Soil erosion trials

Introduction

The literature unanimously identifies soil erosion as a major problem in the northern mountainous region of Vietnam. Maize and cassava based systems are the most susceptible. In farmers' fields, surface erosion rates can reach up to 350 t/ha (Ziegler et al. 2009). Reduction in tillage and a move towards no-tillage systems may be an important soil management option to control erosion in the northern mountainous region of VN. Besides protecting the soil from raindrop impact, residue retention would also increase soil structural stability as organic matter may build up and reduces soil erodibility. Several publications investigate these beneficial effects, but generally do not extrapolate from biophysical processes to farmer adoption. Reduction in tillage lessens labour, i.e. it is potentially farmer friendly, but requires herbicide application, which farmers may not be able to afford or may not know how to use. Other tillage related options are reducing tillage to the flatter slopes only, cultivation along the contour or deliberately placing barriers (e.g. charred logs or hedges) horizontally across the hill slope to form revetments to curb soil loss.

Methods

Research on soil erosion usually requires setting up Wischmeier-type erosion plots which makes it difficult, if not impossible to assess erosion in real-life farmer fields, and is expensive. We used a low cost modified profile meter method (pin method) to monitor erosion in farmers' fields (Hudson, 1993). Unlike Wischmeier plots, this method has minimum impact on farm operations. However, measurement errors can be large due to slumping of soils after tillage and soil swelling. We compensated for these shortcomings by taking a large number of measurements, monitoring of soil bulk density to account for slumping of soil and assumed shrink-swell was negligible on these 1:1 type clay soils. The pin method monitors the change in soil surface during the maize season. As these pins are not installed in a confined plot, the change in soil surface is due to the cumulative effect of both erosion and deposition, in other words it monitors '*soil movement'*.

The objective of our study was to assess soil erosion in farmers' fields and evaluate different farmer–friendly erosion prevention techniques. The research conducted monitored soil movement in complete randomized block experiments at two sites, Na Ot (Mai Son district) and La Nga (Moc Chau district).

Profile meters in our pin method comprised of four soil pins inserted into the ground to ~40 cm in a 70x100 cm rectangle and measuring soil surface to pin distance at eight constant locations within this erosion station at ~10 times during the growing season. It is important to note that the assessment of soil surface level changes measures both, erosion and disposition. It is therefore more appropriate to term this a method that monitors soil movement rather than soil erosion alone. In year 4 of the project erosion barrier that collect eroded soil were installed to visualise and corroborate the data collected using the pin-method.

Other key measurements were rainfall intensities, final maize yields, bulk densities and infiltration rates. Following discussion with farmers, treatments were adjusted to what farmers though they may use in future. Cultivation at both sites was done using a hand hoe.

In general, the treatments at Na Ot were (i) Control (slash, burn and cultivate), (ii) Minimum-tillage, (iii) Mini-terrace and (iv) No-tillage - at La Nga treatment were (i) No-tillage, (ii) Minimum-tillage, (iii) Intercropping Rice Bean with Maize and (iv) Control (cultivate with or without burning). However, implementation of treatments was not consistent for the three growing seasons 2011, '12 and '13. Details are given in the Table 1 on the next page.

Table 1: Treatments

Na Ot	La Nga	Comments
(i) Control	(iv) Control	The normal farmer practice was slash and burn before cultivation. But in 2011 the farmer at La Nga decided not to burn. Due to animal grazing in La Nga, mulch was imported in 2011.
(ii) Minimum Tillage	(ii) Minimum Tillage	Residue retained, cultivation of one row where maize was sown
	(iii) Minimum Tillage, rice bean intercrop	Different row spacing but same plant density. Rice bean did not grow in 2011 and 2012, hence this treatment in La Nga is the same as Minimum Tillage except for the different row spacing.
(iii) Mini-terraces		Build in 2011 and reshaped in 2012 and 2103, residue retained.
(iv) No-tillage	(i) No tillage	Residue retained and maize planted in small hole.
No free grazing	*Free grazing*	*Due to the difference in animal management between sites, the La Nga site was fenced off in years 2012 and 13.*

At La Nga the amount of residue from the past crop ranged from 1 to 3 t/ha, the additional residue applied ranged from 3 to 5 t/ha. At Na Ot the average amount of residue amount left from the last season was 4.3 t/ha with an average groundcover of 83% before land preparation. The difference in residue amounts between the two sites is due to grazing during the dry season.

Results 2011

During the 2011 maize season average soil movement at La Nga was a loss of 38 t/ha, with a very large variation from 3 to 95 t/ha, but no significant differences between treatment and it was not possible to differentiate between erosion rates at the start and towards the end of the maize season. We attributed the lack of significant differences to the similarity of treatments where all treatments had residue retained.

At Na Ot total soil movement rates were much higher compared to La Nga and segmental regression of erosion rates showed that there was a significant difference between the start and the end of the maize season. Most movement occurred until the 7 July 2011. The first erosion measurement was done on the 22 April and maize sown on the 11 May. This suggests that a large proportion of soil movement occurred during the initial phase probably occurs after land preparation and before the maize is planted and aggravated by weeding (Podwojewski et al. 2008). Initial soil movement was a loss of 226 t/ha for treatment (i), i.e. slashes and burn. There were no significant differences between the other treatments where residue was maintained and average initial soil movement was a loss 101 t/ha. The difference between residue burnt and residue maintained was significant at the 5% level. The average soil loss rates after the 7 July 2011 was 17 t/ha with a range of 5 – 25 t/ha and no significant differences between treatments. There were no significant differences in bulk density changes. However, overlaying soil surface movement as measured using the pins with estimated soil slumping using the bulk density values, no significant differences between treatments were observed. Examples for Na Ot are given in Figure 1.

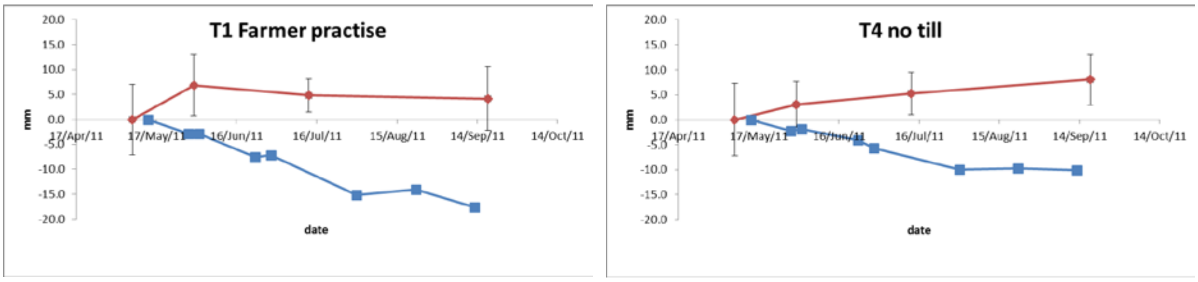

Figure 1: Soil surface changes in Na Ot, red line: slumping as estimated from bulk density changes; blue line: erosion pins.

Although it was not possible to derive estimates of net soil loss, the data clearly shows substantial soil movement in that maize fields as erosion and deposition occur simultaneously. The lack of clear soil loss as up-slope topsoil material is deposited down-slope is probably also a contributing factor that farmers do not notice an impact on soil productivity. It is a classic case of resource relocation where productivity of lower slopes is increases at the expense of upper slope productivity – at least at present.

There were no maize yield advantages to using erosion control soil management practices in La Nga and in Na Ot in 2011,. Due to the small impact on yield after '*trying something new*', it is unlikely that the farmers will change their normal practice; i.e. it lacks an immediate tangible outcome.

Results 2012

The trend in yield differences persisted in 2012. In Na Ot the farmer practice treatment had the highest yield however difference was not statistically significant. Yields at La Nga were affected not only by insect problems following sowing, but also by severe rodent infestation. Farmers attributed this to the presence of crop residue.

The soil movement observations in 2012 were improved due to more frequent and more reliable bulk density measurements. However, following the data from 2011, we were unable to demonstrate that farmer practice has more severe erosion compared to the erosion prevention methods we tested. Large amounts of soil movement were observed again in all treatments. The graphs in Figure 2 below give examples for Na Ot and La Nga.

The soil movement at La Nga is compounded by weed infestation. This was most pronounced in the farmer practice treatment where erosion was followed by soil deposition on the grass.

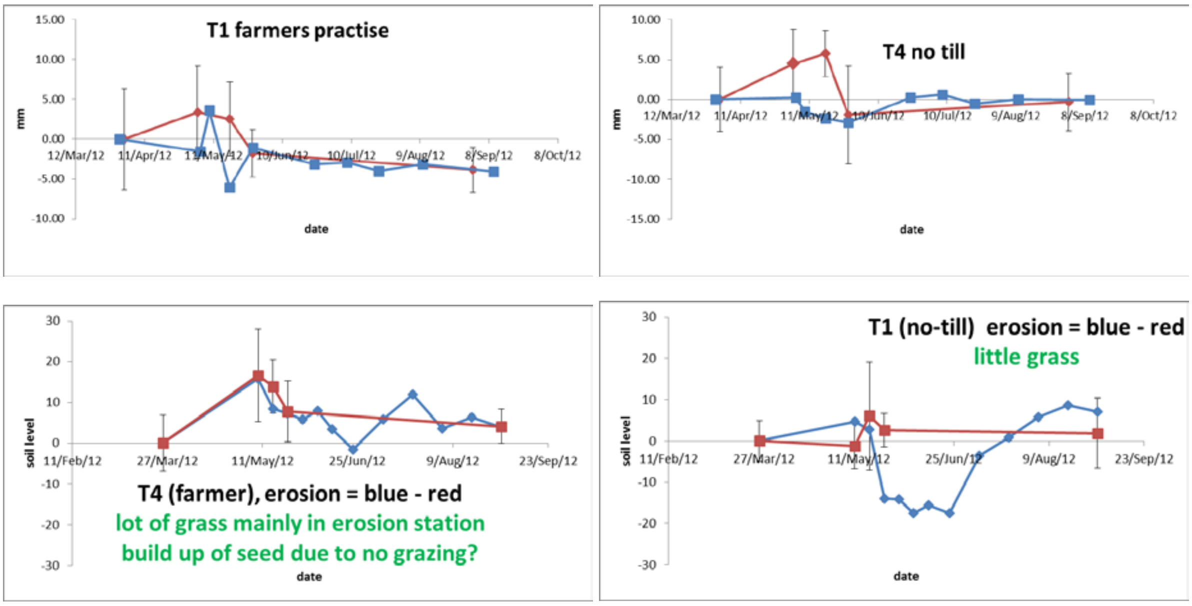

Figure 2: Examples of soil surface movement for Na Ot (top) and La Nga (bottom). Red line: slumping as estimated from bulk density changes; blue line: erosion pins

Results 2013

Following the observation from the previous year that soil deposition makes it difficult if not impossible to derive an estimate for net soil loss, we installed erosion barriers above the erosion station to minimise deposition. The up-slope section of these barriers was spray-painted with different colours following large rainfall event so that deposition above the barrier could be visualised. This simple method may be of benefit to demonstrate soil moment to farmers. Although this modification hinders deposition for the benefit to estimate soil loss within the erosion station, the erosion rates must be treated with caution as they do not represent the entire field and extrapolation, as with Wischmeier plots, to landscape scale erosion rates is not possible. Due to set-up problems only the erosion barriers at the Na Ot could be used. Visual inspections of the erosion barriers clearly showed that most erosion occurred, as expected, between plating and tillering with relatively little erosion between tillering and harvest. However, the most striking observation was that there were no visual differences in erosion between treatments. One would have expected that maintaining groundcover reduces erosion, but our data suggested that these slopes are too steep to control erosion with groundcover. Reasons for high erosion rates with groundcover maintained could be spatial variability of raindrop. On a small scale, single raindrops deliver water into the uncovered soil surface at a higher rate than infiltration rates resulting in runoff. Alternatively it could be a consequence of exfiltration on very steep slopes.

Infiltration rates

Field infiltration rates at both sites were in the order of 50 mm per 10 minutes, i.e. very high and exceeded rainfall intensities. This would mean that there should not be any erosion, yet erosion rates are very high. We argue that unprotected soil that gets pounded by raindrops will form a very thin impermeable layer of broken down small aggregates which prevent water intake and are easily eroded. This mechanism would not be picked up using the field infiltration method we used (i.e. single ring) where the soil surface is purposely protected during the measurement to ensure undisturbed and comparable results between treatments. Aggregate destruction during raindrop impact would also explain why maintaining residue has the main effect to reduce erosion and different techniques of residue retention are less important.

We simulated soil surface protection on intact large cores by measuring saturated hydraulic conductivity before and after the soil surface was rained. Results are given in Figure 3.

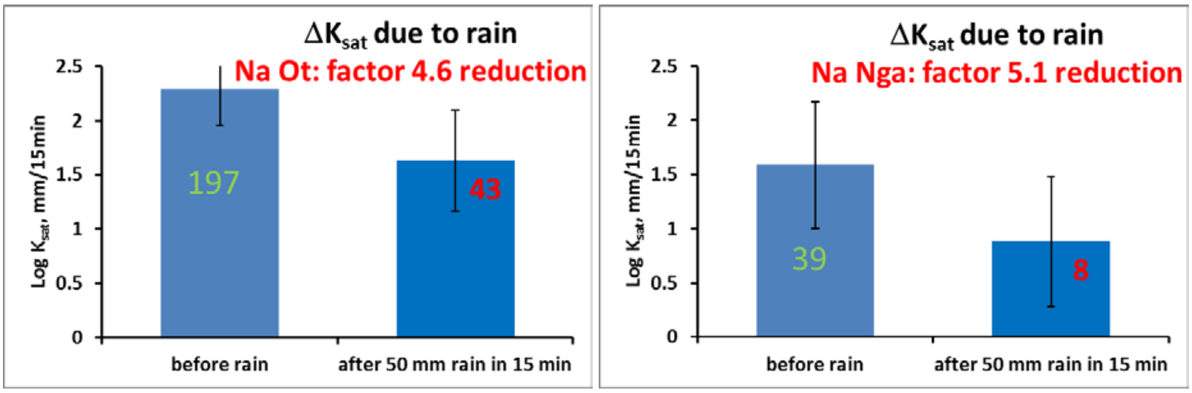

Figure 3: The effect of soil surface cover on saturated hydraulic conductivity (K_{sat})

Reduction in infiltration due to raindrop impact was similar on both sites, around a 5-fold decrease in K_{sat}. Infiltration rates at La Nga are considerably lower than Na Ot which is probably due to soil derived from different parent material, shale *vs* limestone. At Na Ot the infiltration rates at the rainfall we simulated (50 mm/15 minutes) are sufficiently high to take in water without runoff (factor of 3 higher) if the soil surface was protected; if it was not protected the infiltration rates would be ~15% too low. At La Nga the infiltration rates are too low with soil surface protection (23% too low) but 85% too without soil surface protection. Although this data was a preliminary investigation on the effect of ground cover on soil water intake potential, it clearly shows the large differences between soil types and soil responses to raindrop impact. This in turn will affect what soil erosion prevention methods it need on what soil under what condition.

Ground coverage under filed conditions are given in Table 4. This data shows that ground cover prior to land preparation is well above the recommended cover suggested by FAO.

Table 2. Available pre-cultivation ground cover data.

year	**Control** (T1 Na Ot – T4 Na Nga)	**Min-till** (T2 Na Ot – T2 Na Nga)	**Zero-till** (T4 Na Ot – T1 Na Nga)	**Mini Terrace** (T3 Na Ot)	**Rice Bean** (T3 Na Nga)
2011 – Na Ot	92.0a	78.3a	84.3a	77.7a	
2012 – Na Ot	97.2a	91.8a	88.7a	91.8a	
Na Nga	8.8^{b} – post cultivation	83.7^{a}	88.2^{a}		81^{a}
2013 – Na Ot	85.7^{a}	87.3^{a}	92.0^{a}	79.0^{a}	

We have little data on percent ground cover after land preparation, but total biomass before and after land preparation is available and given in Table 3. Except for the control, land preparations reduced total biomass left on the soil surface. This suggested that reduced tillage would be an option not only to reduce erosion but also to increase soil organic carbon. However, our results show that maintaining ground cover achieved neither objective. We assume that the slope are simply too steep.

Table 3. Pre- and post-cultivation soil surfce biomass.

year	**Farmer Practise** (T1 Na Ot – T4 Na Nga)	**Min-till** (T2 Na Ot – T2 Na Nga)	**Zero-till** (T4 Na Ot – T1 Na Nga)	**Mini Terrace** (T3 Na Ot)	**Rice Bean** (T3 Na Nga)
2011 – Na Ot					
Before tillage	4.8^{a}	4.94^{a}	4.1^{a}	4.3^{a}	
After tillage	1.0^{b}	4.94^{a}	4.1^{a}	4.3^{a}	
Na Nga					
Before tillage	1.31^{ns}	2.31^{ns}	1.92^{ns}		1.8^{ns}
After tillage	1.31^{b}	4.96^{a}	6.22^{a}		1.8^{b}
2012 – Na Ot					
Before tillage	6.2^{a}	5.1^{a}	5.8^{a}	5.6^{a}	
After tillage	0.7^{b}	5.1^{a}	5.8^{a}	5.6^{a}	
Before harvest	0.2^{b}	0.8^{ab}	1.1^{a}	1.0^{a}	
Na Nga					
Before tillage	3.97^{b}	5.24^{ab}	7.85^{a}		7.78^{a}
After tillage	0.28^{b}	6.70^{a}	8.01^{a}		8.11^{a}
2013 – Na Ot					
Before tillage	3.43a	3.37a	3.65a	3.66a	
After tillage	0.35b	3.37a	3.65a	3.01a	

Soil chemical properties

Soil chemical properties at the two sites are given in Table 2 and Table 3. The main difference between sites is higher organic carbon at Na Ot, yet lower CEC. This is a reflection of parent material of the soil: Na Ot soil derived from shale, Na Nga derived from Limestone. These soil properties suggest no limitations for maize production if normal maize fertilisation recommendations are followed.

Table 4. Soil properties at the NaOt site

depth	pH, H_2O	SOC, Wt %	CN ratio	Col P, mg/kg	CEC, cmol(+)/kg
0-5	4.8	3.4	24	28.7	2.3
5-20	4.8	2.7	31	22.2	1.3
20-40	4.6	1.9	47	14.4	0.6

Table 5. Soil properties at the La Nga site .

depth	pH, H_2O	SOC, Wt %	CN ratio	Col P, mg/kg	CEC, cmol(+)/kg
0-5	4.9	1.8	27	39.7	4.7
5-20	4.7	1.4	37	20.5	3.6
20-40	4.6	1.1	14	7.3	3.2

Soil samples were collected at the completion of the field experiments, but no analysed due to insufficient funds. However, there is little reason to expect major changes, in particular soil organic carbon content. Although there are often expectations that organic carbon contents increases under no-till systems were crop residue is maintained, there is growing evidence that this does not increase soil organic matter (Dalal *et al* 2011). Decomposition rates of organic matter in a warm and moist environment like the NW of Vietnam are likely to exceed build-up rates. Soil

Conclusions

There is a worldwide push to move towards conservation farming practices. In the maize growing region of Northwest Vietnam this practice change has the premise to reduce soil erosion. There are four key principles for successful conservation farming: minimum tillage, permanent ground cover, crop rotation and adequate fertiliser use (Vanlauwe, 2014). Minimum tillage on the soils and slopes we investigated did not have a consistent impact on soil erosion. Permanent ground cover is seen as a major impediment for crop protection. In part, this is simply due to having residue on the ground but it is, or will be, aggravated in a maize-only cropping system. Crop diversification or intercropping may help overcome crop protection issues, but how effective the soil erosion prevention methods we tested are in such diversified systems, is not known. However, given the steepness of the slopes were maize is grown, it can be projected that rather drastic soil erosion prevention methods are needed; i.e. simply reducing tillage and maintaining some ground over is insufficient. It is currently not know which type erosion prevention methods are suitable and effective on what slopes, on what soils and which cropping systems. It is possible that slopes of ~30° (~58%) are too steep for upland cropping in this region.

The method we used to assess erosion was able to demonstrate substantial soil movement. It was not able to demonstrate any significant impact on soil erosion reduction using the soil conservation methods we trialled. This means the method is not suitable or the erosion control methods we trialled are inadequate. However, field observations confirm that even the reduced tillage treatment eroded substantially which was unambiguously corroborated but the erosion barrier assessment.

The main questions that require further investigation are:

- What are the threshold slopes where maize cropping becomes unsustainable?
- How much ground cover is needed and what are the limitations of conservation agricultural practises on what soils and slopes?
- What are land management options on slopes that are too steep for maize production, and farmers incentives to adopt them?

References

Dalal RC, Allen DE, Wang WJ, Reeves S, Gibson I (2011) Organic carbon and total nitrogen stocks in a Vertisol following 40 years of no-tillage, crop residue retention and nitrogen fertilisation. Soil & Tillage Research 112(2), 133-139.

Hudson, N. W. (1993). Field measurement of soil erosion and runoff. Food and Agriculture Organization of the United Nations, Rome, 1993. Silsoe Associates, Ampthill, Bedford, United Kingdom. (fao.org/docrep/T0848E/t0848e00.htm)

Podwojewski P, Orange D, Jouquet P, Valentin C, Nguyen VT, Janeau JL, Tran DT (2008) Land-use impacts on surface runoff and soil detachment within agricultural sloping lands in Northern Vietnam. Catena 74, 109-118.

Vanlauwe, B (2014). A fourth principle is required to define Conservation Agriculture in sub-Saharan Africa: The appropriate use of fertilizer to enhance crop productivity. Field crops research (0378-4290), 155.

Ziegler AD, Bruun TB, Guardiola-Claramonte M, Giambelluca TW, Lawrence D, Lam NT (2009) Environmental Consequences of the Demise in Swidden Cultivation in Montane Mainland Southeast Asia: Hydrology and Geomorphology. Human Ecology 37, 361-373.