CASE STUDIES

Conservation Agriculture: a complex avenue to conserve and improve soils

Helena Gómez-Macpherson and Francisco Villalobos

PHOTO: Pump installation in Namanhumbir village, Tanzania. ONGAWA.

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CONSERVATION AGRICULTURE: A COMPLEX AVENUE TO CONSERVE AND IMPROVE SOILS

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1. Introduction

Soil erosion leads to soil degradation and water pollution; it is considered the main environmental threat associated with agriculture. Conservation Agriculture (CA) was developed to counteract this trend. Widespread implementation of CA in North and South America and Australia suggests significant farmer profitability, achieved through a combination of sustained or increased agronomic productivity and reduced input costs. Many believe similar agronomic benefits can accrue to farmers in Europe and Africa, despite differences in biophysical and socio-economic environments across these regions. However, the adoption of CA is minimal in both continents.

This case study explores the requirements for developing successful CA systems in general and for smallholder farmers in Sub-Saharan Africa (SSA) in particular. The case study is largely based on the study “The impact of conservation agriculture on agricultural yields: A review of the evidence”, commissioned by the Independent Science and Partnership Counsel (http://ispc.cgiar.org/) and published in Agriculture, Ecosystems and Environment Journal (Brouder and Gómez-Macpherson, 2014).

The case includes, firstly, an introduction to soil erosion, its estimation, and identification of factors driving it, and secondly, an introduction of CA, its key elements and the complex interaction of factors and paths within the system. Class activities proposed are to enable students to become familiar with the Universal Soil Loss Equation (USLE) and its use for evaluating land uses. The viewing of several videos on soil quality and various aspects of conservation by the students at home is also proposed.

1.1. Disciplines covered

Agronomy; crop ecology; soil and water conservation; soil erosion; on-farm management.

1.2. Learning outcomes

- Understand interacting biophysical factors and process pathways towards soil quality and crop performance influenced by CA technologies.
- Ability to estimate soil erosion according to local conditions in order to evaluate land use options and their potential impact on soil erosion.

1.3. Activities

Home Activity 1

Two main groups will be formed: Conventional Agriculture and Conservation Agriculture. Each group will discuss pros/cons for both systems and find arguments to defend their assigned system and against the other system.

Class Activity 1

The two big groups, Conventional Agriculture and Conservation Agriculture, will have a debate on the two systems. One person per group will present their assigned system in 5 minutes. After this, different students will present the arguments following a given order.

Class Activity 2

In small groups, students will estimate soil losses for different environmental conditions and crop managements. Each group will present their results and a table will be filled in with the information. All groups will together discuss which factors affect soil erosion more and what can farmers do about it.

2. Description of the context

During last century, the development of powerful tractors replaced the less intensive traditional soil management methods. The new methods allowed rapid farm work and were extremely effective at controlling weeds, but also resulted in soil degradation Tillage disrupts and exposes protected soil aggregates and organic matter to aeration and microbial attacks, and therefore, increases the risk of water and wind soil erosion. Tillage also incorporates crop residues into the soil during its preparation to facilitate crop sowing, but at the same time leaves the soil surface unprotected against erosive elements.

Erosion is the process of soil loss. Firstly, it requires energy for removing the particles, and then, some transport medium. The energy is obtained from the impact of raindrops and the transfer of momentum from water (surface runoff) or wind. Soil water erosion is accompanied by soil nutrient losses and accumulated sediment and pollutants in surface water. As a result, soil erosion reduces soil fertility and water storage capacity and thus, soil productivity capacity. On a larger scale, soil loss implies a reduction of vegetation, which in turn intensifies erosion and ultimately leads to desertification. Soil erosion is considered the main environmental threat associated with agriculture, even in irrigated cropping systems, due to the expansion of sprinkler and drip irrigation into inappropriate land (Fig. 1).

Soil degradation due to inappropriate management can have devastating effects. The “Dust Bowl” in mid=west USA early in the 20th century is the best known example. The impact on society and the environment was such that it led to the creation of the Soil Conservation Service in USA in a bid to avoid its repetition (Fig. 2).

The Mediterranean region is particularly prone to water erosion because of heavy rainfall events that occur in autumn or winter when fields have little vegetative protection (Fig. 3). In this region, soil is prepared for cultivation in the summer and cereal crops are sown in autumn, while spring crops are sown as soon as temperatures start to rise in March. In general, crop residues are either incorporated into the soil or removed from the field and sold for additional income. The magnitude of the problem of soil erosion in the region was acknowledged in the Pan-European Soil Erosion Risk Assessment, which illustrated that risk figures of above 10 tn/ha/yr are relatively common in the southern European countries (Montanarella, 2005).

Conservation Agriculture (CA) was developed to solve the problem of land degradation due to inappropriate agriculture practices by reducing soil disturbance to the minimum, maximizing soil cover with residues and increase crop diversification via a process of crop rotation (FAO, 2015a). Current global estimates of the extent of adoption of CA as a package are 124 million hectares (FAO, 2015b), nearly 85 % of which is concentrated in five countries: the United States, Brazil, Argentina, Australia, and Canada. The prevalence of CA in these areas alone suggests CA to be privately profitable for adopters. Furthermore, several environmental benefits have been theorized and some are now documented (Hobbs et al., 2008). Nonetheless, the potential environmental and economic benefits of CA adoption for crops in agro-ecologicalzones beyond the intensively studied systems of the Americas and Australia remain uncertain and contested (Stevenson et al. 2014). In fact, CA is hardly adopted in Europe and Africa.

This case study explores the requirements for developing successful CA systems, in general, and for smallholder farmers in Sub-Saharan Africa (SSA) in particular. The case study is largely based on the study “The impact of conservation agriculture on agricultural yields: A review of the evidence”, commissioned by the Independent Science and Partnership Counsel (ispc.cgiar.org) and published in Agriculture, Ecosystems and Environment Journal (Brouder and Gómez-Macpherson, 2014). Before addressing CA, some concepts related to soil erosion and how to estimate it are provided.

2.1. Estimation of soil erosion

The main factors that determine soil erosion are topography (slope and length of slope), rainfall level, soil properties and soil management practices. Soil water erosion is proportional to runoff, which occurs when precipitation is higher than water infiltration into the soil, and to erodibility, a parameter that reflects how easily a particular soil is eroded.

Soil erosion can be quantified using the Universal Soil Loss Equation, USLE (Wischmeier and Smith, 1978), or its revised version, RUSLE (Renard et al. 1997), both of which were developed in the U.S.A. (www.iwr.msu.edu/rusle/). USLE is primary used as a predictive tool to evaluate land use options and can be expressed as:

$$A = R \times K \times LS \times C \times P$$

where A (Mg / ha / yr) is the average annual soil loss by erosion; R is the rainfall-runoff erosivity factor; K is the soil erodibility factor; LS, the slope length and steepness factor; C, the cover-management factor; and P, the support practice factor.

R depends on the energy and duration of rainfall, but can be roughly calculated based on the monthly rainfall distribution (Bergsma 1981):

$$R = 4.17\ \Sigma(P_i^2/P) - 152$$

where P_i is the precipitation (mm) of month i and P the annual precipitation (mm). Local rainfall can be measured by installing a pluviometer or rain gauge in the field. There are automatic ones that can record hourly or daily rainfall. However, very simple models can be fabricated at home (Fig. 4).

The erodibility K (Mg / ha / yr) depends mostly on structural stability of the soil, which is proportional to the texture and organic matter. K is equivalent to the soil loss that would occur in standard conditions, that is, if the land was kept as clean fallow, has a slope of 9% and a length of 22 m. Soils with a high silt content are most erodible as they tend to crust, produce high rates of runoff and particles are easily detached. High organic matter reduces erodibility because it improves structural stability by reducing the susceptibility of soil particles to detach with rain, runoff or wind. Figure 5 shows a map of estimated K in Europe.
LS represents the combined effect of slope length (L) and slope steepness (S) on soil erosion. LS is the ratio of erosion in the conditions of interest, to that happening in the standard situation (length of 22 m; slope of 9%). LS can be roughly calculated as:

$$LS = [0.065 + 0.0456\ p_t + 0.006541\ p_t^2]\ (l_t/22.1)^{NT}$$

where p_t is the slope (%) of the land, l_t is the length (m) and NT is a factor that depends on the slope steepness.

The C factor reflects the effect of the crop (Cc) and the soil management method (Cm) on rainfall erosivity in relative terms from the deviation from standard clean-tilled continuous-fallow conditions. The C factor is obtained as the product of Cc and Cm.

Finally, the P factor indicates the effect of measures for erosion control, i.e. practices that reduce the velocity of runoff and the tendency of runoff to flow directly down-slope.

There have been extensive studies to calibrate these factors for different situations. However, if no information is available, Table 1 provides an approximation to factors for an initial estimate of average annual soil loss (A). USLE is a poor predictor of actual erosion, but the factor values reflect the relative effects of alternative practices on erosion. Farmers can reduce the risk of soil erosion by carefully choosing the crop and sowing time and the tillage system. Any tillage that reduces soil disturbance and keeps residues on the ground reduces the risk of soil erosion. In annual crops-based systems, zero tillage with mulch is most effective.

Table 1 *USLE: values of factors.*

K Factor			
Texture	Average	Organic matter	
		<2%	>2%
Fine clay	0.17	0.19	0.15
Clay	0.22	0.24	0.21
Clay loam	0.30	0.33	0.28
Loam	0.30	0.34	0.26
Sandy loam	0.13	0.14	0.12
Sand	0.02	0.03	0.01
Silty clay	0.26	0.27	0.26
Silty clay loam	0.32	0.35	0.30
Silt loam	0.38	0.41	0.37
Sandy clay loam	0.20	0.20	0.20
Loamy sand	0.04	0.05	0.04
NT parameter to calculate LS Factor			
Slope (%)			
<1			0.20
1-3			0.30
3-5			0.40
>5			0.50
Cc parameter			
Cereals			0.35
Sunflower			0.50
Horticultural crops			0.50
Fruit orchards + cover crop			0.10
Pastures			0.02
Cm parameter			
Autumn tillage			1.00
Spring tillage			0.90
Vertical tillage + some residues			0.60
Ridge planting			0.35

Zero tillage + some residues	0.25
100% soil cover by residues	0.03
P factor	
Tillage following the slope	1.00
Tillage in different direction to slope	0.75
Tillage following contour lines	0.50

2.2. CONSERVATION AGRICULTURE (CA)

Conservation Agriculture (CA) represents a package of agronomic technologies that allow for minimum disturbance of soil, maintenance of soil cover with residues and spatiotemporal diversification of cropping systems (FAO, 2008), accompanied by other good agronomic practices as proposed in the Nebraska Declaration (Stevenson et al. 2014). CA systems are clearly identified in the field because at crop emergence time plants appear on a soil covered by residues or mulch (Fig. 6).

In spite of its success in America, CA is hardly adopted in Europe and Africa. The diversity of soils, climatic conditions, and socioeconomic contexts, as well as potential environmental risks, may partly explain the restricted expansion of CA in these regions (Kassam et al., 2012). Low adoption of CA may also be due to problems related to its complex management and interacting factors (*Section 2.3*) translated into poor crop establishment or weed control; lack of appropriate machinery; and/or inadequate extension and government policies supporting CA (Knowler and Bradshaw, 2007; Soane et al., 2012). CA may also be inappropriate for most resource-constrained smallholder farmers (Giller et al. 2009; Corbeels et al. 2014). Concerns about performance of CA for smallholder farmers include negative impacts on yields (*Section 2.5*).

2.3. COMPLEX INTERACTING PATHWAYS LIMITING CA SUCCESS

Uncertainty in CA efficacy with respect to increasing soil quality and crop yields can be traced to the complexity of interacting biophysical factors and process pathways and drivers that are influenced by CA technologies. Direct sowing in **undisturbed soil,** i.e. not being able to sow on tilled soil, can have negative effects for the soil and the crop (Table 2). A major concern is facing the impossibility to de-compact the soil plough layer. Compacted soil reduces root growth and results in lower water infiltration and soil water content; waterlogging and death of seedlings or plants may then occur. Controlled traffic, sporadic or precision tillage may reduce compaction limitations but appropriate techniques are necessary (Cid et al. 2014). Likewise, if no-tilled soils are not protected from rainfall or irrigation, soils may crust before or at sowing, leading to poor crop establishment. Another major concern when adopting no-tillage is the potential increase in incidence of weeds, diseases and pests. Adopting no-tillage requires attentive weed control and increase in use of herbicides. On the other hand, direct advantages of direct seeding include crop sequence intensification (extra crop per year) and better use of the cropping season window permitted by earlier field entry and planting (Rawson et al., 2007).

Table 2 *Effects of keeping the soil undisturbed during crop sequence.*

PRIMARY EFFECT	SECONDARY EFFECT
↑ soil compaction	↓ root growth; ↓ water infiltration
↑ soil crust	↓ crop establishment; ↓ water infiltration
↓ weed control	↓ crop establishment; ↓ plant growth
↑ soil diseases	↓ root/plant growth
advance sowing	extra crop; ↑adjustment to conditions
↑ soil fauna	↑ soil structure; ↑ water infiltration

Most of the potential negative impacts of the adoption of CA can be counteracted by **maintaining residues** (mulch) on the soil surface after harvest (Fig. 7). The mulch protects the soil from wind and raindrops thereby reducing risk of surface crusting. Surface residues reduce soil water evaporation, reduce runoff and increase water infiltration (Boulal et al., 2011); consequently, residue retention with no-tillage may increase water availability to the crop (Lampurlanés et al., 2001) and irrigation use efficiency (Grassini et al., 2011). Generally, a minimum amount of residue is needed to achieve these positive effects (Erenstein, 2002). According to standards devised in the USA, conservation tillage is a system that maintains a minimum of 30% residue cover on the soil surface after planting to protect the soil efficiently (ASABE, 2005), although the specific amounts required for local conditions are not clear.

Maintaining crop residues on the ground and leaving the soil undisturbed improves soil organic matter (SOM) and soil aggregates with time, at least in the top soil layer (Boulal and Gómez-Macpherson, 2010). Furthermore, soil erosion is reduced thereby enhancing soil fertility, improving soil structure, water infiltration and retention in the root zone, and water productivity (Verhulst et al. 2010; Rockstrom et al., 2012). However, the challenge for many farmers is to produce and retain enough crop residues to permit these changes to occur (Baudron et al., 2012), as residues are often used (or sold) for livestock, for construction, or for cooking.

Maintaining crop residues on the ground may also have negative short term effects on plant growth (Fig. 7). In the initial phase of adopting CA, high amounts of residues may result in nitrogen (N) immobilisation (Alvarez and Steinbach, 2009). Higher amounts of fertilizer will then be required to compensate the temporary immobilisation until soil fertility is increased and the system is balanced. Additionally, non-mobile soil nutrients, e.g. phosphorus (K), cannot be incorporated into the soil in detriment of growth, unless drills are prepared to incorporate basal fertilizers. Residues also reduce radiation interception by the soil and hence soil warming during early establishment of spring crops when temperatures are low. Leaving residues on the ground also requires specific drills to enable farmers to sow through them (Baker et al., 2007). The technology has evolved to find different solutions to different conditions, including equipment for two-wheeled tractors used in smallholder farms (Fig. 8).

In CA, **crop rotation** has a major role in facilitating weed control and reducing the risk of pest and diseases incidence (Fig. 7). Having legumes in the rotation may also improve the nutrient cycle (Giller et al. 2009). Additionally, the rotation wouldhelp to maintain a manageable amount of residues in the system by combining high and low producing crops (Boulal et al., 2012). As with other models of sustainable agriculture, CA should be considered to be fully implemented in the long term, which would allow all of its associated benefits to be seen (Rusinamhodzi et al., 2011).

Interacting pathways and tradeoffs as a function of prevailing weather and temperature regimes must be carefully considered. For example: the higher water infiltration with zero tillage (ZT) and residue retention may increase the risk of N leaching, while decreasing the risk of water logging; soil insulation by residues in temperate regions may negatively impact crop establishment, whereas in the tropics itmay keep soil temperatures lower and closer to the optimum for nutrient cycling. It is also crucial to understand time-lags for ZT adoption impacts. Above all, both expanding good agronomy and widening the scope of CA are necessary for developing successful options (Baudron et al., 2012; Rockström et al., 2009).

2.4. Other terms related to CA that may create confusion

The following systems are often associated to CA but not necessarily result in expected benefits for the soil or crop:

No-till (NT) / Zero till (ZT): NT and ZT simply involve the absence of tillage operations on the soil. Crops are planted directly into a seedbed not tilled after harvesting the previous crop. NT or ZT practitioners do not necessarily leave the residues on the ground.

Direct seeding, direct drilling, plantio direto and siembra directa are terms used for ZT in other countries.

Conservation tillage/ Minimum tillage/ Reduced tillage/ Mulch tillage: These are tillage operations that leave at least 30% of the soil surface covered by plant residues. Farmers do not use deep ploughing. It was developed as a management system after the “Dust Bowl” of the 1930’s in the Mid-West areas of the USA.

Strip tillage: narrow strips of 12-15 cm are cultivated and a row of crop is sown in these strips. This system is appropriate when a large amount of residues are produced.

2.5. CA IMPACT ON CROP YIELD IN SUB-SAHARAN AFRICA (SSA)

Whether CA adoption increases crop yield and under what conditions it does so remains unclear, particularly in smallholder systems typically found in developing countries. Studies comparing direct seeded crops in undisturbed soil (ZT) with tilled treatments (CT) have been conducted for three main annual crops in SSA: 22, 10 and 8 studies on maize, cowpea and sorghum cropping, respectively (Brouder and Gómez-Macpherson, 2014). These studies present results that were often incomplete, specifically, critical descriptors for deepening on the drivers of soil quality or crop yield are absent (Fig. 7). Information on residue management, seasonal rainfall, weed control effectiveness or soil texture are also often missing.

In spite of these limitations, some key trends on CA impact on crop yield can be identified in maize. Immediately following adoption (≤ 2 yr), **ZT** generally resulted in lower yields than CT but this effect changed over time in some cases (Fig. 9). Seventeen of the 22 maize studies present results for three or more years. Results are highly variable but there is an apparent, positive tendency for ZT yield improvement over time (~70 kg ha^{-1} yr^{-1} yield difference (ZT – CT)) although the relationship is not significant. Reasons for lower yield in ZT were not clear but the most common argument is poorer weed control. In three studies, higher soil compaction is associated with lower productivity.

Only a few CA studies with sorghum and cowpea crops can be identified. This is probably a reflection of reduced agricultural development efforts in the difficult environments where these two crops are most common. Again, there is a general negative impact on yields when ZT is compared to CT (on average 0.34 and 0.02 t ha^{-1} less grain in sorghum and millet). However, not only are studies of these crops fewer in number but also their duration rarely exceeds 2 years. As for maize, longer duration studies may be necessary to show anticipated positive impacts on soil quality and water balance with sorghum and cowpea, particularly when soils are currently deemed marginal for crop production, under extreme rainfall and temperatures, and where competition for residues with livestock is significant. Furthermore, changing from local cultivation habits in sorghum management to a novel system requires time (Garcia-Ponce et al., 2013). The more complex the novel system is, the longer the period of time required by the farmer and researcher to master it.

The limited number of studies and the variation in treatments make it difficult to infer direct effects due to **maintenance of residues** and having mulch on the soil ground. In maize, only four studies compare ZT and CT with and without the presence of mulch. Results suggest ZT performs slightly better than CT when both treatments have mulch on the surface (0.18 t grain/ha higher on average) but slightly worse when residues are removed or incorporated (0.28 t grain/ha lower on average). Rusinamhodzi et al.'s (2011) review shows no clear benefits to yield of having mulch in zero- and minimum tillage systems and, further, indicates that mulch could have a negative effect over the long term due to increased occurrence of water-logging conditions. It is important to note, however, that these studies consider neither the opportunity costs of crop residues kept on the field versus an alternative use as fuel or fodder, nor the direct costs of mulch supplement.

In maize, the largest collection of studies, preliminary analysis suggests average grain yields are 28 and 33% higher when rotated than when cultivated continually in ZT and CT, respectively (10 and 33 cases). In two maize studies where monoculture was compared to a rotation with a legume, the rotation benefit is higher in ZT than CT (25 and 9 % increment in grain yield, respectively).

In summary, results from the review suggest that, in the short term, CT generally outperforms ZT for the staple crops examined. This may be the result of direct, short-term effects per se, e.g. increased soil compaction, or the need for farmers and researchers to learn about the various new technologies embedded in the CA system. For example, we mentioned above that more attention is needed for weed control in ZT to optimize management efficacy. The use of herbicide will facilitate ZT success but there is a need to develop a reliable herbicide regime for each system which may be combined with early hand weeding (Mishra and Singh, 2012). Good management is the first step for detecting tillage or mulch effects on crop productivity (Baudron et al., 2012). If access to inputs is limited and agro-environmental conditions are difficult, the technology options should be adapted accordingly (see "best-fit" options in Giller at al., 2011). Examples of intermediate systems can be found in Lahmar et al. (2012), Bayala et al. (2012) and Rockström et al. (2009).

The initial negative impact of ZT on grain yield may reduce with time (Fig. 9) as several positive factors may only come into play in the long-term, particularly those linked with mulching (Fig. 7). Well-designed long-term studies are needed in order to respond to some of the points raised above (Govaerts et al., 2006.). Moreover, not only must good general agronomic practices be pursued for the duration of the experiment, but the specifics of management implementation and efficacy must be captured. These detailed studies should be accompanied by on-farm studies that can provide feedback for targeted research and by surveys for local characterization and identification of structural problems beyond the field scale (Giller at al., 2011). Studies at farm scale will also capture the economic benefits and/or costs of CA, an essential consideration for smallholder farmers.

3. Class activity

3.1. First part: Exploring factors influencing soil erosion (30mins to calculate values; 30mins to discuss results)

In this class activity, the Universal Soil Loss Equation (USLE) and Table 1 will be used to compare land use options and conditions. Students will be divided into small groups. Each group will be assigned one location (long-term monthly rainfall provided below) and will calculate the potential soil loss (A, Mg/ha/yr) using USLE (Section 2.1) for the following conditions and systems:

Scenario	Average slope Pt (%)	Slope length Lt (m)	NT	Texture	SOM	crop	Tillage time/type	Tillage direction
1	6	50	0.5	clay	<2%	wheat	Autumn	follow slope
2	6	50	0.5	clay	<2%	wheat	vertical till+some residues	follow slope
3	6	50	0.5	clay	<2%	wheat	zero till+some residues	follow slope
4	6	50	0.5	clay	<2%	wheat	100% soil covered by residues	follow slope
5	6	50	0.5	clay	>2%	wheat	100% soil covered by residues	follow slope
6	6	50	0.5	clay	<2%	wheat	Autumn	follow contour lines
7	6	50	0.5	clay	<2%	sunflower	Autumn	follow slope
8	6	50	0.5	sand	<2%	wheat	Autumn	follow slope
9	2	50	0.3	clay	<2%	wheat	Autumn	follow slope
10	6	25	0.5	clay	<2%	wheat	Autumn	follow slope

Wheat and sunflower are commonly cultivated in temperate regions. In the tropics, other crops dominate: maize, sorghum, millet, cowpea, soybean, etc. We have used wheat and sunflower only to facilitate comparisons.

Long-term (1991 – 2014) monthly rainfall (mm) in Nampula (Mozambique):

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
220	210	180	80	20	20	10	10	0	10	70	180

Long-term (1902-2014) monthly rainfall (mm) in Harar (Ethiopia)

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
19.7	28	59.4	94.9	102.3	65.2	108.7	139.7	102.2	50.6	12.5	8

Long-term (1984-2014) monthly rainfall (mm) in Córdoba (Spain):

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
64	53	40	61	34	17	3	3	24	62	85	89

Long-term (1898 – 2014) monthly rainfall (mm) in Wagga Wagga (Australia):

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
37.9	37.2	37.6	38.8	43.9	50.3	49.0	47.6	47.9	51.5	40.8	41.2

Long-term monthly rainfall (mm) in Your Location (search closest station in www.weatherbase.com)

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec

Once erosion estimates have been calculated for each scenario, students should discuss which strategies are most effective to control soil erosion.

Compare results from different locations:

- Is the most effective strategy in your location the most effective in other locations?
- Is the erosion risk higher in the tropics or in temperate regions?
- Is there any strategy that results in similar erosion risk in all locations?

3.1.1. Solution and evaluation criteria

The estimated factors for each location are shown in the next tables. Check that values calculated by students are correct. Discussion around different factors influencing soil erosion is the most important element in this activity.

NAMPULA

Scenario	Erosivity R	K (Mg/ha/yr)	LS	Cc	Cm	P	**A (Mg/ha/yr)**
1	549	0.24	0.863	0.35	1.00	1.0	**39.8**
2	549	0.24	0.863	0.35	0.6	1.0	**23.9**
3	549	0.24	0.863	0.35	0.25	1.0	**9.9**
4	549	0.24	0.863	0.35	0.03	1.0	**1.2**
5	549	0.21	0.863	0.35	0.03	1.0	**1.0**
6	549	0.24	0.863	0.35	1.00	0.5	**19.9**
7	549	0.24	0.863	0.50	1.00	1.00	**56.9**
8	549	0.03	0.863	0.35	1.00	1.00	**5.0**
9	549	0.24	0.233	0.35	1.00	1.00	**10.7**
10	549	0.24	0.611	0.35	1.00	1.00	**28.1**

HARAR

Scenario	Erosivity R	K (Mg/ha/yr)	LS	Cc	Cm	P	**A (Mg/ha/yr)**
1	233	0.24	0.863	0.35	1.00	1.0	**16.9**
2	233	0.24	0.863	0.35	0.6	1.0	**10.1**
3	233	0.24	0.863	0.35	0.25	1.0	**4.2**
4	233	0.24	0.863	0.35	0.03	1.0	**0.5**

5	233	0.21	0.863	0.35	0.03	1.0	**0.4**
6	233	0.24	0.863	0.35	1.00	0.5	**8.4**
7	233	0.24	0.863	0.50	1.00	1.00	**24.1**
8	233	0.03	0.863	0.35	1.00	1.00	**2.1**
9	233	0.24	0.233	0.35	1.00	1.00	**4.6**
10	233	0.24	0.611	0.35	1.00	1.00	**11.9**

CORDOBA

Scenario	Erosivity R	K (Mg/ha/yr)	LS	Cc	Cm	P	**A (Mg/ha/yr)**
1	107	0.24	0.863	0.35	1.00	1.0	**7.8**
2	107	0.24	0.863	0.35	0.6	1.0	**4.7**
3	107	0.24	0.863	0.35	0.25	1.0	**1.9**
4	107	0.24	0.863	0.35	0.03	1.0	**0.2**
5	107	0.21	0.863	0.35	0.03	1.0	**0.2**
6	107	0.24	0.863	0.35	1.00	0.5	**3.9**
7	107	0.24	0.863	0.50	1.00	1.00	**11.1**
8	107	0.03	0.863	0.35	1.00	1.00	**1.0**
9	107	0.24	0.233	0.35	1.00	1.00	**2.1**
10	107	0.24	0.611	0.35	1.00	1.00	**5.5**

WAGGA WAGGA

Scenario	Erosivity R	K (Mg/ha/yr)	LS	Cc	Cm	P	**A (Mg/ha/yr)**
1	33	0.24	0.863	0.35	1.00	1.0	**2.4**
2	33	0.24	0.863	0.35	0.6	1.0	**1.4**
3	33	0.24	0.863	0.35	0.25	1.0	**0.6**
4	33	0.24	0.863	0.35	0.03	1.0	**0.1**
5	33	0.21	0.863	0.35	0.03	1.0	**0.1**
6	33	0.24	0.863	0.35	1.00	0.5	**1.2**
7	33	0.24	0.863	0.50	1.00	1.00	**3.4**
8	33	0.03	0.863	0.35	1.00	1.00	**0.3**
9	33	0.24	0.233	0.35	1.00	1.00	**0.6**
10	33	0.24	0.611	0.35	1.00	1.00	**1.7**

3.2. Second part: Debate between two groups of students in favour of Conservation Agriculture or Conventional Agriculture. (1 hour)

Students will be assigned to either of these two groups, Conventional Agriculture or Conservation Agriculture, and will have a debate on the two systems. Ideally the groups will have prepared their debating strategy during the Home Activity (see next section).

One person per group will present their assigned system in 5 minutes. After this, different students will present the arguments following a given order. Arguments should consider technical, socioeconomic and environmental issues and can be in favour of their assigned system, or against the other system. Arguments should be well-elaborated and based on literature, if/where possible. Short videos or slides may be used to support their arguments (see Further/Suggested Material Section).

3.2.1. Solution and evaluation criteria

There is no single solution. The evaluation will be by group and the following criteria should be considered:

- Clearness of presentation
- Coherence in arguments
- Technical, socioeconomic and environmental issues addressed
- Tools used in the debate: quality of slides if prepared by the group, justification of videos or others tools used

4. Homework activity

This activity is divided into two parts. Firstly, students will independently look for information on their assigned system (4 hours). Secondly, students will work in groups to prepare the debate (4 hours). Each group may be organized in subgroups to prepare different parts of the argument.

4.1. Solution and evaluation criteria

The evaluation will be done during the debate in the class activity.

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FURTHER/SUGGESTED MATERIAL

- Web page on CA with different type of resources (articles, PPT presentations, videos…) by The Conservation Agriculture Group at Cornell University (http://conservationagriculture.mannlib.cornell.edu/index.html).
- Movie: The Grapes of Wrath (1940), directed by John Ford.
- Video: No-Till Agriculture Prevents Soil Erosion, by World Bank (https://www.youtube.com/watch?v=LpltrgkLqWc&list=PL2AC32AFA191F85D9&index=6)
- Video: USDA-NRCS Ohio state agronomist Mark Scarpitti demonstrates differences between tilled and no-till soils in ability to absorb fertilizer and avoid runoff (http://www.notill.org/resources/basics-of-no-till/differences-in-tilled-and-no-till-soils).
- Video: 1) Introduction to Conservation Agriculture Cropping Systems by UCANR (https://www.youtube.com/watch?v=Df59FO9Uxx0&index=5&list=PL2AC32AFA191F85D9).
- Video: 2) The Value of Residues in Conservation Agriculture Systems by UCANR (https://www.youtube.com/watch?v=pNqXOeQJ4MU).
- Video: Controlled Traffic Farming by NACC (https://www.youtube.com/watch?v=zUlr9PKkQRM).
- Video: Spreading Conservation Agriculture in Malawi by CIMMYT (https://www.youtube.com/watch?v=nyuhU9JBwWA).
- Video: Sustainable Intensification of Maize-Legume Systems for Food Security in Eastern and Southern Africa by CIMMYT (https://www.youtube.com/watch?v=vlszRU2rVig).

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