



Funded by
the European Union



Climate and soils influence the benefits of crop residue mulching for adaptation and mitigation of climate change



Highlights:

- With adequate weed control, crop residue mulching only marginally improves yield in Agro-ecological regions with sub-humid climate (AER II- 750-1000 mm yearly rainfall), but more strongly (at least 10%) in the lower rainfall regions (AER III, 650-750mm, and AER IV, 450-650mm).
- When composed of very large quantities of straw, mulch helps to control weeds in maize plots, and this benefit is stronger in AER II than in the semi-arid AER III and AER IV.
- On sandy soils, mulching darkens the soil and decreases surface albedo¹ in a way that reduces the climate change mitigation benefits of mulch related to carbon sequestration in topsoil, because less solar radiation may be reflected back to space. On clayey soils, this climate change mitigation benefit might be enhanced because the mulch brightens the surface.



¹*Albedo is the physical property of a surface determining the proportion of incoming solar radiation that is reflected back to space. Albedo varies between 1 and zero. A white surface has an albedo of 1 and reflects 100% of solar radiation whereas a black surface absorbs 100% of the incoming solar radiation and reemits only thermal (infra-red) radiation.*

Details of the question / issue:

Crop residue mulching is an agroecological practice where crop residues (e.g. maize stalks) are kept on the soil after harvest, rather than burnt or fed to livestock. This practice is being promoted throughout the country by the Zimbabwean governmental 'Pfumvudza' program. It is promoted as a 'climate smart' practice that i) helps reduce soil water evaporation, leading to lower water stress for crops, ii) helps reduce weed pressure, iii) strongly reduces soil erosion and subsequent losses of organic matter and nutrients and iv) contributes to climate change mitigation through topsoil carbon sequestration. However, these widely acknowledged benefits are also known to be context dependent, and need to be validated for the diverse agroecological regions and soil types under smallholder farming in Zimbabwe. The impact of agricultural practices on climate change is often evaluated based on biogeochemical effects, such as soil organic carbon sequestration and emissions of greenhouse gases. However, biogeophysical effects, such as a change in surface albedo and evapotranspiration also need to be accounted for. Depending on the pedoclimatic context and on the practice, these effects can be antagonist or synergistic. It is therefore crucial to investigate both biogeochemical and biogeophysical effects to assess the net climate impact of agricultural practices.

Findings:

Mulching led to marginal or no yield increase in the frequently weeded on-station trials in Harare and Domboshawa and in the on-farm trials in Murewa, AER II (Figs. 1A, 1B). Possibly, water stress was not strongly limiting yield, so that improvement in soil moisture with mulch led to minor improvement in maize yield. We also observed that with mulch, small showers can be totally absorbed by the mulch, showing that under specific conditions, mulch can also reduce soil available water for plants.

However, application of mulch in large quantities (effect observed for 8 Mg ha⁻¹, albeit not significant), helped to reduce weed density in maize plots, and this positive impact was stronger in Agroecological region II, where weed density in the absence of mulch was the highest, than in AER III and IV (Fig. 1C). Wetter agroecologies led to greater weed development and increased soil cover from the mulch provided a better opportunity to control those weeds. In cooler environments (AERII), it is possible that mulch also decomposes less rapidly than in the warmer environments of AERIII and IV.

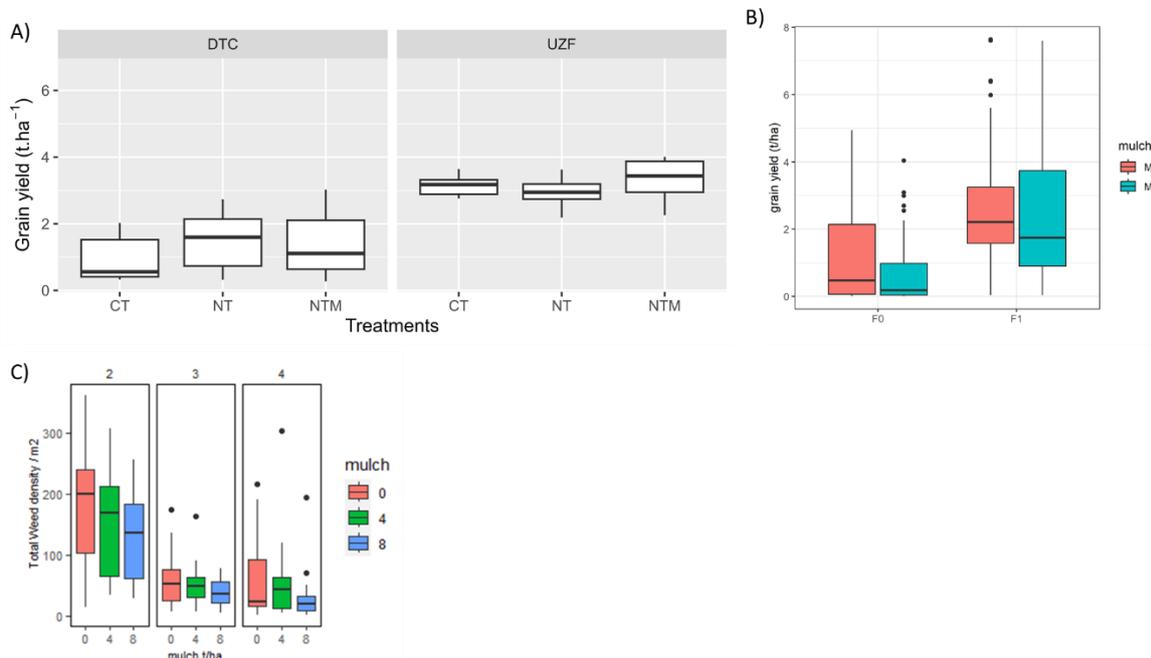


Figure 1. A) Impact of no-tillage (NT) and no-tillage+ 2.5 t DM ha⁻¹ of mulch (NTM) on maize grain yield at on-station trials at Domboshawa training centre (DTC) and University of Zimbabwe farm (UZF) for 2022 and 2023 harvest, as compared to conventional tillage soil preparation (CT). B) Impact of 4 t DM ha⁻¹ mulch (M1) versus no mulch (M0) on maize grain yield in nine on-farm trials in Murewa (AER II) for 2021/22 and 2022/23 seasons, with (F1) and without (F0) mineral fertilizer. C) Impact of mulch (0, 4, 8 t DM ha⁻¹) on weed density in six trials in Murewa (AER II, subgraph 2), and Mutoko (AER III and IV, subgraphs 3 and 4 respectively) for 2023 harvest.

We found that application of mulch on a sandy soil induced climate warming due to the albedo effect (Fig. 2). Indeed, maize straw constituting most of the mulch, has a much darker color than the soil surface in the case of the sandy soil of Domboshava, explaining this negative effect. On such a bright sandy soil, the climate benefit due to soil organic carbon (SOC) sequestration resulting from mulching is reduced by the climate warming caused by the darkening effect of crop residues leading to a reduction in surface albedo. Yet, its other benefits such as erosion reduction were not evaluated in this study.

Our findings indicate that the benefits of mulch on adaptation to climate variability and change and mitigation of climate change are context-dependent. More studies are required to better targeting of this technology within the ‘Pfumvudza’ package.

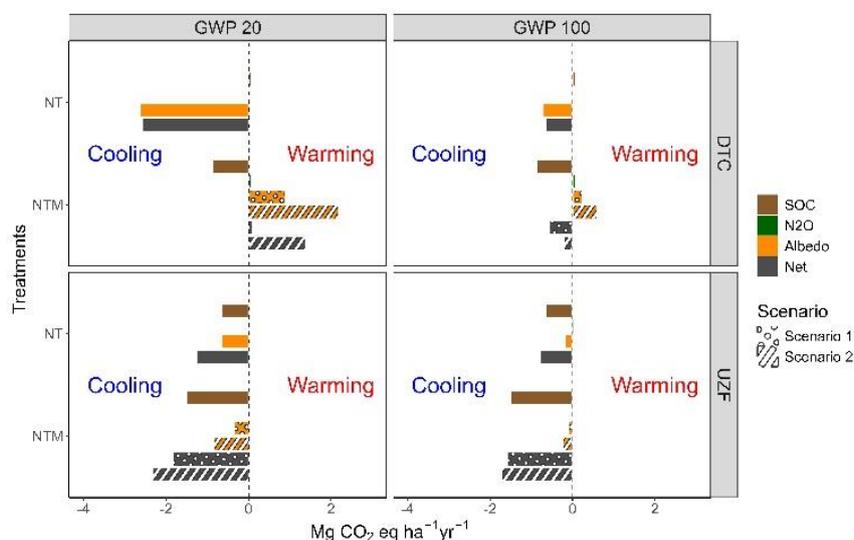


Figure 2. Climatic effects in CO₂-equivalents due to change in soil organic carbon (SOC), nitrous oxide (N₂O) emissions and surface albedo under no-tillage (NT) and no-tillage with mulch (NTM) compared to conventional tillage (the reference system) at DTC and UZF sites; Net represents the aggregated climatic impact related to SOC changes, N₂O emissions and surface albedo. Results are presented either with a Global Warming Potential (GWP) of 20 or 100 (years) time horizon. Scenario 1 represents mulch application before sowing (during the wet season), Scenario 2 after harvest (during the dry season).

Discussion / limitations/ perspective:

- The limited impact of mulch on maize yield in AER II needs to be confirmed with more observations and possibly crop modelling using historical and future climates.
- Mulch appears as a promising practice to control weeds, but the labour involved in collecting and applying the mulch need to be compared to the labour savings in terms of weeding, since biomass yield is too low to create mulches of sufficient quantity only from the residues of the crop. More data and analysis will help explore this issue. Other studies in mostly sub-humid environments in Southern Africa by CIMMYT have also demonstrated limited yield benefits to mulching in conservation agriculture systems.
- The use of mulch can potentially introduce unwanted pests and diseases in the crop of choice. Pests and diseases overwinter in the mulching material during the off-season, thereby possibly necessitating the need to control those pests and diseases.
- The net climate effect of mulch needs to be further investigated, by also considering the reduced soil evaporation with mulch, evaporation being known to have a cooling effect on local temperatures.

Methodology:

- On-farm trials were established on farmers home and outfields on sandy soils and clay soils in Murewa (AERII) to assess the impact of mulch on maize production. An additional factor (manure + 160 kgN ha⁻¹) was also investigated in combination with mulching. For weed



monitoring, field trials were implemented on two contrasting soil types (sandy vs red clay soils) in three agroecological regions (II, III and IV) in Mashonaland East, Zimbabwe. Mulching was applied in sole maize and maize-cowpea cropping systems at 0t DM ha⁻¹, 4t DM ha⁻¹ and 8t DM ha⁻¹.

- Surface albedo was monitored at two long-term experiments established in 2013 by CIMMYT at the Domboshawa Training Center (DTC) in the Goromonzi district and at the University of Zimbabwe Farm (UZF) in the Mazowe district. DTC has light-coloured sandy soil and UZF has dark-coloured clayey soil.

Contact details:

Rémi Cardinael - CIRAD/UZ

remi.cardinael@cirad.fr

Regis Chikowo – University of Zimbabwe

regischikowo@yahoo.co.uk

Gatien Falconnier - CIRAD/UZ/CIMMYT

gatien.falconnier@cirad.fr

Juliet Murimwa – University of Zimbabwe

jwfmurimwa@gmail.com

Isaiah Nyagumbo - CIMMYT

i.nyagumbo@cgiar.org

Valentin Pret - CIRAD

valentin.pret@cirad.fr

Francois Affholder

francois.affholder@cirad.fr

Disclaimer :

This document has been produced with the financial assistance of the European Union. The contents of this document are the sole responsibility of CIRAD, University of Zimbabwe and CIMMYT, and can under no circumstances be regarded as reflecting the position of the European Union.