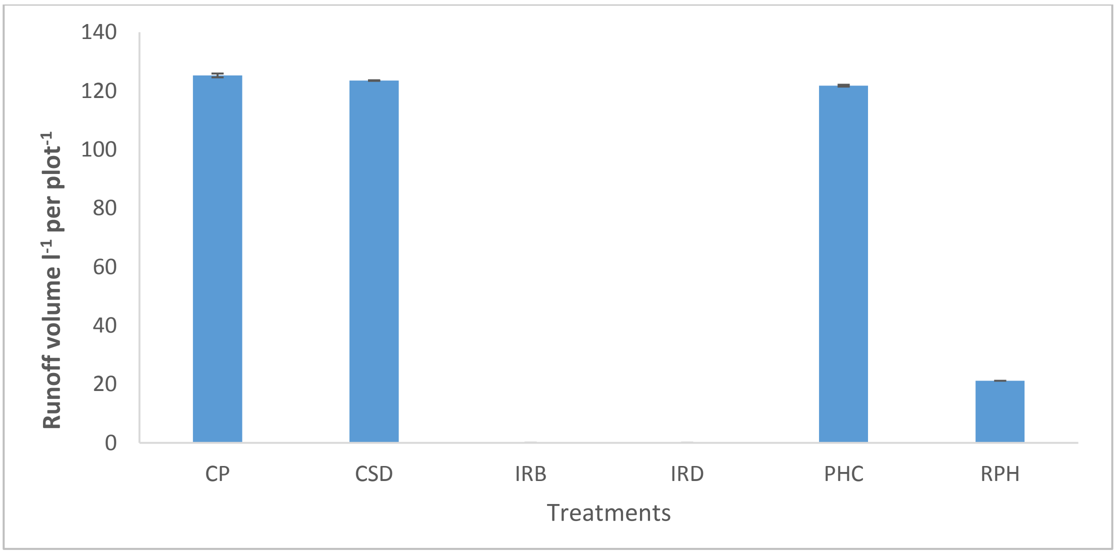

Figure 10. Runoff in November. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m^2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough) (CSD). Bare soil tilled (mouldboard plough) (CP).

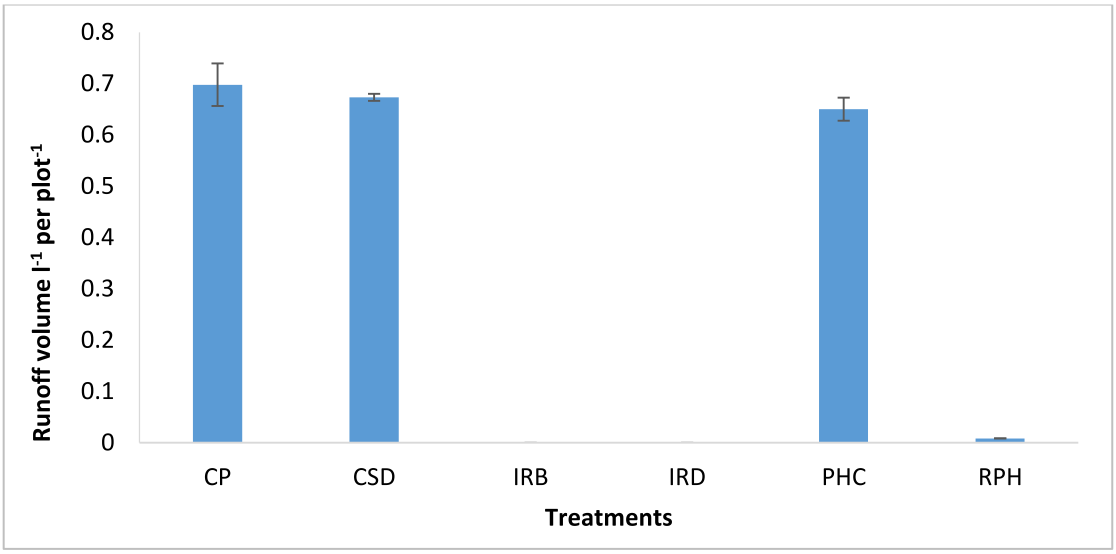

Figure 11. Runoff in December. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m^2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough).

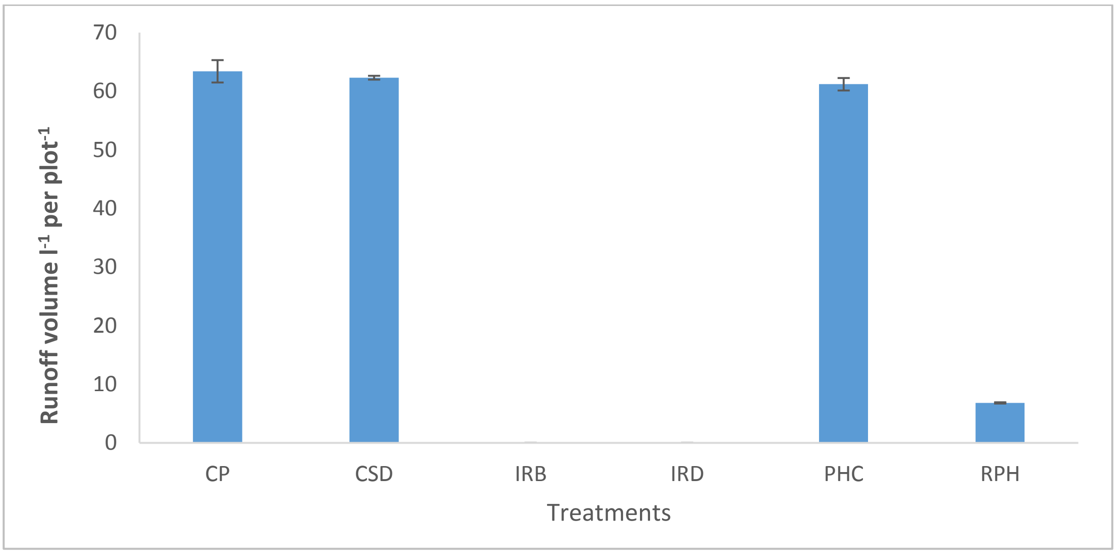

Figure 12. Runoff in January. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough).

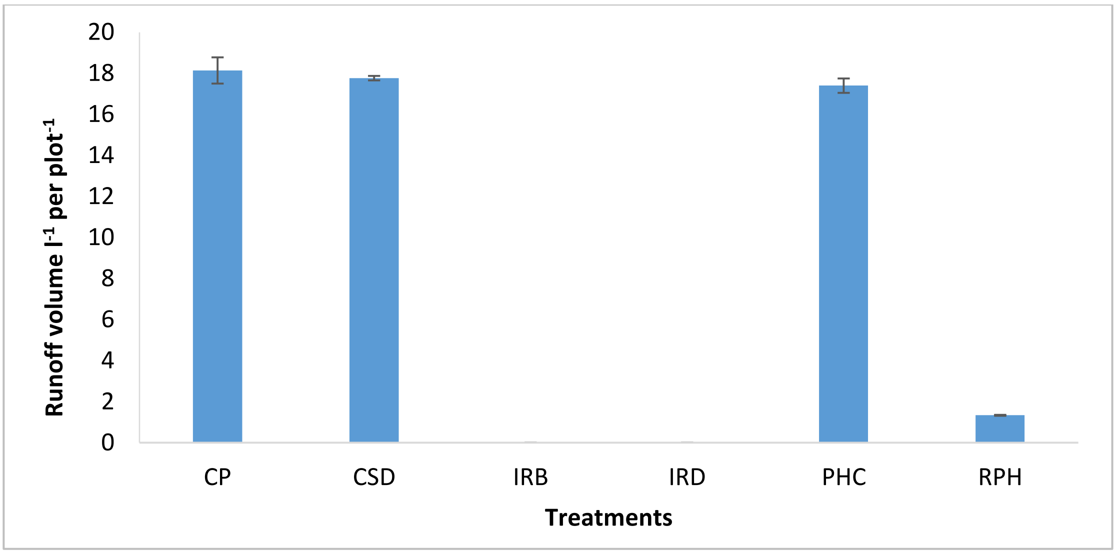

Figure 13. Runoff in February. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m^2. Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough) (CSD). Bare soil tilled (mouldboard plough) (CP).

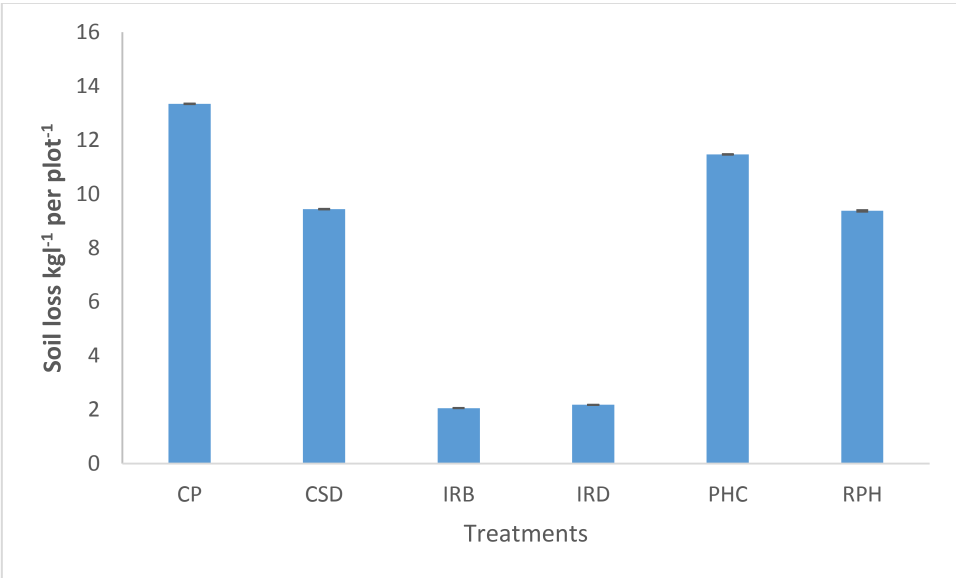

Figure 14. Soil loss from the 22nd of January to the 15th of March. Error bars represent standard deviation. . Erosion sub-plot area is 22.5 m2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough) (CSD). Bare soil tilled (mouldboard plough) (CP).

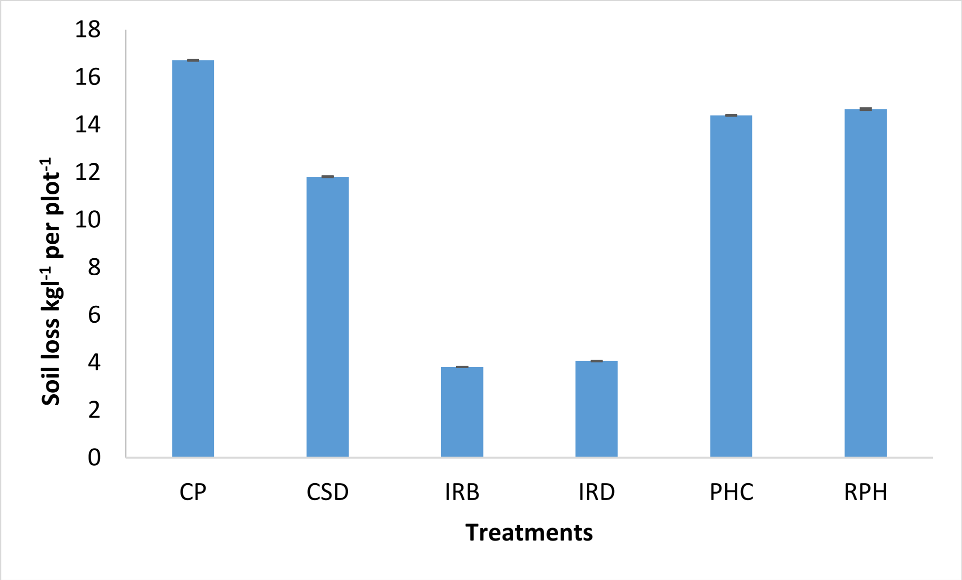

Figure 15. Soil loss in November. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m^2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough)

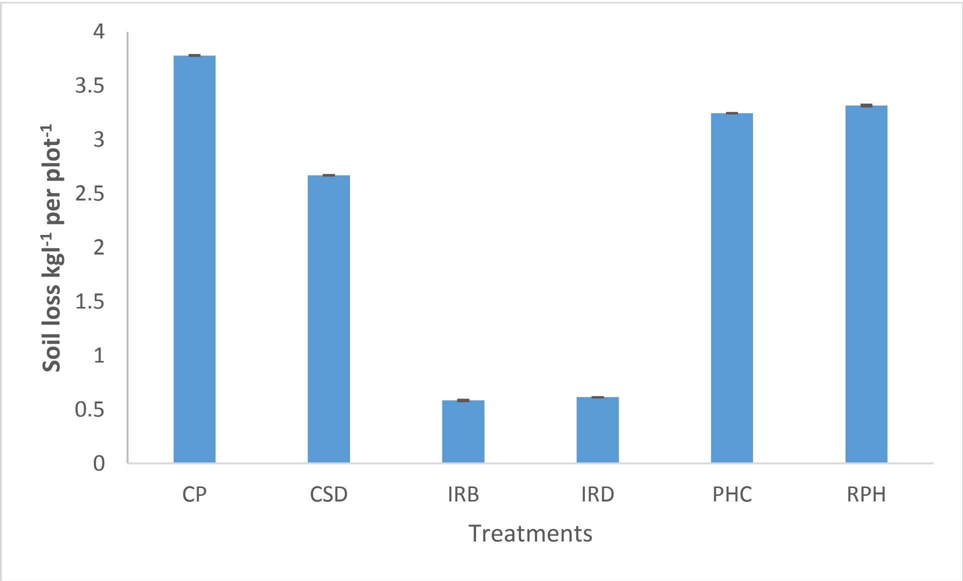

Figure 16. Soil loss in December. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough).

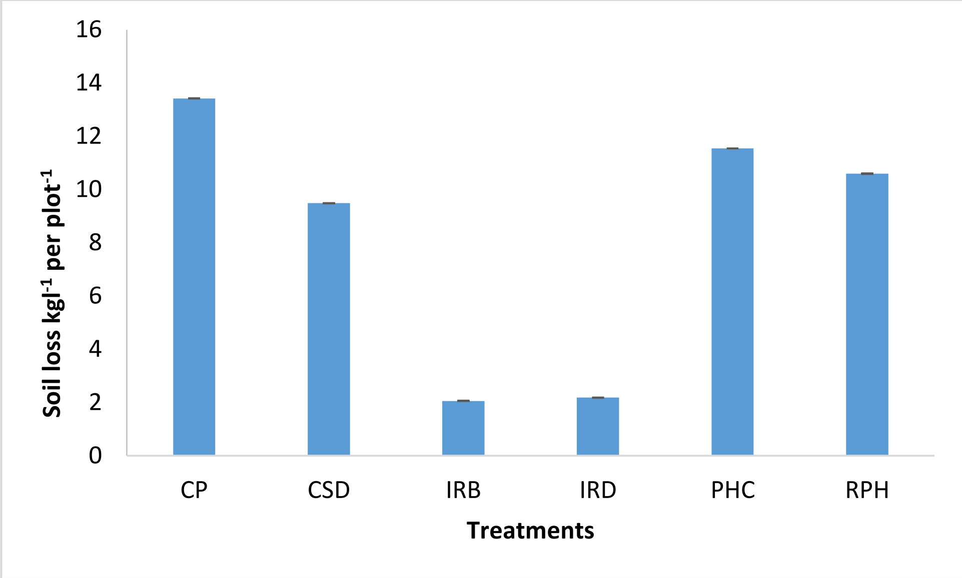

Figure 17. Soil loss in January. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough).

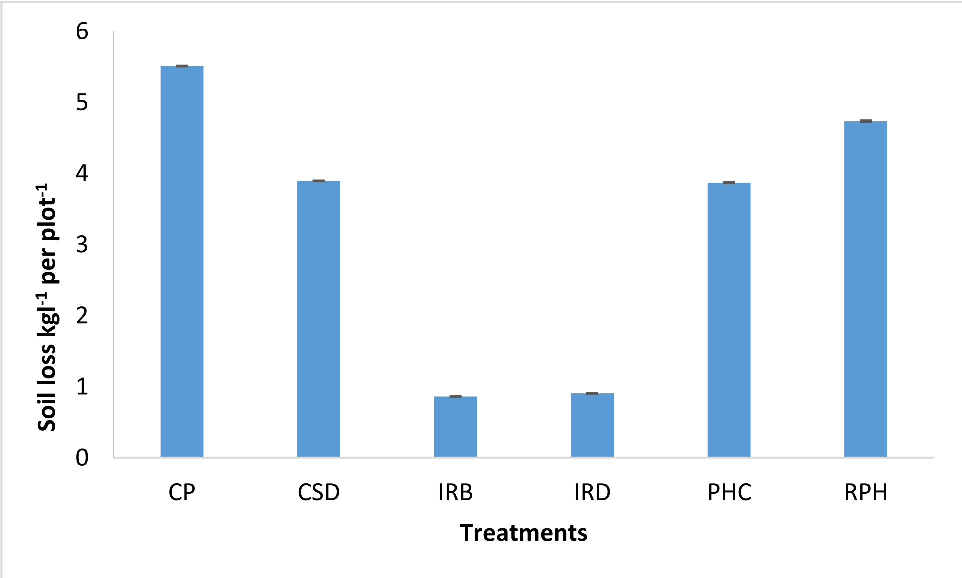

Figure 18. Soil loss in February. Error bars represent standard deviation. Erosion sub-plot area is 22.5 m2. Treatments: Italian ryegrass drilled (IRD). Forage rye post-harvest (RPH). Bare soil with strips (ripvator cultivator) (PHC). Bare soil tilled (disc plough).

6.3 Discussion

The presence of cover crops did not significantly affect either runoff or soil loss compared to the standard practice without cover crops. This is likely to be due to the high variability (standard deviation) within treatments. Although no significant effects were observed, data from the field experiment show trends in the performance of treatments. The standard practice (control) treatment which comprised of bare soil tilled [mould plough] had the greatest mean runoff production in both collection periods and the greatest mean soil loss compared to the other treatments.

Forage rye provides ground cover only from the end of February while Italian ryegrass provides ground cover immediately after the harvest of the maize, protecting the soil from the impact of the rainfall for a longer period. Subsequently there is less runoff in the plots with Italian ryegrass (IRD; IRB) compared to the control bare soil tilled plot [mouldboard plough] (CP) for both collection periods (Figure 6 and 7). Conversely to predictions from the hypothesis, the bare soil tilled [disc plough] (CSD) and bare soil with tilled strips [ripvator cultivator] (PHC) controls, and the plots with forage rye (RPH), did not produce runoff greater than the plots with Italian ryegrass. This may be due to the location in the field of these plots.

The high variability in runoff and soil loss data of the field experiment is probably due to a limited number of runoff generating rainfall events, and the lack of plot randomisation. It is feasible that some plots were located in areas with low moisture storage capacity due to the presence of a shallow water table or less permeable layer (we found out that there are shallow shale layers in the field). Upon sediment collection, it was also observed that quantities of sediments accumulated in the pipes. This could have lead to an underestimation of soil loss, and partially explain the differences between estimates of loss predicted by the model and actual soil loss.

The results from the model confirm the hypothesis, and reflect trends identified by the field experiment. The model predicts that the controls (PHC; CP; CSD) produced the greatest runoff and soil loss. Italian ryegrass performed the best, having almost 100% runoff and 85% soil loss reduction compare to the plots having bare soil. According to the model, the common practice of creating tilled strips across the slope (ripvator cultivator)) did not decrease runoff or soil loss compared to bare soil tilled (disc plough). Findings of the model will be explored in future field experiments.

6.4 Conclusion

The MMF model and trends observed during the initial Phase 1 field trials indicate that, Italian ryegrass (IRD and IRB) may be a more effective cover crop in terms of both runoff and erosion control than forage rye (RPH) and bare soil. This is in large part due to the high % of surface cover associated with the IRD/IRB treatments as compared with RPH. However, the MMF outputs and trends observed during Phase 1 need to be further validated. It is important to note that trends observed in the field experiment are not statistically robust due to the high variation (standard error) within each treatment variable.

6.5 Future directions

Laboratory analysis that will be performed between March, April and May which will determine whether the CC treatments had any effect on soil organic matter, total carbon, availability of soil nutrients and on the size and structure of the microbial community.

Phase 2 of the field experiment will start in May 2015. New erosion plots will be installed post sowing of maize and will remain in place until harvest when they may need to be temporarily removed before re-installation in order to fully test the projects research hypotheses.

The Phase 2 will have several keys differences: the erosion plots location will be randomised, the storage tanks will not be buried in the soil, pipe inclination will be higher and if possible, the number of replicates will be increased. Cover crop species may also be changed subject to discussions. Treatments choice will depend on feedback coming from the Maize Growers Associations and newly published journal articles.

Phase 3 of will focus on evaluating the role of soil biology towards controlling soil erosion. Aggregate stability under simulated rainfall will be used as a proxy of soil erosion. The new experiment will investigate effect of soil microbial communities on soil aggregate stability. Loose fresh soil taken from the field experiment will be used to fill some cores. ¼ of the samples will be repeatedly treated with fungicides, ¼ with antibiotics, ¼ with antibiotics and fungicides, and ¼ will not be treated. After about month soil aggregation will be measure together with the microbial biomass and fungal biomass. This will allow understanding the impact of microbial communities on soil aggregates. Depending on the future developments of the project, it would be possible to recognise the species associated with higher aggregate stability.

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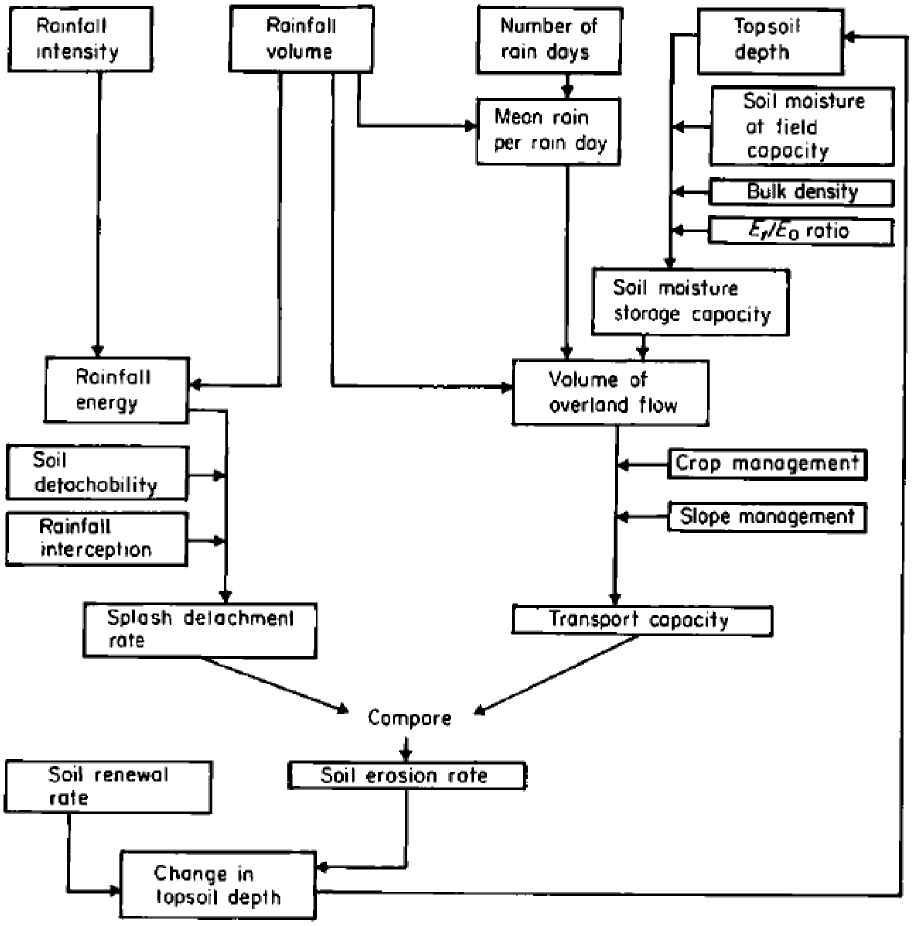
Appendix A

A.1 MMF model



Figure_A 1. Flowchart of the MMF model (Morgan et al., 1984)**.ù**

A.2 Model Parameters

Factor	Parameter	Definition
Climate	R	Mean annual rainfall (mm)
	T	Mean annual temperature (°C)
	R_n	Mean annual number of rain days
	I	Typical intensity of erosive rain (mm h^{-1}). Use 10 for temperate climates, 25 for tropical climates and 30 for strongly seasonal climates (e.g. Mediterranean type or monsoon)
Soil	%c	Percentage clay
	%z	Percentage silt
	%s	Percentage sand
	ST	Percentage rock fragments on the soil surface
	MS	Soil moisture at field capacity (% w/w)
	BD	Bulk density of the top soil layer (Mg m^{-3})
	EHD	Effective hydrological depth of the soil (m)
	RFR	Roughness of the soil surface (cm m^{-1})
Slope	S	Slope steepness (°)
	L	Slope length (m)
	W	Slope width (m)
Land cover	PI	Permanent interception expressed as the proportion (between 0 and 1) of rainfall
	E_t/E_0	Ratio of actual to potential evapotranspiration
	CC	Canopy cover expressed as a proportion (between 0 and 1) of the soil surface protected by the vegetation or crop canopy
	GC	Ground cover expressed as a proportion (between 0 and 1) of the soil surface protected by vegetation or crop cover on the ground
	PH	Plant height (m), representing the effective height from which raindrops fall from the crop or vegetation cover to the soil surface
	D	Average diameter (m) of the individual plant elements (stems, leaves) at the ground surface
	NV	Number of plant elements per unit area (number m^{-2}) at the ground surface

Figure_A 2. Model input parameters (Morgan & Dunzant, 2008).

Table_A 1. Rainfall characteristics derived from the weather station present on site. Total rainfall (mm) (TR). Number of raining days (NRD). Rainfall intensity (I), mean temperature (T).

	TR (mm)	NRD	I (mm/h)
November	73.00	21	0.83
December	19.60	14	0.58
January	72.00	26	0.55
February	35.60	30	0.40
Jan-March	70.60	16	0.56

Table_A 2. Cover Crop parameters. The parameters have been measured in the field in March, the other parameter have been estimated based on March's values. D is plat diameter, NP is number of plant stems for unit area.

MARCH	PLANT HEIGHT (m)	D (m)	NP(m-2)	FEBRUARY	PLANT HEIGHT (m)	D (m)	NP(m-2)
IRB1	0.18	0.003	180.00	IRB1	0.18	0.003	180.00
IRB2	0.22	0.006	206.67	IRB2	0.22	0.006	206.67
IRB3	0.18	0.005	166.67	IRB3	0.18	0.005	166.67
IRD1	0.18	0.004	144.00	IRD1	0.18	0.004	144.00
IRD2	0.17	0.004	233.33	IRD2	0.17	0.004	233.33
IRD3	0.12	0.005	160.00	IRD3	0.12	0.004	144.00
RPH1	0.07	0.004	46.67	RPH1	0.07	0.004	42.00
RPH2	0.10	0.004	68.57	RPH2	0.09	0.003	61.71
RPH3	0.11	0.007	60.00	RPH3	0.10	0.006	54.00
JANUARY	PLANT HEIGHT (m)	D (m)	NP(m-2)	DECEMBER	PLANT HEIGHT (m)	D (m)	NP(m-2)
IRB1	0.17	0.003	162.00	IRB1	0.15	0.003	145.80
IRB2	0.20	0.006	186.00	IRB2	0.18	0.005	167.40
IRB3	0.16	0.004	150.00	IRB3	0.15	0.004	135.00
IRD1	0.16	0.004	129.60	IRD1	0.14	0.003	116.64
IRD2	0.15	0.004	210.00	IRD2	0.14	0.003	189.00
IRD3	0.10	0.004	129.60	IRD3	0.09	0.003	116.64
RPH1	0.06	0.004	33.60	RPH1	0.05	0.003	26.88
RPH2	0.08	0.003	49.37	RPH2	0.06	0.002	39.50
RPH3	0.09	0.005	43.20	RPH3	0.07	0.004	34.56
NOVEMBER	PLANT HEIGHT (m)	D (m)	NP(m-2)				
IRB1	0.134	0.0022	116.640				
IRB2	0.145	0.0041	133.920				
IRB3	0.117	0.0030	108.000				
IRD1	0.113	0.0026	93.312				
IRD2	0.108	0.0026	151.200				
IRD3	0.075	0.0026	93.312				
RPH1	0.038	0.0022	21.504				
RPH2	0.052	0.0019	31.598				
RPH3	0.057	0.0035	27.648				

Table_A 3. Soil parameters. The parameters have been measured in the field in March. BD is bulk density.

treatment	replicate	BD	% clay	%silt	%sand
cp	1	1.31	15.10	52.59	32.31
cp	2	1.28	15.10	52.59	32.31
cp	3	1.28	15.10	52.59	32.31
csd	1	1.30	17.27	64.70	18.03
csd	2	1.29	17.27	64.70	18.03
csd	3	1.30	17.27	64.70	18.03
irb	1	1.27	16.36	62.51	21.13
irb	2	1.27	16.36	62.51	21.13
irb	3	1.32	16.36	62.51	21.13
ird	1	1.59	14.95	61.56	23.49
ird	2	1.30	14.95	61.56	23.49
ird	3	1.30	14.95	61.56	23.49
phc	1	1.31	15.94	58.66	25.40
phc	2	1.31	15.94	58.66	25.40
phc	3	1.29	15.94	58.66	25.40
rph	1	1.28	16.12	56.57	27.31
rph	2	1.29	16.12	56.57	27.31
rph	3	1.29	16.12	56.57	27.31