Conservation Agriculture potential effects on soil erosion for rainfed crops in the Lake Alaotra region in Madagascar

Van Hulst F[1], Naudin K[2], Domas R[3], De Graaff J[1], Visser S[1], **Scopel E**[2]
[1] Land Degradation and Development Group, Wageningen University,Wageningen, Netherland; eric.scopel@cirad.fr
[2] UPR Systèmes de Culture Annuels, SCRiD Team, CIRAD, F-34398 Montpellier, France
[3] BRL, Ambatondrazaka, Madagascar

Keywords: RUSLE, Erodibility, C factor, small scale farming, Ferralsols

Introduction

Africa is facing an increasing population and food demand that has already led to large scale land use changes, increasing pressure on land and water resources (Drechsel et al., 2001). Soil degradation in tropical agro-ecosystems is strongly linked with water erosion of productive top soils. Such a process is particularly important for land dedicated to agriculture compared to natural ecosystems. It rapidly becomes an obstacle for achieving an increased food production in a more sustainable way in order to attend the growing population demand (Lal, 2007).

The three principles of Conservation Agriculture (CA) of no tillage, permanent soil cover and crop rotation (FAO 2008) are often seen as a promising solution for mitigating soil erosion processes and enhancing sustainable resources management (Lal, 1985). Reducing soil tillage intensity often results in a higher stability of soil aggregates, and protecting soil surface reduces water rainfall energy to detach and transport sediments (Scopel et al., 2005). The third principle has more indirect impacts on soil erosion. The protection they ensure the soil directly by their presence and by the total biomass produced as a mulch will differ as a function of the crops grown and their succession in time.

In the case of the Lake Alaotra Region in Madagascar, the fertile lowlands are now fully occupied by irrigated rice cropping and farmers are using more and more the hillsides called 'tanety' for producing staple crops such as maize, rice, legumes grains or cassava (Domas et al., 2010). Nevertheless these new rainfed fields are infertile loamy yellow and red ferralsols which are very susceptible to erosion. Diversified CA systems have thus been actively promoted in this region combining several crops and cover crops in rotation and/or intercropped.

The aim of this study was to quantify potential effects of CA systems in reducing soil erosion using the RUSLE model to explore different crops/cover crop combinations.

Materials and Methods

This study was conducted in the 'tanety' fields of the Lake Alaotra region with altitude ranging from 750 to 1450 m. We used as an example the classical ferralsol from Tafa experimental site (LAT: 17°32'5" and LONG: 48°32'17"). Local climatic conditions are tropical sub-humid with a tremendous variability in annual total rainfall (450-1600 mm) and rainfall distribution. The average yearly temperature is around 21°C.

We compared four different cropping systems:
1. Traditional. A two year rotation where upland rice is grown one year and maize the other. The crop residues are often removed after harvest. After some years the field is left as fallow.
2. CA Stylo 1. A three to four year CA rotation on the basis of the *Stylosanthes guianensis* (stylo). Stylo is introduced in the first year in association with e.g. groundnut. In the second year the Stylo grows alone to a height of about 1.5 meter. Upland rice is grown in the third year in the stylo mulch. Maize is grown in the fourth year as the stylo mulch disappears and new stylo starts to grow again. Data is obtained from test fields.
3. CA Stylo 2. In theory the same as 2 but closer to farmers' fields conditions with less weeding frequency and lower sowing density.
4. CA Dolichos. A two year CA rotation with a basis of *Dolichos Lablab* (dolichos). Dolichos is sown with maize the first year. In the second year upland rice is planted in the mulch of Maize+Dolichos.

To estimate soil losses we used the Revised Universal Soil Loss Equation (RUSLE) which has been applied in and modified for many regions in the world (Renard et al., 1997). RUSLE calculates a yearly average of soil loss at field level by multiplying five factors as in equation 1.

$$A = R \times K \times LS \times C \times P \qquad \text{eq. 1}$$

In our case, based on 46 years of daily effective rainfall measurements, a yearly average erosivity factor (*R)* could be calculated as 8487 $MJ \cdot mm \cdot ha^{-1} h^{-1}$. The average of five estimation methods was used to estimate the yearly soil erodibility factor (*K)* as 0.038 $ton \cdot h \cdot MJ^{-1} mm^{-1}$. Average slope length and steepness scenario was determined, yielding a (*LS)* factor of 1.5. After consulting local experts overall supporting practices (P) values were fixed as 0.4 for the Traditional cropping system and as 0.1 for the CA cropping systems. The major part of this study has been to evaluate the cover-management (C) factor for the different cropping systems and calculate consequences for soil erosion. The C-factor was divided into a crop component C_{crop} and a mulch component C_{mulch} for every month, calculated for each of them as $C_{c_i} = (1 - F_{C_i})$ where F_{ci} is the fraction of ground cover. The C factor for each month has been calculated multiplying both crop and mulch C-factors.

Results and Discussion

The crop management factor C was divided into a crop component and a mulch component. This approach reveals in a transparent manner the respective contribution of crop and mulch cover in reducing soil loss. Results reported in (Figure 1) indicated that Stylo 1 is most effectively reducing soil loss through both crop and mulch. The difference between Stylo 1, situation at test fields, and Stylo 2, situation on farmers' fields, lies in a slower growth of the cover crop rather than the mulch cover. The impact of the Dolichos cropping system can be attributed to the mulch, because there is little difference with Traditional if only the crop cover is considered. Mulch of rice and maize is not adding much to erosion prevention. Dolichos mulch has 'bad timing' with respect to erosive rains compared to stylo mulch. Average outcomes for crop management factor C is 0.04, 0.14, 0.13 and 0.56 respectively for the four cropping systems: Stylo 1, Stylo 2, Dolichos and Traditional, where the soil is often poorly covered.

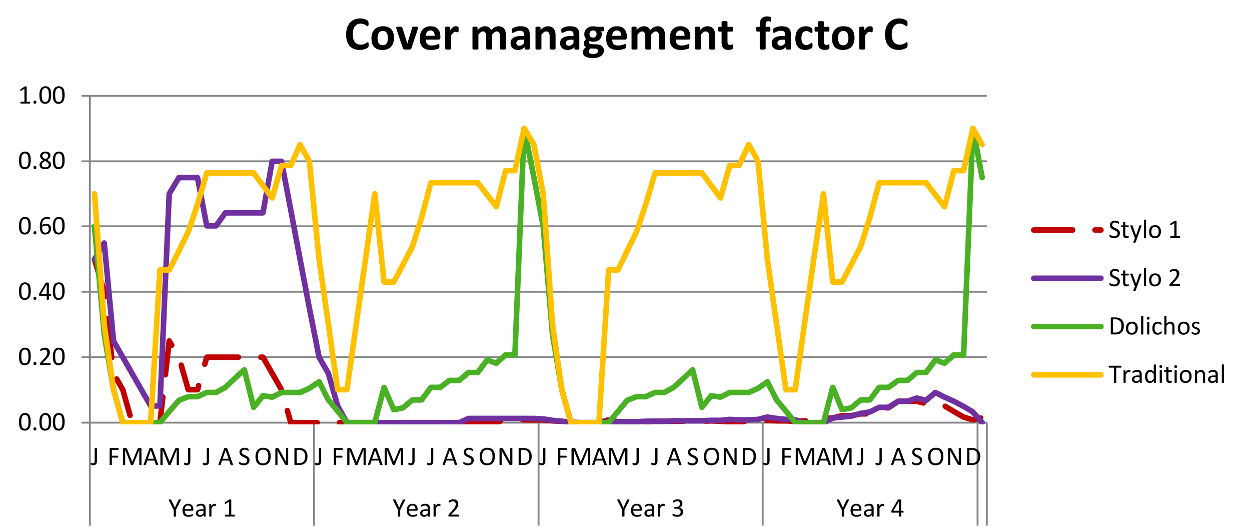

Figure 1. Variability of the C-factor throughout the years of rotation, for four cropping systems

For the traditional cropping system an actual soil loss of 86.6 ton·ha^{-1}yr^{-1}was found (Table 1). Compared to the calculated potential soil loss of 484 ton·ha^{-1}yr^{-1} for the same *LS* scenario, this is quite a substantial gain. Nevertheless the impact of CA on actual soil loss is even more important as relatively to Traditional, measured in ton·ha-^{1}yr^{-1}, it represents an additional reduction to 2.0 (2.3%) for Stylo 1, to 5.5 (6.9%) for Stylo 2 and to 9 (10.3%) for Dolichos.

Table 1. Actual calculated soil loss (ton·ha^{-1} yr^{-1}) from monthly crop cover factor (*C*) for the respective years of the rotation for four cropping systems

Cropping system	**Year**	**Soil loss from monthly cover management *C* (ton·ha^{-1}yr^{-1})**
Stylo 1	1	7.2
	2	0.1
	3	0.2
	4	0.5
	Av.	2.0
Stylo 2	1	18.4
	2	2.5
	3	0.3
	4	0.8
	Av.	5.5
Dolichos	1	7.3
	2	10.6
	Av.	9.0
Traditional	1	79
	2	94.1
	Av.	86.6

Such a reduction of erosion processes will positively impact on the long term soil organic matter and soil C stocks (Scopel et al., 2005), and will allow maintainance of crop productivity longer without resorting to expensive external inputs. This capacity to reduce soil degradation processes might be a key issue to convince small-scale farmers of CA advantages and overcome the difficulties for CA adoption in Africa as reported by Giller et al. (2009).

References

Drechsel P., Gyiele L., Kunze D., Cofie O., 2001. Population density, soil nutrient depletion, and economic growth in sub-Saharan Africa Ecological Economics, 38: 251-258.

Domas R., Penot E., Andriamalala H., 2010. When 'tanety' hillsides meet the rice fields at Lake Alaotra: Diversification and innovation in Upland zones in an increasingly saturated land occupation context. In Regional Workshop on Conservation Agriculture proceedings, MAF/NAFRI/CIRAD eds., Held in Nov 2008 in Phonsavan, Laos. 62-80.

FAO, 2008. Investing in Sustainable Agricultural Intensification. The Role of Conservation Agriculture. A Framework for Action. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/ag/ca/doc/proposed_framework.pdf

Giller K.E., Witter E., Corbeels M., Tittonell P., 2009. Conservation agriculture and smallholder farming in Africa: the heretics' view. Field Crop. Res. 114, 23–34.

Lal R., 1985. Soil erosion and sediment transport research in tropical Africa. Hydrological Sciences Journal, 30-2.

Lal R., 2007. Anthropogenic influences on world soils and implications to global food security. Advances in Agronomy, Volume 93, 69-93.

Renard K.G., Foster G.R., Weesies G.A., McCool D.K. and Yoder D.C. (Coordinators) 1997, Predicting soil erosion by water - a guide to conservation planning with the revised universal soil loss equation (RUSLE), published as Agriculture Handbook 703, US Govt. Printing Office, 384 p.

Scopel E., Findeling A., Chavez Guerra E., Corbeels M., 2005. The impact of direct sowing mulch-based cropping systems on soil erosion and C stocks in semi-arid zones of western Mexico. Agronomy for Sustainable Development, 25: 425-432