გერმანიის თანამშრომლობა
DEUTSCHE ZUSAMMENARBEIT

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Cost Benefit Analysis of Agricultural Burning Practices in the Dedoplistskaro Municipality, Georgia

- A combination of anthropogenic and climatic factors, particularly traditional burning of crop residues, are reducing agricultural yields in an important food producing region of Georgia.
- There are a number of private and public costs and benefits associated with two scenario that allow to reduce the indendence of burning in the agricultural sector. Both scenarios yield positive net-benefits for both small and large farmers as well as wider society.
- Reducing burning will also have a positive impact on a number of environmental metrics and support achievement of the United Nations Sustainable Development Goals.

Background

Fire is used extensively in agricultural practices around the world, contributing to an estimated 8 – 11 % of global fires. The Russian Federation, for example, is the largest contributor to agricultural burning globally producing 31 – 36 % of all agricul-tural fires (Korontzi et al. 2006). Georgian farm sys-tems are no exception – fire is used extensively after the harvesting period.

In the summer of 2015 large wildfires ravaged the Shiraki valley (43,000 ha) within the Dedoplistskaro district in Georgia (Figure 1). The valley is known as the breadbasket of Georgia, having provided the country with the lion's share of its wheat for centuries. The valley has deep soils with high humus content offering significant potential for high agricultural yields. However, a combination of warmer climates, more frequent droughts, strong winds, the degradation of windbreaks and non-sustainable agricultural practices has led to reduced agricultural yields. The degradation of windbreaks started after the fall of the Soviet Union, when the population of Dedoplistakaro began to cut trees to meet the demand for fuel.

In a project implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), from 2008 onwards, around 70 km of windbreaks have been rehabilitated. However, the wild fires of 2015 severely damaged all remaining windbreaks and restoration efforts by GIZ.

In the context of increasing occurrence of dry spells and heat waves favoring the recurrence of more frequent and larger fires, it is imminent that the main driver of fire – namely, human ignition of crop residues – is put under scrutiny.

The Georgian Ministry of Environment and Protected Areas has therefore initiated legal changes to ban crop residue burning. Enforcing such a policy, however, needs to be justified on economic and ecological grounds. For this purpose, an ecosystem service valuation study has been undertaken, analyzing the economic benefits and costs of implementing such a policy.

Figure 1: Location of the Dedoplistskaro district of Georgia.

To do so, two scenarios are contrasted, namely:

- ✔ **Business as Usual (BAU):** No policy change and a simply continuation of the status quo.
- ✔ **Ban on burning:** A legal action to prohibit crop residue burning. Small and large farmers stop burning and instead integrate residues in the soil and or collect, compress and sell straw bales, depending on the benefits of each activity.

The 'ban on burning scenario' is valued relatve to th former BAU.

The results of this valuation study are presented below and are calculated for farmers that cultivate up to 5 hectares (small farmers) as well as farmers that cultivate 5 hectare or more (large farmers). This segregation has been made because the analysis of the farm data revealed that 5 hectares is a critical cutting point that allows to detect signifi-cantly different price structures with respect to: rental cost of harvesters, straw collection and inte-gration machines, as well straw prices and yields.

The time frame for the analysis is 10 years (2017 - 2026), assuming the policy could be enacted in 2017. Future cost and benefit are discounted into present value terms using the Georgian real interest rate of 4 %.

Benefits and Costs

Value of protecting remaining windbreaks and banning crop residue burning

Modeling results liking probable future fire hazards and windbreak destruction rates[1] suggest that remaining 50 km of windbreaks could be lost within 10 years if there is no policy change.

To estimate the value of protecting the remaining windbreaks and the welfare economic impacts of banning crop residue burning, a hypothetical market was created using a choice experiment valuation survey using increases (willingness to pay) or decreases (willness to accept compensation) in the 'land registration fee[2]' as the payment vehicle. An example of one of 8 choice-set is shown in Fig-ure 2.

The survey was undertaken with 300 farmers in Dedoplistskaro and was also used to form all valuation questions below.

The stated preference valuation survey showed that the loss of windbreaks would cause an ex-pected welfare loss of GEL 6.4 per year[3] per hec-tare over the 10-year time horizon, if remaining windbreaks were to be. Thus, the benefit of protect-ing remaining windbreaks is the avoided loss. There is no significant difference in preferences amongst large and small farmers in this regard (table 1 and 2).

The same valuation exercise furthermore showed that 70% of farmers would prefer a legally enforced ban of crop residue burning and that the ban would deliver an Expected Annual Net Benefit (EANB[4]) of GEL 36 to 38 per hectare land cultivated, with small farmers enjoying the slightly larger EANB.

The result implies that farmers, whether small or large, have a preference for using collective action through enforcement rather than voluntary action to better protect them and Shiraki valley landscapes and soils against damages from fires originating on other farms.

Value of straw as fertilizer

Removing or burning straw exports nutrients and soil organic matter out of the field and leaves the soil susceptible to erosion.

Shredding of straw during harvest and subsequent integration of straw into the soil builds up soil organic matter and help retain moisture in the ground.

By using an integrated water balance crop model known as AquaCrop, calibrated with data from soil samples taken in Dedoplistskaro, we find that agricultural yields would increase by between 11% and 23% within 3 years, if farmers integrate straw into the soil instead of burning it. Farmers who burn every year have the most to gain (23%) from terminating burning.

Small and large farmers face different rental costs of machinery allowing for the integration of straw in the soil. Large farmers, however, burn more fre-quently than small farmers. Accounting for these differences, whilst using 2015 farmgate market prices for cereals, we find that:
Small farmers who stop burning can expect GEL 78 per hectare (table 1) in additional annual net bene-fits if they end burning, whilst large farmers can expect GEL 105 per ha (table 2) in annual net ben-efits.

Straw for sale

The burning of residues represents a lost economic opportunity in the sense that residues can no longer be used for fodder, fuel or animal bedding.

Farmers therefore also have the choice to collect and compress straw residues in bales for marketa-ble purposes or own-use. Using conservative farm-gate market prices for straw, the expected annual net-benefit of collecting straw residues is in the order of GEL 147 per ha per year for large farmers (table 2). Small farmers however, have inferior agri-cultural yields; higher machine rental costs and face lower straw bale sale prices. With an average loss of GEL 5 per ha, this makes it uneconomical for the average small farmer to collect, compress and sell straw bales (table 1). In assessing the eco-nomic impact of avoided burning over a 10-year time horizon, it is therefore assumed that all small farmers decide to retain straw in the soil as op-posed to collecting it.

Value of avoided carbon emissions

The Agriculture, Forestry and Other Land Use (AFOLU) sector offers considerable mitigation potential from soil carbon sequestration and the avoidance of new emissions sources such as fires. GHG emissions from the burning of crop residues consist essentially of methane and nitrous oxide gases, while the destruction of windbreaks produces below and above ground carbon emissions (Smith et al., 2007[5]).

Implementing and enforcing a ban on burning results in approximately 50,000 tonnes CO2 equivalent tons of avoided carbon emissions over 10 years (Figure 3), calculated using Tier 1 of IPCC 2006 in the FAO X-ANTE tool. Using a conservative estimate of the social cost of carbon of 94 GEL/ton CO2 equivalent (from EPA 2015) and a real discount rate for Georgia of 4%, the value of the avoided global damages

1. To project the possible incidence of fire hazards from 2017 to 2026 under no policy change, random numbers were drawn from a normal distribution characterised by the same mean and standard deviation of the fire events in Dedoplistskaro from 2000 to 2015 (collected using MODIS data). Windbreak monitoring data from GIZ was used to establish a correlation between wildfire severity and windbreak mor-tality.
2. An annual tax per hectare of farmland cultivated
3. 1 GEL= 0.43 USD (2016)
4. Also known as annuity values, which is equivalent to the present value the average annual additional income generated over the 10-year accounting period.
5. Smith, et al., (2007). Agriculture. In Climate Change 2007: Miti-gation. Contribution of Working Group III to the Fourth Assess-ment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

amounts to 4.4 million GEL over a 10-year period for the whole of the Shiraki valley (Figure 4).

Cost of implementing and enforcing a ban

Implementing and enforcing a ban on crop residue burning involve costs associated raising awareness organising meetings and workshop with farmers, running information capaigns in newsletters, and patrolling during the fire seasons. Based on estimates from the Georgian Ministry of Environment and GIZ, information and enforcement costs sum up to approximately GEL 122,000 GEL in present value terms over the 10-year accounting period for the Dedoplistskaro district alone (figure 4).

Results

Bringing together all these benefits, whilst ac-counting for the additional costs of shredding, integrating or collecting crop residues and en-forcing a policy to ban crop residue burning, we find a global net-benefit from a ban on burning in Dedoplistskaro district, to be in the order of GEL 21.2 million GEL in net present value (NPV) terms over a 10-year period. This figure include the social benefits of avoided carbon emissions and law enforcement and implementation costs.

The societal NPV benefit to Georgia amount to GEL 16.8 million, assuming that small farms re-tain and integrate all crop residues in the soil (table 3).

The NPV over a 10-year period for small farmers is GEL 994 per hectare and the Benefit Cost Ratio (BCR) is 5.2, implying that for every Lari invested, farmers can expect 5.2 Lari's of benefit over a 10 year period.

Large farmers can expect to enjoy a NPV benefit of between GEL 1206 and 1547 per hectare and BCR of 2.9 to 6.9 depending on whether they decide to sell straw or retain it in the soil (table 2).

It should be kept in mind though, that these results are sensitive to the actual level of enforcement of the ban on burning by authorities, the decisions made by farmers regarding what they do with the leftover straw after harvest, as well as changes in farm gate market prices for straw bales, wheat and machinery rental costs.

Discussion and conclusion

Crop residue burning is an inexpensive and quick method to remove excess residue that facilitates planting and controls pests and weeds. But there is a series of negative repercussions on ecosystems, some of which we have quantified here. Our results suggest that it is due time to reconsider 'BAU' and consider enforcing a ban on crop residue burning. Indeed, the benefits of straw usage are 4 to 5 times higher than the additional costs of using different machinery and enforcing a ban on burning (table 3).

Moreover, the farming population itself express preferences for a ban of burning. Because fires easily spread across fields, their impacts cannot be effectively mitigated if farmers do not unilaterally decide to stop burning. It is a collective action problem. The economic potential of the nutrient and soil protection qualities embedded in straw should be exploited and not 'go up in smoke'.

The avoidance of burning should ideally be adopted as part of a package of sustainable land management practices, including integrated pest management, conservation or no-tillage and frequent crop rotations. This will enhance soil biota, fauna and flora, food security and livelihoods in Dedoplistakaro, while favouring the mitigation and adaption to climate change.

Georgia would hereby make a serious contribution towards the achievement of UN Sustainable Development Goal 15 – Life on Land, carbon emissions reductions through the UNFCCC process and goals in the Convention on Biological Diversity.

Choice set 1 (Block 2)	**STATUS QUO**	**Future Alternative 1**	**Future Alternative 2**
Windbreaks	20% windbreaks	100% windbreaks	50% windbreaks (some restoration)
Crop residue management	Fire allowed	Fire banned	Fire allowed
Land registration Relative to what you pay today	**87 Lari/ha** 0 Lari/ha	**110 Lari/ha** +22 Lari/ha	**95 Lari/ha** +7 Lari/ha
Your choice			

Figure 2: Example choice experiment survey questionnaire

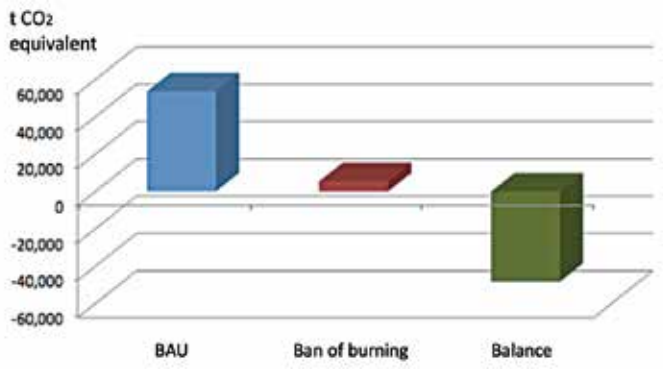

Figure 3: tCO2 equivalent emissions with and without a ban on burning and total carbon balance (2017 – 2026)

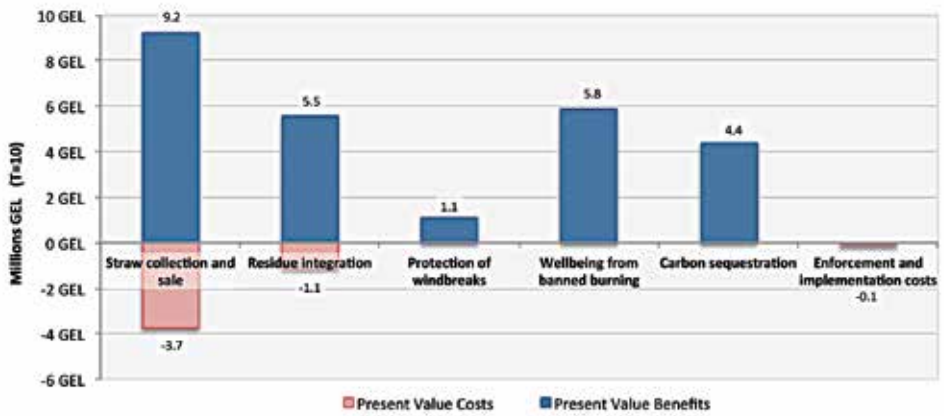

Figure 4: Aggregate PV benefit and PV costs in million GEL from a legally enforced ban of crop residue burning (r=4%)

Table 1: EANB (GEL), NPV (GEL) and Benefit-Cost Ratios (BCR) for small farmers under a ban on burning scenario

Small farmers (< 5 hectares)	EANB/ha	NPV/ha	NPV district wide	BCR
Ecosystem service benefits from not burning				
Residue retention and integration in soil (100%)	78	632	0.8 million	3.7
Collection and sale of straw residues (100%)	- 5	-40	- 32'000	0.9
Welfare economic impacts from a ban of burning				
Welfare benefit from ban of residue burning	38	306	489'600	N/A*
Protection of remaining hedges	6.8	56	89'600	N/A*
Aggregate net-benefits				
Burning banned and all residues are integrated in the soil	123	994	1.1 million	5.2

Table 2: EANB (GEL), NPV (GEL) and Benefit-Cost Ratios (BCR) for large farmers under a ban on burning scenario

Large farmers (≥ 5 hectares)	EANB/ha	NPV/ha	NPV district wide	BCR
Ecosystem service benefits from not burning				
Residue retention and integration in soil (100%)	105	855	7.8 million	5.2
Collection and sale of straw residues (100%)	147	1'196	11.0 million	2.4
Welfare economic impacts from a ban of burning				
Welfare benefit from ban of residue burning	36	295	5.4 million	N/A*
Protection of remaining hedges	6.8	56	1.0 million	N/A*
Aggregate net-benefits				
Burning banned and all residues are integrated in the soil	148	1'206	15.8 million	6.9
Burning banned and all straw collected and sold	190	1'547	17.4 million	2.9

Table 3: Aggregate EANB (GEL), NPV (GEL) and Benefit-Cost Ratios (BCR) for farmers, the Georgian and global society.

Societal net-benefits	EANB/ha	NPV/ha	NPV district wide	BCR
Farmers as a whole	166	1'343	16.9 million	3.8
Georgian society	21.2 million		16.8 million	4.4
Global society, including carbon sequestration			5.3	

Assuming that: 8% and 92% of land in Dedoplistskaro district is cultivated respectively by small and large farmers (as revealed by the household survey undertaken for this study), and that large farmers adopt a mixed strategy of collecting half the straw and retaining the other half in the soil.

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GIZ is responsible for the content of this publication.