Integrated Biodiversity Management, South Caucasus

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

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Report

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Executive summary

Crop residue burning has proved to be an inexpensive and effective way of managing excess straw stalks, controlling weeds and certain pests. There is, however, ample and mounting evidence that excess burning could jeopardize the long-term quality of the soil and affect the profitability of farming systems (Fasching, 2001).

Crop residue, if left, can provide a protective layer for soil erosion by wind or water, can increase the organic matter and water holding capacity of the soil, and can provide “feed and forage” for earth worms. When crop residue is burned all of those benefits are lost and other damage may be done (Holmgren et al., 2014). What ‘other damage’ can look like was witnessed in the Shiraki valley in Dedoplistskaro Municipality in Georgia in the summer of 2015 when wildfires swept the 34,000 hectares of arable land and destroyed the majority of windbreaks in the area.

At the national level, this event has precipitated interest in tightening government regulation around crop residue burning in Georgia. As mentioned above, burning has both positive and negative impacts. To understand the relative weight of these impacts, the Georgian Ministry of Environment and Natural Resource Protection (MoENPR) deemed it necessary to undertake a rigorous economic assessment of the true economic costs and benefits of burning compared to that of no-burning. This study was carried out by the Programme „Integrated Biodiversity Management, South Caucasus“ of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

With focus on the Shiraki valley and the Dedoplistskaro municipality in Georgia, the study presented within this report assesses the consequences of terminating crop residue burning on ecosystems and livelihoods. The main results hereof are summarized for a 10-year time horizon and using a 4% discount rate.

Through a combination of satellite imagery and farmer’s own elicited practices, we find that approximately 10,000 hectares of arable land are burned yearly in Dedoplistskaro. Using a projection of possible fire events in the future and an established relationship between agricultural fires and windbreak mortality, it is demonstrated that remaining windbreaks in Dedoplistskaro will be lost within less than 10 years, if no policy action is taken.

This has negative impacts on livelihoods. Using a stated preference valuation survey with 300 farmers in the Dedoplistskaro district, we showed that the average farmer would experience an average annual present value welfare loss for both small and large farmers of GEL 6.4 per year[1] over the 10-year time horizon, if remaining windbreaks were to be lost.

The same valuation exercise furthermore showed that 70% of all farmers would prefer a legally enforced ban of crop residue burning and that the ban would deliver an Expected Annual Net Benefit (EANB) of GEL 36 to 38 per hectare land cultivated[2], with small farmers enjoying the slightly larger EANB.

[1] 1 GEL= 0.43 USD (2016)
[2] Expressed in terms of willingness to pay for a higher land registration fee, which is esentially a tax per hectare of farmland cultivated.

This 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..

Secondly, using a detailed agronomic analysis, including laboratory tests and the soil sampling on farms with different land management practices, it is shown that ending burning leads to several improvements in soil parameters. These include:

- Increased soil porosity and soil organic matter
- a reduction of water evaporation and crust formation;
- and enhanced water retention capacity of the soils.

This latter effect has a particularly beneficial impact on agricultural yields given the low precipitation levels in the summer. In particular, using a water-crop balance model, we find that:

- Farmers who occasionally burn residues can obtain increases in yield of approximately 11% within 3 years, after they stop residue burning if they integrate straw in the soil as opposed to burn it.

- Farmers who burn on an annual basis can obtain increases in yields of approximately 23% within 3 years after they stop burning.

Small (less than 5 hectares) and large farmers (5 ha or larger) face different rental costs of machinery that can be used to collect straw residue or integrate it into the soil. Large farmers, however, burn more frequently than small farmers. Accounting for these differences, whilst using 2015 farmgate market prices for cereals, we find that:

- Small farmers who stop burning and integrate crop residue in the soil can expect on average an additional annual net benefit of GEL 78 per ha, whilst large farmers can expect GEL 105 per ha in annual net benefits[3]. Expressed in terms of the Benefit Cost Ratio (BCR), for every additional Georgian Lari invested in crop residue integration, small and large farmers can expect respective GEL 3.7 and GEL 5.2 of benefits (table s.1 and s.2)

- Farmers may also decide to collect and compress crop residue in straw bales and sell them. Using lower-bound farmgate market prices for straw, the expected annual net benefit of collecting straw over a 10-year horizon is GEL 147 per ha per for large farmers, using conservative straw prices. Small farmers, however, have inferior agricultural 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 S.1)

Finally, the termination of crop residue burning will also lower greenhouse gas emission from crop residue burning itself and from the reinforced protection of windbreaks. The global benefits

[3] also known as annuity values, which is equivalent to the *present value* the average annual additional income generated over the 10-year accounting period.

in terms of avoided climatic damages from these emissions amount to GEL 4.4 million over a 10-year period for the whole of the Shiraki valley.

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

Small farmers	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	489600	N/A*
Protection of remaining hedges	6.8	56	89600	N/A*
Aggregate net-benefits				
Burning banned and all residues are integrated in the soil	**123**	**994**	**1.1 million**	**5.2**

*Assuming that government authorities bear the costs of prohibiting burning, there is no cost involved for farmers.

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

Large farmers	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	1196	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**	**1206**	**15.8 million**	**6.9**
Burning banned and all straw collected and sold	**190**	**1547**	**17.4 million**	**2.9**

*Assuming that government authorities bear the costs of prohibiting burning, there is no cost involved for farmers.

Table S.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**	**1343**	**16.9 million**	**3.8**
Georgian society			**16.8 million**	**4.4**
Global society, including carbon sequestration			**21.2 million**	**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 integrating the other half,,

Bringing together all these benefits, whilst accounting for the additional costs of shredding, integrating or collecting crop residues and enforcing 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. The societal NPV benefit to Georgia amount to GEL 16.8 million, Assuming that small farms retain and integrate all crop residues in the soil (table S.1), the NPV over a 10-year period for small farmers is GEL 994 per hectare cultivated, while large farmers can expect to enjoy a NPV benefit of between GEL 1206 and 1547 per hectare depending on whether they decide to sell straw or retain it in in the soil (table S.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.

Conclusively, a ban on crop residue burning is a policy that can bring significant net-benefits in terms of improved protection of windbreaks, carbon sequestration, soil fertility and sense of wellbeing amongst the majority of farmers. However, in order to more effectively confront the challenges of the agricultural sector in Dedoplistskaro, 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 Dedoplistskaro, while favouring the mitigation and adaption to climate change.

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List of Abbreviations

a	Annuity factor
AFOLU	Agriculture, Forestry and Other Land Use
B	Above ground biomass
BAU	Business as Usual
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CE	Choice Experiment
EANB	Expected Annual Net Benefit
EANC	Expected Annual Net Cost
ETo	Evapotranspiration
Ha	Hectare
GEL	Georgian Lari
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HI	Harvest Index
IRR	Internal Rate of Return
LR	Likelihood Ratio
MoENPR	Georgian Ministry of Environment and Natural Resource Protection
NPV	Net Present Value
PV	Present Value
r	The discount rate
SCC	The Social Cost of Carbon
t CO_2-eq	Tonnes of carbon dioxide equivalent emissions
Tr	Crop Transpiration
USD	United States Dollar
WTP	Willingness To Pay
WTA	Willingness to Accept compensation
WP	Crop Water Productivity

1. Introduction

Fire is used extensively in agricultural practices around the world, contributing to an estimated 8–11% of global fires. On a regional basis this proportion can be significantly higher. The Russian Federation, for example, is the largest contributor to agricultural burning globally producing 31–36% of all agricultural fires (Korontzi et al., 2006). Georgian farming systems are no exception - fire is used extensively during pre-planting and post-harvesting periods from May to October (See figure A1.2 in appendix 1). Agricultural burning is undertaken to clear crop residue, eliminate pests and weeds and is often a firmly entrenched cultural practice (Ekboir, 2002). If poorly managed, fires pose risk to agricultural and natural ecosystems, cultural values, properties and human health. Despite the prevalence of this practice, little is known – at global or local level - about the impacts of fires on biodiversity and livelihoods.

In the summer of 2015, large-scale destructive wildfires swept the so-called “wheat basket of Georgia”. They originated from farmers practicing open field burning of crop residues. In the aftermath of this event, the Georgian Ministry of Environment and Natural Resource Protection (MoENPR) is in the process of drafting a law to ban crop residue burning. Enforcing such a policy, however, would need to be justified on economic and ecological grounds. This study was assigned by MoENPR and GIZ in order to assess the associated economic and ecological benefits and costs of a ban of burning.

In response to this, the study elaborated in this report has been conceived to value the impacts of implementing and enforcing a ban of crop residue burning. To do so, agronomic field data, laboratory testing and different economic valuation methods are combined to estimate the economic benefits and costs, to society and farmers alike. The main results are presented in the following, starting with an overview of the case-study area, followed by a presentation of the methodology used (Chapter 2), an assessment of the biophysical and ecosystem services impacts (Chapter 3) and a subsequent economic valuation of these (Chapter 4). The results are finally aggregated and the relevant scenarios presented (Chapter 5). Chapter 6 and 7 contextualize the results and draw conclusions. The time frame for the analysis is 10 years, (2017-2026) using an interest rate of 4% and presuming that the policy could be enacted in 2017. The actual study has been undertaken from the end January 2016 to June 2016.

1.1 Case study area

Georgia is situated in the South Caucasus, between latitudes 41° S and 44° N, and longitudes 40° W and 47° E, covering an area of 67,900 km^2 and has a total population of 3.7 million (Geostat Census 2014). Georgia is divided into 9 regions and 69 municipalities. Dedoplistskaro is one of them, located within the region of Kakheti. It has a population of 21,221 (Geostat Census 2014) and covers an area of 2,529 km² (80,000 ha). 74% of Georgia’s wheat is produced in Kakheti, and within Kakheti the main wheat growing area is Shiraki valley located in Dedoplistskaro Municipality (see Figure 1). Barley, sunflower, wine is also grown in the valley and there are some pastures under private ownership as well. Figure 2 shows the proportion of land dedicated to different farm systems on the basis of a valuation survey undertaken in relation to this project (see Section 3 for more information).

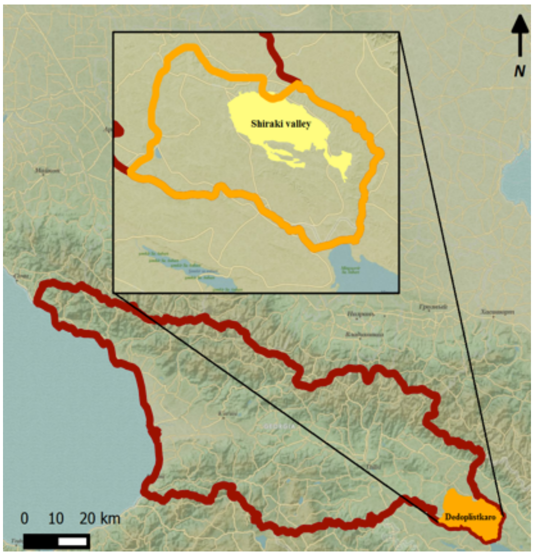

Figure 1: Location of Shiraki Valley in Dedoplistskaro Municipality of Georgia

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The valley covers a total of 43,000 ha of which 34,000 ha is arable land. With its very fertile, deep soils with high humus content, the valley has ideal farming conditions. However, the combination of warmer climates, more frequent droughts, strong winds, the degradation of windbreaks and non-sustainable agricultural practices, including crop residue burning, have led to reduced agricultural yields in the past decades (Camacho et al., 2015).

In Georgia as a whole, about a third of its 3 million hectares of agricultural land is affected by soil erosion, 11% is affected by acidity, 8% by waterlogging due to malfunctioning drainage systems, 5 % is affected by excessive potassium and nitrates, and another 20-40% is affected by salinity (World Bank 2007). With low levels of productivity, a variable climate and a high reliance on rain fed agriculture, Georgia has a significant food security risk. Additionally, the increasing occurrence of extreme dry spells and heat waves currently observed, as well as climate modelling based predictions, suggest that extreme weather periods favouring the recurrence of more frequent and larger fires and higher associated damages will aggravate in the coming years and decades (GFMC 2015).

In this context, it is imperative that climate change adaptation options that give the greatest return on investment from an economic, social and environmental perspective are prioritized. In the remaining of this paper we investigate the economic case for terminating the use of post-harvest burning of crop residues in Georgia.

The social and economic consequences of agricultural fires have received comparatively little attention in Georgia media and literature, despite the scale of the practice and its implication for climate, nature and livelihoods. It is therefore due time that a study of this kind is undertaken to help clarify grey zones, specifically with regard to farmer's preferences and agricultural productivity.

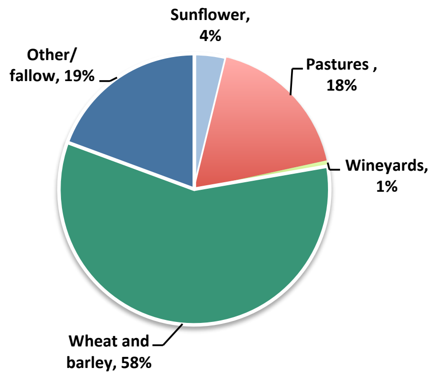

Figure 2: Share of types of land use in Shiraki valley

2. Methodology and research methods

2.1 Terminology

Agricultural burning affects a range of ecosystem goods and services, in addition to marketable goods, such as straw. It is, thus, of relevance to undertake a comprehensive economic valuation, of both the market and non-marketable goods and services impacted by burning. This is operationalized using cost benefit analysis (CBA).

In CBA, benefits and costs are expressed in monetary terms, and are adjusted for the time value of money so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their net present value.

To derive the **Net Present Value (NPV)** of a given land use system, for each year, costs are subtracted from benefits, for every year and discounted using the interest rate of *r* to reflect the net-benefits in present value terms. These are then summed up to derive a NPV for the total time horizon (T) that is being evaluated (Equation 1).

Eq 1 $$\mathrm{NPV} = \sum_{t=0}^{T} (B_t - C_t)/(1+r)^t$$

In general, policy initiatives with positive NPV should be considered; the greater the NPV, the more justifiable the initiative.

The **benefit cost ratio (BCR)** is another convenient criterion that can be used to judge the relative of interest in one land use or policy scenario vis-à-vis the other. It is the ratio of the benefits of a project, expressed in discounted present values, relative to its costs, also expressed in discounted present values (Equation 2), where r is the interest rate.

Eq 2 $$\mathrm{BCR} = \sum_{t=0}^{T} \frac{\mathrm{Benefits}_t/(1+r)^t}{\mathrm{Costs}_t/(1+r)^t}$$

The Expected Annual Net Benefit (EANB) also known as the annuity value, is equivalent to the present value the average annual additional income or welfare benefit generated over the 10-year accounting period. It has the same NPV as the project itself. The EANB of a project is computed by dividing the NPV by the appropriate annuity factor, a^t_r according to equation 3.

Eq 3 $$\mathrm{EANB} = \frac{\mathrm{NPV}}{a^t{}_r}$$

Where the annuity factor is the present value of an annuity of GEL 1 for the life of the project (10 years), and r = interest rate used to compute the NPV.

The **Internal Rate of Return** (IRR) on an investment or project is the rate of return that makes the NPV of land use cash flows equal to zero. It is the discount rate at which an investment breaks even, that is, the rate at which present value of all future revenues is equal to the initial investment. In this report, the IRR is only used in the financial analysis of the pellet producing facility.

For further background on ecosystem service valuation methodology please see the user-guide developed by the ELD initiative (ELD initiative 2015).

2.2 The discount rate

The discount rate is a critical parameter in cost-benefit analysis whenever costs and benefits differ in their distribution over time, especially when they occur over a long time period. In selecting the discount rate, we have used a so-called descriptive approach, based on the opportunity cost of drawing funds from the private or the public sector.

Accordingly, the cost of investing a Georgian Lari (GEL) in land management systems without burning today is the value that each Lari would have produced in its alternative use. Therefore, for no-burn to be worthwhile at the societal level, the invested capital should grow more than if the "Lari" had been invested elsewhere. This expectation is reflected through the use of positive interest rates when evaluating NPV and BCRs.

The real rate of interest is equal to the nominal lending interest rate adjusted for inflation. The real rate of interest is the appropriate discount rate for benefit cost analysis. Most variations in nominal rates are due to changes in inflationary expectations since the rate of return on capital (e.g., factories, equipment) is fairly stable over time.

Currently, the actual inflation rate in Georgia is 3.5% and the nominal interest rate is 7.5%. The real interest rate approximate is thus 4%. The inflation rate has ranged between 3-5% since July 2014[4] and was approximately 4% during most of 2015. The National Bank of Georgia kept its refinancing rate unchanged for the third consecutive time at 8% in April 2016. Tight monetary policy has helped to stabilize national currency and inflation expectations have eased. 4% is therefore considered a stable benchmark to use for the costs and benefit calculated throughout this paper. The sensitivity of results to changes in the discount rates is also estimated (in Chapter 5).

2.3 The accounting period

A 10-year time horizon has been chosen for the valuation study. Even though ending of burning will have very long-lasting consequences, it was considered that national decision-makers and farmers alike are most concerned about the immediate future. We have therefore opted for a relatively short time horizon of 10 years.

2.4 Scenarios

In terms of how future land use and burning practices may evolve, we assess two different possible scenarios. Either there is 'no change' relative to today (BAU – "business as usual"), that is, farmers continue to burn if and when they would like to, without any legal consequences. Under the BAU, individual farmers may also voluntarily decide to stop burning residues and integrate and/or collect straw residues. But voluntary action does not guarantee a farmer from not being affected by the fires of neighbouring farmers. In the alternative scenario, the government enacts a law to ban crop residue burning. In that case, farmers can decide to integrate leftover crop residues in the ground, collect and sell them or do a combination of the two. It is also possible that alternative uses, such as fuel pellets can be made from the straw residues that are collected provided adequate investments into pellet producing facilities (see chapter 5). On this basis the valuation study considers two different valuation scenarios, namely:

- **BAU scenario:** No change, a simple continuation of the 'business as usual (BAU)'
- **Ban on burning scenario:** A legal action to prohibit crop residue burning. Small and large farmers stop burning and decide to integrate residues in the soil, and/or collect, compress and sell straw bales depending on the benefits and costs of each activity.

The latter scenario is valued relative to the former, business as usual. The valuation scenarios are illustrated in Figure 3.

[4] IIECONOMICS.com/Georgia-inflation-rate-forecast.

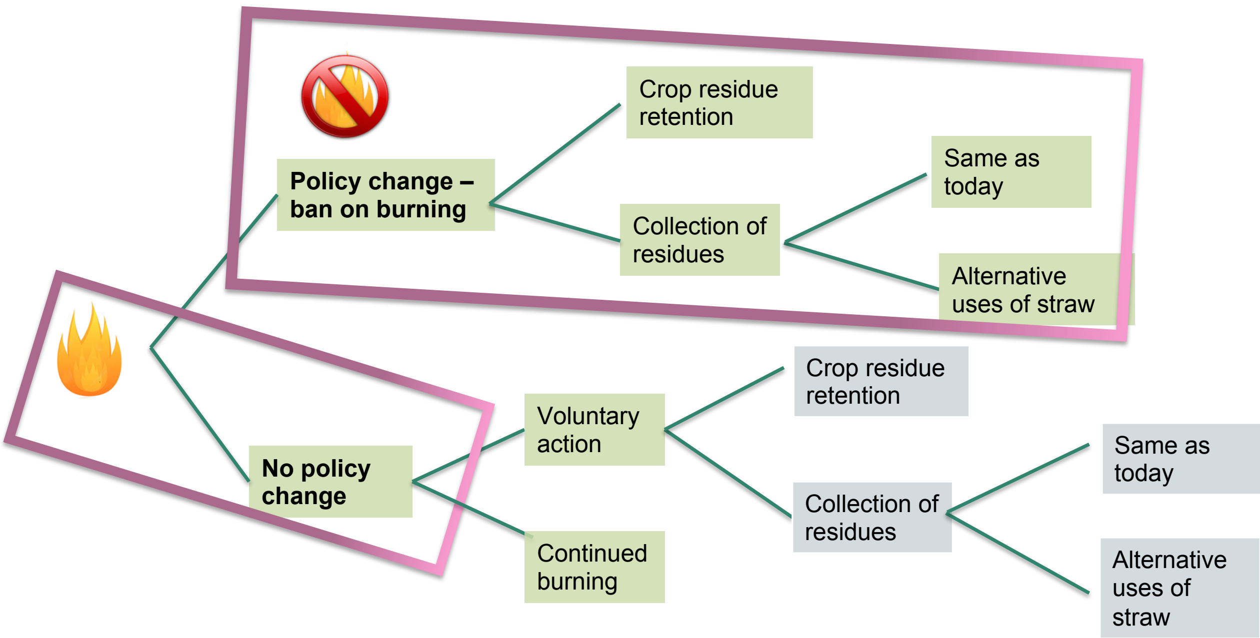

Figure 3: The policy scenarios under consideration

2.5 Ecosystem services and social impacts being valued

Agricultural fires have many direct and indirect impacts on ecosystems, biodiversity and people's livelihoods. It is beyond the scope of any CBA to account for all occurring impacts. The first part of the study therefore served to define which were the crucial goods and services to be valued. That was done during a workshop with both national and local decision makers (see Appendix 2 for further details). Following these workshops it was decided that the following elements should be assessed:

- The value of protecting remaining windbreaks from fires;
- The benefits and costs to farmers associated with shredding, integrating and/or collecting and selling residues as opposed to burning them;
- The impact on carbon emissions from a prohibition of crop residue burning;
- The economic feasibility of developing alternative uses of straw;
- Farmer's true preferences over residue management and how much they would need to be compensated, or would be willing to pay, to forego the burning of crop residues.

2.6 Questionnaire design and data collection

In order to value above mentioned ecosystem services and livelihood aspects, a detailed valuation survey was implemented with 300 randomly selected farmers in Dedoplistskaro Municipality between March and April 2016[5]. The survey had several aims:

- first, to have an understanding of the characteristics of the farms within Shiraki valley;
- secondly, to understand the economic values associated with restoring windbreaks and;
- thirdly, to assess the welfare economic impacts of implementing a policy that prohibits the burning of crop residues.

Data collection was undertaken using face-to-face interviews conducted on the farms. Each interview lasted on average 45 minutes. The population from which the sample was selected included farmers cultivating more than 0.5 ha of land and living within the Dedoplistskaro municipality, approximately 4,820 farmers. Descriptive statistics of the households are provided in Appendix 3. 300 randomly sampled farmers were interviewed so as to achieve 95% confidence level for sample statistics.. In collecting a sample that reaches a desired level of statistical precision, Neuman (1991) suggests a ratio of 30 per cent for small populations (those under 1000); 10 per cent for moderately large populations (those of, say, 10,000) and 1 per cent for large populations (those over 150,000). But smaller samples can be justified when the underlying population is homogeneous (e.g. mainly agrarian), as in the case of the Shiraki valley. For example, if the target population of agricultural households is believed to be 90 per cent of rural households, then the appropriate sample size to reach a 95% confidence level for sample statistics would be approximately 300 (UNSD 2008)[6]

Statistical representation of our data is confirmed by holding up data from the household survey with census data. For example, 85% of farmers in our sample own less than 4 hectares of land, which is similar to the proportion (83%) found in Geostat census data from Dedoplistskaro (Geostat Census 2014). In our sample, we also find that 50% of farmers cultivate 5 hectares or less, and 50% cultivate more than 5 hectares, corresponding as well to the information provided by the mayor of Dedoplistskaro (Table A4.7, Appendix 4). ≥

The first section of the questionnaire served to reveal information on socio-demographic and economic characteristics of the farm households. The second part consisted of stated preference valuation exercise known as choice experiments and the third part sought to reveal more about farmers' land use practices and their attitudes about the burning of agricultural residues.

2.7 Data sources and valuation methods

The valuation study is largely informed by the household questionnaire. The data from the survey has been combined with data from secondary literature, satellite imagery and field and lab experiments. The marketable and non-marketable goods and services that we value in the following are shown in Table 1, including the valuation method that was used to value it and where the data inputs have come from.

[5] Dedoplistskaro municipality and the villages: Arboshiki, Mirzaani, Samtatskaro, Zemo Qedi, Arkhiloskalo, Qvemo Qedi, Samreklo, Sabatlo, Gamarjveba, Khornabuji, Pirosmani, Zemo Machkhaani.

[6] Using formulae, developed by United Nations Statistical Division (2008) that allows for the estimation of a target sample size for purposes of collecting data on a population with a desired level of statistical precision. The size of the target population relative to the total survey population plays a crucial role in the choice of a sample size.

Table 1: Valuation methods and data types associated with benefits and costs used in this study

Benefits and costs of ending fires	Valuation method	Data
Protection of remaining windbreaks	Stated Preference	Remote sensing and valuation survey
Welfare impacts of burning on livelihoods	Stated Preference	Valuation survey
Changes in yields	Productivity change	Field study and lab experiments, and valuation survey
Changes in carbon emissions	Avoided costs	Remote sensing, valuation survey data and secondary data
Collection and sale of straw	Market prices	Valuation survey
Costs associated with the disposing of residues by other means than burning	Market prices	Valuation survey

3 Biophysical changes associated with ending crop residue burning

This chapter focuses on assessing the biophysical and agronomic impacts of ending crop residue burning. That enables us in Chapter 4 to assess the economic implications of these impacts.

3.1 What 'banning of fire' implies for windbreaks

In order to project the possible incidence of fire hazards from 2017 to 2026 under a 'no-change' and 'ban of burning scenario', normally distributed random numbers were drawn from a distribution characterised by the same mean (6,917 ha) and standard deviation (8,990 ha) of observed fire events in Dedoplistskaro from 2000 to 2015 (Costa, 2016; see Appendix 1). This method was used, because past climatic data, agricultural yields and fire events did not allow us to establish any statistically significant robust leading variables that we could use to predict future fire hazards. It was neither possible to infer a trend in wildfire events over the last 20 years (Costa 2016; see Appendix 1). The resulting distribution of the random draws is shown in Figure 4.

It should also be highlighted that even if burning is banned, it is unrealistic to assume that a ban of burning would lead to a complete termination of fires (Costa, 2016, personal communication). At any one year, there may be non-intentional fires or farmers who ignore legislation. In the 'ban of burning' scenario it is therefore assumed that at least 10% of the fires seen under a no-change scenario remain (Costa 2016).

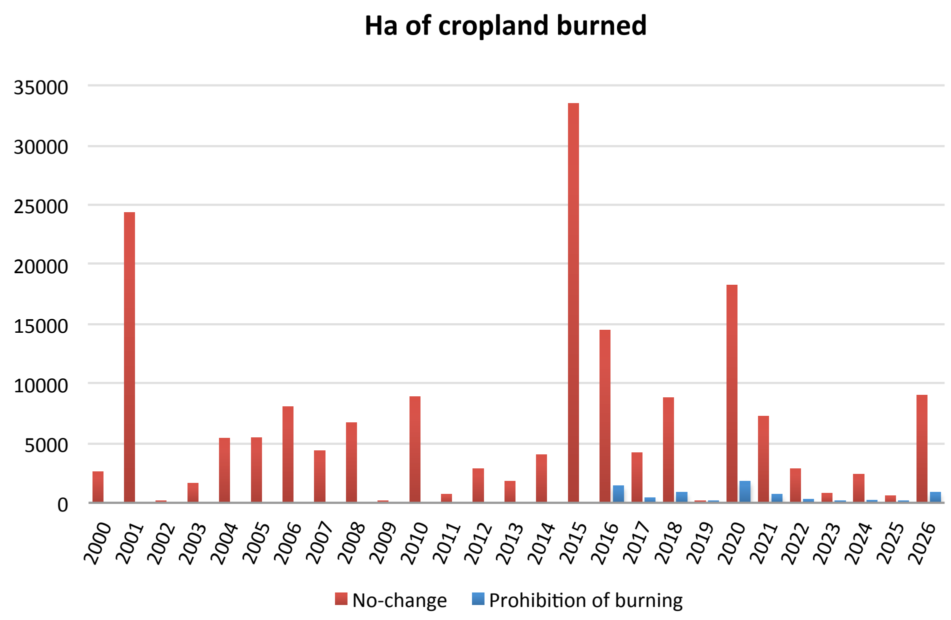

Figure 4: Historical record of cropland burned in Shiraki valley and possible wildfire projection

3.2 Predicting the extent of windbreaks in the 'business as usual' and ban on burning scenario

The degradation of windbreaks started after the fall of the Soviet Union, when the population of Dedoplistskaro began to cut trees to meet demand for fuel. Even though the pressure from the local population decreased as the people mostly buy fuel wood from the forest through local wood sellers (Helbig, 2016), the windbreaks still continued to deteriorate because of the yearly agricultural burnings. Efforts were made to restore the windbreaks in the frame of the GIZ programme "Sustainable Management of

Biodiversity, South Caucasus" with support of the Austrian Development Agency (ADA). The fires of 2015 severely damaged remaining windbreaks and restoration efforts by GIZ.

Windbreaks consist of rows of trees and shrubs planted along the edges of agricultural fields to protect crops and soil from strong winds (GIZ, 2014). They improve the climate for crops growing in their shelter and provide nesting sites for birds that support natural pest control.

Prior to the collapse of the Soviet Union, there were 1,800 km of tree windbreaks in Shiraki valley (NFA). After the collapse of the Soviet Union, gas supplies were cut and the institutions that used to govern windbreaks broke down. Windbreaks, thus, belonged to the commons and as a result degraded quickly as households were cutting trees for heating. In 1999, 614 km of field windbreaks remained according to a map prepared by GIZ based on ortho-photos from 1999[7].

The fires of summer 2015 had a particularly large toll on windbreaks. An area of more than 33,490 hectares of arable land burned. The wildfires were so large that fire trenches, roads and other infrastructures that normally protect windbreaks were ineffective. Field studies by GIZ revealed that out of the 68 km of windbreaks planted by GIZ, 55.5 km[8] or 83 % were destroyed (Klein, 2015).

If there is no change in fire and land use management practices, with the current trend, the remaining windbreaks will soon be lost as well. This was also highlighted by local farmers during the stakeholder consultation in January 2016 (see Annex 5 with outcome of inception workshop). A ban of crop residue burning will help to protect the existing windbreaks. In order to test that hypothesis we used the wildfire scenarios (section above) to infer what will happen to windbreaks in a BAU scenario versus 'ban of burning' scenario.

According to a windbreak inventory by GIZ in Georgia only 50 km of windbreaks remain in Shiraki valley (Weigel, 2016). Detailed data from the windbreak inventory of the replanted windbreaks from 2015 is used to establish causality between wildfires and windbreak mortality (Klein, 2015). From this data, it can be deduced (using Equation 3) that for every hectare of cropland burned, 1.65 m of windbreaks were destroyed. In that case, the extent of windbreaks that remain in year t, for the BAU and ban on burning policy scenarios can be estimated using Equation 4. Consulting the results in Table 2, it can be seen that if there is BAU fire management regime, all windbreaks will have been destroyed within less than 10 years. In the case that burning is prohibited however, even after 10 years, 90% of windbreaks will remain. To simplify the analysis, we have abstained from other factors that may influence the windbreaks, such as deliberate felling of trees. This is because we are essentially interested in valuing the changes resulting from reduced burning.

Eq 4 $$\text{Windbreaks burned per ha cropland burned}_{2015} = \frac{\text{55 300 m of windbreak}}{\text{33 490 ha of wildfire}} = 1.65 \frac{\text{m windbreak}}{\text{ha of cropland burned}}$$

Eq 5 $$\text{Remaining windbreaks}_{s,t} = \text{remaining windbreaks}_{s,t-1} - 1.65 * \text{ ha of burned cropland}_{t}$$

[7] Lasha khizanishvili

[8] or 55 ha, as windbreaks restored by GIZ were 10 meters broad

Table 2: Lifeline of the remaining windbreaks in the baseline scenario and the 'no burn' scenario

	Hectares of burned cropland		Meters of remaining windbreaks	
Year	BAU scenario	Ban on burning scenario	BAU scenario[9]	Ban on burning scenario
2016	14,505	1,451.5	50,000	50,000
2017	4,221	422.1	40,425	49,042
2018	8,804	880.4	36,171	48,617
2019	25	2.5	29,546	47,955
2020	18,275	1,827.5	27,463	47,746
2021	7,290	729.0	15,937	46,594
2022	2,882	288.2	10,095	46,010
2023	791	79.1	6,534	45,653
2024	2,416	241.6	4,055	45,405
2025	604	60.4	735	45,074
2026	9,022	902.2	0	44,835
Average	5,981 ha	591 ha		

3.3 Avoided Greenhouse Gas emissions

Climate change poses a major risk for irreversible impacts on ecosystems and economic activity. Changing food production systems, rising sea levels, more incidences of droughts, floods, storms as well as biodiversity and species loss are the main expected direct impacts of climate change (Stern, 2007). There is growing evidence of the scale and severity of the business as usual path of greenhouse gas (GHG) emissions. This evidence-base provides the rational for structural integration of climate change mitigation opportunities in project and policy design, including the question of whether the burning of crop residues should be allowed or not.

To assess how greenhouse gas emission levels may change as a result of invigorating a ban on burning the FAO EX-ACT tool was used. EX-ACT is a land-based accounting system that relates activity data from Agriculture, Forestry and Other Land Use (AFOLU) sectors to: Estimated values of the five carbon pools: above ground biomass, below ground biomass, dead wood, litter and soil organic carbon. This way EX-ACT derives values of carbon stocks, stock changes and emissions of CH_4, N_2O and CO_2 emission. EX-ACT has been developed using mostly IPCC 2006 Guidelines for National Greenhouse Gas inventories (IPCC) that furnish EX-ACT with recognized default values for emission factors and carbon values, the so-called Tier 1 level of precision (Smith et al., 2007). FAO's ex-ante carbon balance tool 'EX-ACT' measures GHG impacts per unit of land, expressed in tonnes of CO2-equivalent emissions per hectare and year. It is able to account for changes in deforestation, afforestation and reforestation, land use change and conservation, land degradation, annual crop production and sustainable land management practices.

3.4 Extent of burning of crop residues on farmland

Data from the valuation survey was used to assess the prevalence of residue burning in Shiraki valley. From Figure 5a, it can be seen that 27% of farmers burn every year, 29% burn occasionally (every 2-3 years) and another 44% never burn. For each of these farmer groups, we have studied the area of cereal

[9] We assumed that windbreaks are on average of 15 m broad, especially those along the roads. In that case, 1 km of windbreak = 1.5 ha of windbreak. This relation is used to estimate avoided GHG emissions from the deforestation and burning of windbreaks.

land that is under their control to make an approximation about how much land that is burned occasionally, burned every year and never burned.

On this basis, we may infer that 25% of farmland is burned every year, 40% of the farmland is burned regularly (every 2-3 years) and 35% is never burned by the farmer. Additionally, 25% of farmers claim to be affected every year by the fires caused by neighbouring farmers (Figure 5b).

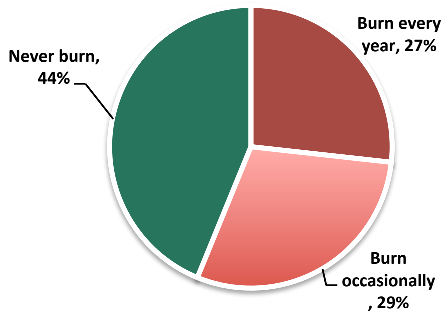

Figure 5a: Share of farmers who burn, burn occasionally and do not burn

Using these statistics, it is fair to assume that at least 50% of all cropland is burned at any one year when there are no 'extreme/uncontrolled fire events like the 2015 event. That corresponds to about 10,000 ha since approximately 20,000 ha of arable land is used for barley and wheat cropping (see Table A4.7, Appendix 4).

This is different to what is captured by MODIS satellite data (Appendix 1), indicating that an average of 6,000 ha is burned per year. This is also the data upon which future wildfire incidences are predicted (in Table 2). The discrepancy between what farmers reveal themselves and what is captured by satellite imagery can be explained by the fact that only fires larger than 2.5 km² are detected with MODIS satellite data which has a 500 m x 500 m resolution. In order to have a more realistic estimate to total cropland area burned, we have therefore upward adjusted by 4,000 ha the predicted extent of fire hazard on cropland.

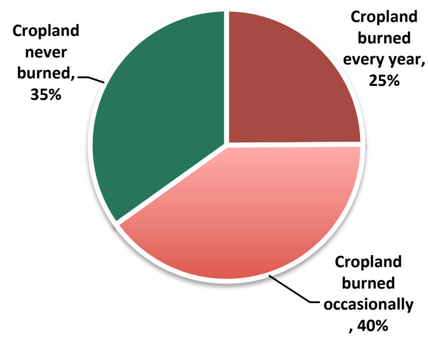

Figure 5b: Approximate share of farmland burned annual, occasionally and never

GHG emissions from the burning crop residues consist of methane and nitrous oxide gases. Burning one hectare of crop residues generate on average 0.31 t CO_2-equivalent emissions. This estimate and those that follow have been computed within EX-ante's annual systems module (figure 7), using IPCC Tier 1 Guidelines for National GHG Inventories (IPCC, 2006).

In the BAU scenario, an average of 10,000 ha[10] of cropland is burned per year compared to only 10% if burning is banned. As a consequence, over an accounting period of 10 years, an estimated 28,200 t CO_2-eq emissions will be avoided per year (Figure 6). Figure 7 illustrates the CO_2eq GHG emissions produced in ban of burning and BAU scenarios from annual crops (residues) and deforestation (windbreaks).

Fire induced deforestation release 303 t CO_2-eq per hectare of windbreak burned. Over an accounting period of 10 years, a total of approximately 20,000 t CO_2-eq emissions are avoided by protecting remaining windbreaks (Figure 8). Reduced emissions from avoided deforestation and residue burning will together result in the avoidance of approximately 49,000 t CO_2-eq emissions. The difference between emissions in the BAU and the ban on burning scenario are illustrated in Figure 8.

[10] On average 5,981 ha per year derived from Table 2 plus an additional 4,000 ha, so as to arrive at 10,000 ha, which is the total estimated area of farmland that is burned every year on the basis of the farmer's own revealed practices.

All GHG in tCO2eq	Gross fluxes			Share per GHG of the Balance			
Components of the project	BAU	No-burn	Balance	CO_2		N_2O	CH_4
Land use changes				**Biomass**	**Soil**		
Deforestation	22,399	1,792	-20,607	-15,027	-5313	-120	-147
Agriculture - Annuals	31,300	3,130	-28,170	0	0	-7,797	-20,373
Total	53,699	4,922	-48,778	-15,027	-5,313	-7,917	-20,520
Per hectare	2.6	0.2	-2.4	-0.7	-0.3	-0.4	-1.0
Per hectare per year	0.3	0.0	-0.2	-0.1	0.0	0.0	-0.1

Positive = source / negative = sink

Figure 6: GHG emissions in the EX-Ante annual systems module

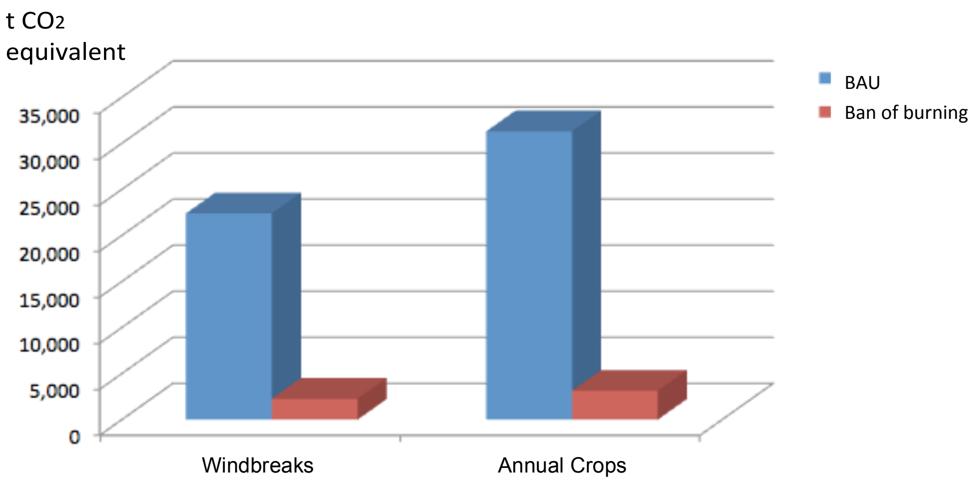

Figure 7: GHG emissions associated with deforestation of windbreaks and burning of residues in BAU and ban of burning scenario

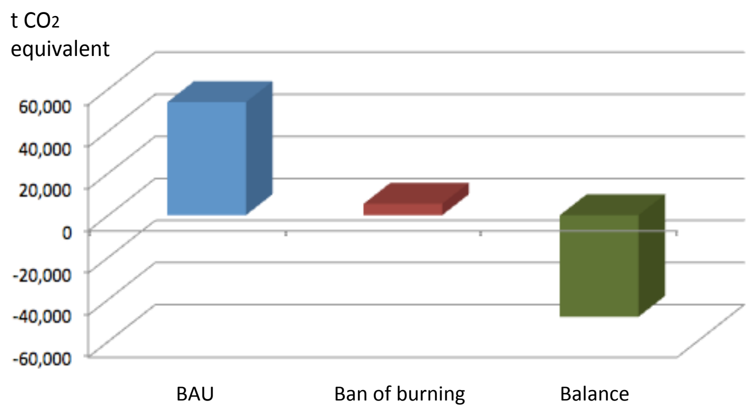

Figure 8: GHG emissions in BAU and ban of burning scenario and net-sequestration in case residue burning is prohibited (T=10)

3.5 Biophysical impact of fires on soil and agricultural yields[11]

Fire significantly affects the physical, chemical and biological properties of soils and therefore also the yields and the livelihoods of those cultivating the soil. The degree of alteration caused by fires depends on fire intensity and duration, which in turn depend on factors such as amount and type of fuels, air temperature and humidity, wind, topography; soil properties of moisture content, texture and organic matter content and properties of above ground biomass (DeBano et al., 1998). Effects of fire on soil include a loss of soil organic matter (SOM), (Albalasmeh et al., 2013), the altering and removal of above-ground vegetation and topsoil biomass, and increasing erodibility of soil (Carroll et al., 2007) - leading to subsequent shift in plant and microbial populations (Janzen & Tobin- Janzen, 2008).

The aim of the agronomic study (see Giorgi Ghambashidze 2016 for detailed analysis) was to assess possible changes in soil properties, particularly changes in soil organic matter and water retention capacity of soils resulting from the termination of crop residue burning.

3.5.1 Study-site selection and data collection

Site selection for soil sampling was based on differences in agricultural practices established by farmers. Three different types of management practices were selected: 1) annual burn of crops residues; 2) no burning of crop residues 3) no burning of crop residues, but burned occasionally or accidently, e.g. due to intensive fires in 2015. A total of 9 different plots were sampled that had these characteristics. A description of the 9 sites and the results of the laboratory analysis are provided in Appendix 5.

In all cases soil sampling was conducted at two depths, 0-5 cm and 0-20 cm. Sampling of the 5 cm soil was based on the assumption that it is the soil depth which is most affected during fire. Sampling at 0-20 cm is used to assess general soil properties and its fertility level, as it represents basic plough depth in the study area.

The selection of soil parameters to be analysed was based on existing research describing impacts of fire on certain soil properties, such as organic matter, bulk density, nitrogen, phosphorus, potassium. In addition, the parameters that may not be changed easily, like particle size distribution, cation exchange capacity, pH, calcium carbonate, were also determined to obtain general main soil properties, which help in identification of any substantial differences between soils. These parameters can be also affected by long-lasting high temperature fires, in places where fuel load are much higher than on agricultural lands, such as in forests or within windbreaks.

A comparison of the sampling sites was done based on changes in organic matter content, and soil bulk density, which can be altered as a result of organic matter reduction. Concentrations of the plant macro nutrients like nitrogen, phosphorus and potassium were also compared. The comparison shows the main differences between fire affected and non-affected soil in organic matter and bulk density.

In order to evaluate statistical significance of observed changes one-way ANOVA (analysis of variance) test were applied using SPSS software. The 9 sites were divided into two groups: burned and non-burned sites. Burned sites unite the plots, which burn regularly and those burn occasionally or accidentally, as it is difficult to assess severity of each fire event. Sites studied under windbreaks (Site 3 and Site 5) were excluded from statistical tests as they serve as “natural reference” and cannot be compared to arable lands, which experience permanent anthropogenic impact.

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[11] This section draws heavily on Giorgi Ghambashidze (2016), with some modifications

The results of statistical analysis in Table 3, shows that only changes in organic matter content is statistically significant. Soil bulk density indicates on substantial differences between sites, but it is statistically non-significant at the 90% level of confidence. Existing differences in macro-nutrients (N, P, K) contents are statistically negligible and thus are not directly correlated to burn or no-burn practices.

Table 3. Results of the one-way ANOVA test

Organic Matter

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.516	1	.516	8.356	.034*
Within Groups	.309	5	.062		
Total	.825	6			

*Significant at the 95% level of confidence

Bulk Density

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.018	1	.018	3.978	.103
Within Groups	.023	5	.005		
Total	.041	6			

Nitrogen

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	1	.000	.097	.769
Within Groups	.002	5	.000		
Total	.002	6			

Phosphorus

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	1	.001	1.499	.275
Within Groups	.005	5	.001		
Total	.006	6			

Potassium

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	1	.000	.000	.986
Within Groups	.081	5	.016		
Total	.081	6			

3.5.2 Comparative soil analysis between burned and non-burned sites

Among the nine plots that were sampled, two plots (Site 1 and Site 2) located side by side offer a good basis for comparison, because of similar agro-ecological characteristics, but opposing management characteristics on the plots.

On site 1, crop residues are integrated into the soil through shredding using a combi-harvester (grain-harvesting machine) followed by use of a disc-cultivator to allow for better incorporation of residues into the soil[12]. Site 1 has not been affected by fire during the last three years – even during the massive 2015 fires. No mineral fertilizers have been applied during last 3 years except 100 kg nitrogen fertilizers in the form of ammonium nitrate (≈34 kg N per hectare) to support decomposition of shredded straw and followed by rotary cultivator for better incorporation into soil.

Site 2 was burned during the last three years prior to the field sampling and the owner of the site burns the entire amount of straw after grain harvest. The farmer furthermore applies NPK fertilizers regularly.

A comparison of the physical and chemical properties of the soil for the two comparable sites described above indicate significant improvements in soil parameters when burning is not undertaken. These improvements include:

- An increase in soil organic matter content by 18%;
- Reduced soil bulk density by 10%;
- Reduced fuel consumption used by agricultural machinery during soil cultivation as a result of reduced bulk density;
- An equal water infiltration rate on the entire plot where burning has not been undertaken (Site 1), equivalent to 480 mm/day. Repeated measurements on "Site 2" showed a lower and a significantly different water infiltration rate within the plot, which may also be caused by the use of heavy agricultural machinery.
- The incorporation of straw and shallow tillage of soil prevents crust formation and cracking of soil and reduces water evaporation;
- Regular addition of fresh organic matter in form of crop residues to soil and increased maintenance of moisture creates favourable conditions for soil organisms. The presence of earthworms observed during soil sampling on "Site 1" is a good indicator of this. No earthworms were found on "Site 2".
- Finally, due to higher organic matter content the soil on "Site 1" can hold about 145 t more water per ha in the top 20 cm of the soil.

All of these improvements in soil properties have direct or indirect impact on soil productivity and yield formation. The differences found between the neighbouring plots clearly indicate the importance of proper soil management and avoided burning.

The characteristics of the remaining sites (3-9) which cannot be directly compared are explained in Appendix 5.

3.5.3 Water balance under different soil management regimes

AquaCrop (ver. 5.0) model simulation

Adequate supply of water is crucial to allowing cereal crops to realize their growth potential. Moreover, because Dedoplistskaro municipality is characterized by rain-fed agriculture, water management is a key determinant for agricultural productivity with increasing importance, as climate change becomes more pronounced. Moreover, because of year-to-year changes in available precipitation within the growing season in Dedoplistskaro, yields may vary greatly from one year to another. Therefore, the only way to improve and stabilize the agricultural production is to establish better agricultural practices in which proper soil management plays a crucial role.

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[12] Farmers who burn crops also use a rotary cultivator after burning to prepare for the planting season (revealed in the valuation survey). So the rotary cultivator does not lead to increased costs for the farmer who decides not to burn.

In order to assess how different soil management practices actually affect agricultural yields in Dedoplistskaro, we have used a water-balance crop model known as 'AquaCrop' to isolate the impact of fires on yields. The Food and Agricultural Organization (FAO) developed the AquaCrop model in 2009 (Jin, et al, 2014). The model was first built on "yield response to water" data of Doorenbos and Kassam (1979) and further developed to a normalized crop water productivity (NCWP) concept (Steduto et al. 2009). Compared with other models, AquaCrop is relatively simple to operate and allows for simulation of crop performance in multiple scenarios.

AquaCrop is also capable of predicting crop productivity, water requirements, and water use efficiency under limited water conditions. To date, this model has been successfully tested for cotton, maize, wheat, sugar beet, sunflower, groundnut, potato, quinoa, barley, green onion and tomato under a wide-range of environments.

3.5.4 AquaCrop data inputs and calibration process

In addition to offering a high level of accuracy, the AquaCrop model requires a limited set of input parameters, most of which are relatively easy to acquire. Input consists of weather data, crop and soil characteristics, and management practices that define the environment in which the crop will develop. Weather data is typically collected from agro-meteorological stations and include minimum and maximum air temperature, ETo (evapotranspiration) and Rainfall. Climatic data for the model developed in this study was provided by the Ministry of Environment and Natural Resource Protection of Georgia.

Crop data is taken from calibrated and validated crop characteristics from the data bank of AquaCrop software. Soil physical characteristics are adjusted based on field observations and texture class determined based on laboratory tests. The AquaCrop model furthermore takes into account field management practices such as soil fertility level and practices that affect the soil water balance. The simulation was done for winter wheat, the main crop in Shiraki valley. Average yield information was taken from local farmers, in order to validate the results of the AquaCrop simulation[13].

The assumptions underlying the AquaCrop model and the sequence of calculations made to arrive at the main results (table 4) are as follows:

1. **Soil water balance:** The amount of water stored in the root zone is simulated by accounting for the incoming and outgoing water fluxes at its boundaries.
2. **Crop development:** In the simulation of crop development, the canopy expansion is separated from the expansion of the root zone. AquaCrop uses canopy cover to describe crop development and the interdependence between shoot and root is indirectly accounted for via water stress.
3. **Crop transpiration (Tr):** Crop transpiration is obtained by multiplying the evaporating power of the atmosphere (ETo) with a crop coefficient. The crop coefficient (Kcb) is proportional to CC and hence continuously adjusted. The evaporating power is expressed by the reference grass evapotranspiration (ETo) as determined by the FAO Penman-Monteith equation.
4. **Above ground biomass (B):** The cumulative amount of water transpired (Tr) translates into a proportional amount of biomass produced through the biomass water productivity;
5. **Partitioning of biomass into yield (Y).** Given the simulated above ground biomass (B), crop yield is obtained using a Harvest Index (HI) (Yield = HI*B). In response to water and/or temperature stresses, HI is continuously altered during yield formation.

The core equation of the AquaCrop growth engine is shown in Equation 6:

Eq 6 $$B = WP \cdot \Sigma Tr$$

[13] As farmers typically report yields in fresh mass, fresh yield estimates have been converted to dry yields.

where *B* is the cumulative aboveground biomass production (kg/m^2), Tr is the crop transpiration (in mm/day) and WP* is the normalized crop water productivity (kg of biomass per m^2 and per mm of cumulated water transpired over the time period in which the biomass is produced) (AquaCrop, Reference manual, 2011). WP is normalized for [CO_2] and local climate (i.e., expressed by ETo).

Based on the results of soil analysis presented above, three different levels of soil fertility were selected to demonstrate potential grain yields under climate conditions similar to those of 2015. “Site 1” described above, was taken as a reference plot with non-limiting soil fertility, which valued as 100% fertility in the AquaCrop model. The sites affected by occasional or accidental fires were compared to the reference plot.

The results of the AquaCrop simuations in Table 4 shows considerable differences in agricultural yields under the three different crop and fire management regimes. A farmer, who burns his crop residues every year in the Shiraki valley, can expect to have a fresh yield of 3.67 ton/ha under 2015 climate conditions, while farmers who burn occasionally and never may expect fresh yields of respectively 4.14 ton/ha and 4.53 ton/ha, corresponding to 11% to 23% higher yields compared to the farmers burning residues. The differences are attributed to the fact that crops on fields that are not burned make more effective use of water. However, these benefits are not immediate. Discussions with farmers that represent each of these sites indicate that the soil fertility improvement presented here materializes 3 years after the farmer stops burning. This information is used when calculating the NPV of integrating straw residues (section 4.3, equation 13)

Table 4: Yield simulation by the AquaCrop model for year 2015

Management regime	Grain Yield t/ha Dry Mass	Grain Yield t/ha Fresh Mass	Water productivity (yield per cubic meter of water)	% Increase in fresh yield from a transition to no-burning*
Annual consistent burning of residue	3.21	3.67	0.68 kg / m^3 of water	**23%**
Occasional burning of residues	3.60	4.14	0.75 kg / m^3 of water	**11%**
No burning of soil	3.94	4.53	0.82 kg / m^3 of water	

*These differences in yields are realised as of year 3, after the farmer stops burning residues

Discussion of results

The findings from the AquaCrop simulations are consistent with other findings from the literature on soil management. For example, Steiner (1989) and Li et al (1992) showed that wheat straw mulching is regarded as one of the best ways of retaining more water in the soil and decreasing water evaporation. Certain types of soil organic matter can hold up to 20 times their weight in water (Reicosky, 2005). On the converse, it has been shown that fire has a direct impact on the physical properties of soil, decreasing soil porosity, increasing bulk density (Alauzis et al., 2004; Stoof et al., 2010, 2015) and decreasing the retention of water in the soil (Stoof et al., 2010, 2015; Shakesby, 2011) and water infiltration (Martin and Moody, 2001; García-Corona et al., 2004; Stoof et al., 2015). Moreover, burnt organic matter (OM) and ash may form a hydrophobic coating on soil surface (DeBano, 2000; González-Pelayo et al., 2010; Stoof et al., 2015), which reduces infiltration, increases runoff and soil erodibility (Nunes et al., 2005; Moody and Ebel, 2014; Stoof et al., 2015). Consequently, there is no doubt neither in Dedoplistskaro or elsewhere, that continuous burning of crop residues negatively affects soil parameters that are critical in ensuring resilient and high-yielding agricultural farm systems.

4. Valuation of the biophysical and social impacts of terminating crop residue burning

In this chapter the biophysical changes that are induced from a termination of burning are valued using productivity change, avoided damages, stated preference, market prices and avoided cost valuation approaches.

These changes are calculated for farmers with 5 hectares or more (large farmers) as well as farmers that cultivate less than 5 hectares of land (small farmers).

The segregation between small and large farmers has been done because the analysis of the household data has revealed that 5 hectares is a critical cutting point allowing to detect significantly different price structures with respect to: rental cost of combi-harvesters and straw collection machines as well as straw prices. Furthermore, as revealed in the next section, small and large farm also have different farming practices.

4.1 Small versus large farmers

Figure 9 shows that 50% of all small farmers never burn their crop residues, whereas only 37% of large farmers claim never to burn crop residues. Consistent with these finding, Figure 10 shows that a greater proportion of small farmers believe that burning is bad for soil fertility. Finally, in terms of who are affected by the burning of neighbouring farmers it can be seen that large farmers are relatively more exposed with 34% claiming that they are affected every year by burning from other farmers (Figure 11).

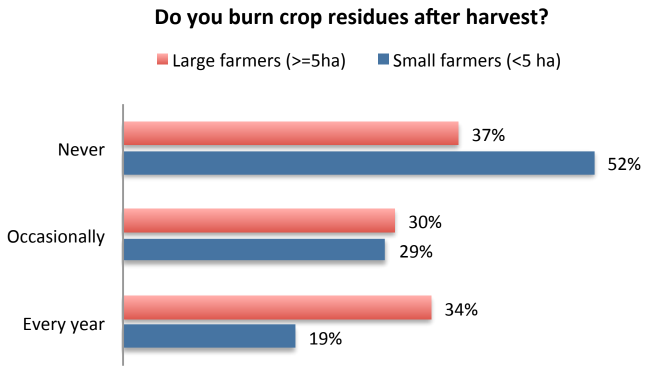


Figure 9 : Prevalence of burning among small and large farmers

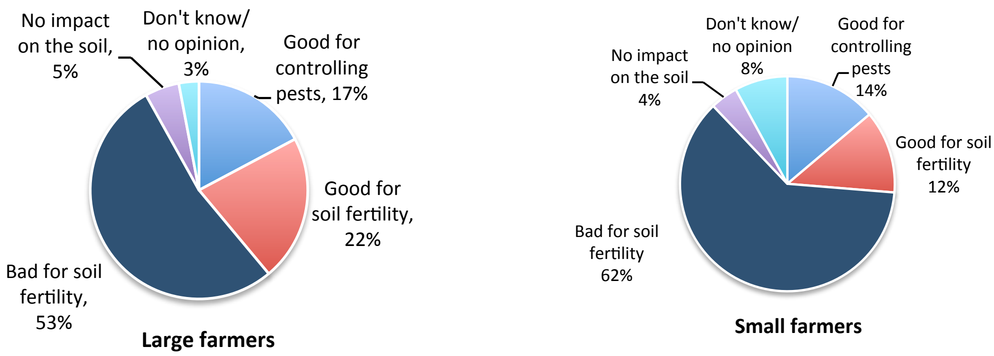


Figure 10 : Beliefs about the impact of burning among small and large farmers

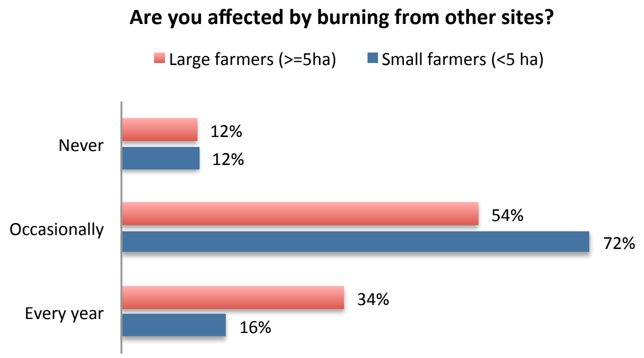


Figure 11 : The extent to which small and large farmers are affected by the burning of neighbouring farmers

4.2 Societal benefit of prohibiting burning and protecting remaining windbreaks

To assess farmers' actual preferences for burning agricultural residues a stated preference valuation study was undertaken as part of the valuation survey. The stated preference study employed a choice experiment (CE) method. In CEs, a number of respondents are asked in a questionnaire to select their preferred option from a range of potential management alternatives, usually including a status quo alternative. Discrete choices are described in a utility maximising framework and are determined by the utility that is derived from the attributes of a particular good or situation. It is based on the behavioural framework of random utility theory (Manski, 1977) and Lancaster's theory of demand (Lancaster, 1966). As a hypothetical market, CE can be used ex-ante to estimate marketable and non-marketable values for any environmental resource, and in particular the implicit economic value of its specific attributes and their internal ranking (Louviere et al., 2000; Birol et al., 2006). Choice modelling is regarded as the most suitable method for estimating consumers' willingness to pay (WTP) for quality improvements in with multiple dimensions[14].

Farmers were asked to evaluate eight choice sets and to choose between three landscape scenarios: a continuation of the present landscape and two future scenarios involving a ban of burning and/or a change in extent of windbreaks relative to the current situation. Each scenario was associated with annual cost, above and below what they currently pay for the land registration fee. The farmers were asked to choose their preferred scenario and identify if either of the two future scenarios were too expensive to pay or unfavourable. In that case, they should choose the present situation. Visual aids were used to depict the policy attributes (Figure 12). Out of the 300 households, there were 12 protest bidders who were eliminated from the sample[15]. With 288 households each evaluating eight choice sets, a total of 2,304 (8 x 288) choices were observed, (representing 3 x 8 x 288 trade-offs).

[14] CIE (2001) Review of willingness-to-pay methodologies. Centre for International Economics -

[15] Farmers who stated they were not able to pay more in land registration fee, but nevertheless chose scenarios involving a significant increase in the land registration fee. A source of strategic bias.

Choice set 1 (Block 2)	STATUS QUO	Future Alternative 1	Future Alternative 2
Windbreaks	20% windbreaks 	100% windbreaks 	50% windbreaks 
Crop residue management	Fire allowed 	Fire banned 	Fire allowed 
Land registration fee 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 12: Example of one out of 8 choice sets from choice experiment

4.2.1 Econometric Estimation

To describe discrete choices in a utility maximising framework, the CE employs the behavioural framework of random utility theory (RUT). In RUT, the individual *i*'s utility *U* from alternative *j* is specified as:

Eq 7 $$U_{ij} = V_{nj} + \varepsilon_{ij}$$

where V_{ij} is the systematic and observable component of the latent utility and ε is a random or "unexplained" component that is assumed to be independently and identically distributed (IDD) (Louviere et al., 2000).

The utility function used to generate the core results for this study is specified to be linear in the parameters. Observed preference heterogeneity associated with differences in farm sizes is incorporated into the deterministic part of the utility function by interacting respondent characteristics with the management attributes[16].

Eq 8 $$V_{ij} = \beta_{ASC} + \beta_1 X_{no\_windbreaks} + \beta_2 X_{50\%\_windbreaks} + \beta_3 X_{100\%\_windbreaks} + \beta_4 X_{Ban\_on\_burning} + \beta_4 X_{tax} + \delta_1 (X_{Ban\_on\_burning} \cdot S_{<3ha\ farmers}) + \delta_2 (X_{Fire\_Ban} \cdot S_{3\text{-}4.9ha\ farmers}) + 1(X_{Ban\_of\_burning} \cdot S_{5\ ha\ or\ larger\ farmers})\delta_3$$

Where β_{ASC} is the parameter for the alternative specific constant (ASC), which accounts for variations in choices that are not explained by the attributes or socio-economic variables. The vector of coefficients $\beta_{1...}$ β_K and δ_1 is attached to a vector of attributes (*X*) and farm size characteristics (S) that influence utility.

The WTP is calculated using Equation 9, whereby the policy attribute β_k is divided by the price attribute β_{tax}

Eq 9 $$WTP_k = -(\beta_k/\beta_{tax})$$

Given the presence of interactions between the 'ban on burning' parameter and farm-sizes of the respondents, we also adjust the WTP estimation to take into account this heterogeneity in the underlying sample. For example, using equation 10 WTP for a ban on burning amongst farmers with 5 hectares or

[16] Since social and economic characteristics are constant across choice occasions for any given respondent, they can only enter as interaction terms with the management attributes.

more land is calculated as follows:

Eq 10 $\text{WTP}_{\text{Ban\_on\_burning}} \geq 5\text{ ha} = -(\beta_4 + \delta_1/\beta_{tax})$

All models are estimated using STATA 13 software. The parametric models are specified so that the probability of selecting a particular management scenario is a function of the attributes of that scenario and of the alternative specific constant (ASC). The ASC variable is specified to equal 0 when either of the future policy and landscape management scenarios are chosen and 1 when the status quo option is chosen. Different model specifications including a basic conditional logit model (CLM) and CLM with socio-demographic and economic interactions (CLM-interactions) are presented in the following. The purpose of the latter model (Equation 6) was to understand differences in farmer's preferences towards the ban of residue burning and the value of protecting existing windbreaks. The results of the basic CLM are presented in the next section. The CLM with interactions is included in Appendix 3 (Table A3.1).

4.2.2 Basic conditional logit model

In the basic CLM model, windbreak protection and restoration and a legal ban of crop residue burning are significant factors in the choice of a future management scenario. All the attributes are significant at 99 % level of confidence, implying that the farmers understood very well the exercise. Signs are as expected and the overall fit of the model, as measured by the adjusted Pseodu ρ^2 of 0.27, is very good by conventional standards used to describe probabilistic discrete choice models (Louviere et al., 2000).

Table 5: Basic conditional logit model

Parameter	Estimate	Std Error	P>z	WTP/ WTA	WTA-WTP Confidence interval
Alternative specific constant	20.2	510.4	0.98	820.3	
Loss of remaining windbreaks	-0.25	0.10	***	-10.0	-17; -2
Moderate rehabilitation of windbreaks (20% to 50%)	0.89	0.08	***	36.1	28; 43
Large-scale rehab of windbreaks (50% to 100%)	1.49	0.09	***	60.3	52; 67
Ban of burning, farmers with less than 3 ha	0.57	0.06	***	23.2	12; 33
Ban of burning, farmers with 3 ha – 4.9 ha	0.93	0.18	***	60.7[A]	35; 86
Ban of burning, farmers with > 5 ha	0.4	0.17	***	39.2[A]	15; 63
Price	-0.024	0.001	***		

[A]Calculated as shown in equation 10.
***Denotes significance at 1% level. Obs=6912, LR=2096, Pseudo R2=0.27, Log likelihood=- −2840.3

4.2.3 Results - Benefits of protecting existing windbreaks

The choice experiment results reveal that the average farmer would experience a loss equal to GEL 10 per hectare (he cultivates) if remaining windbreaks would be lost. In theoretical terms, the farmer requires a compensation of GEL 10 per ha to be equally well off as without the windbreaks. The compensation demand does not vary between small and large farmers.

Interestingly, the model with the socio-demographic interactions (in Appendix 2), demonstrates that farmers that have some remaining windbreaks (28% of the sample) experience a higher loss, equivalent to 26 GEL per ha. When including this interaction in the estimation, compensation demand for those farmers without windbreaks is zero. This implies that windbreaks are essentially valued (by farmers) for their contribution to the individual farm's productivity and not so much for their broader societal amenity benefits.

It is worth noting that the most important policy attribute is the large-scale restoration of windbreaks. Considering that the current land registration fee (of GEL 87 per ha) is expensive to most farmers, it is remarkable that the average farmer reveal on an additional willing to pay of GEL 60 per ha for a large-scale restoration of windbreaks. It should be said however, that stated preference studies are sometimes subject to hypothetical biases, which inflate WTP estimates (Murphy et al., 2005). This is further discussed within the section on the limitations of this study (section 6.1.).

4.2.4 Results: Benefit of banning crop residue burning

Farmers that cultivate less than 5 hectares of land are WTP an average of GEL 41 GEL per ha[17] to ensure the implementation and enforcement of a policy that bans crop residue burning, while farmer with 5 hectares or more are WTP an additional GEL 39 GEL per ha in land registration fee[18].

With an effective prohibition of burning, farmers will be better protected from unpredictable fires that originate from neighbouring farms. If farmers unilaterally decide to stop burning, they cannot avoid the externalities imposed by other farmers burning. In that light, it is not surprising that farmers as a whole demonstrate significant WTP to enforce a ban on burning. Although it is individually rational for farmers to continue to burn if they ignore the fertility improving effects of retaining crop residue it is collectively rational to stop burning. It should also be mentioned that the theoretical underpinnings of the choice experiment ensure independent estimation of attributes, implying that farmers WTP for banning of burning does not include the perceived benefit of protecting remaining windbreaks. So, there is no double-counting when adding the benefits of protecting remaining hedges and banning crop residue burning

Finally, consistent with the choice experiment findings, Figure 13 shows that the overwhelming majority of valuation survey respondents think that residue burning should be banned.

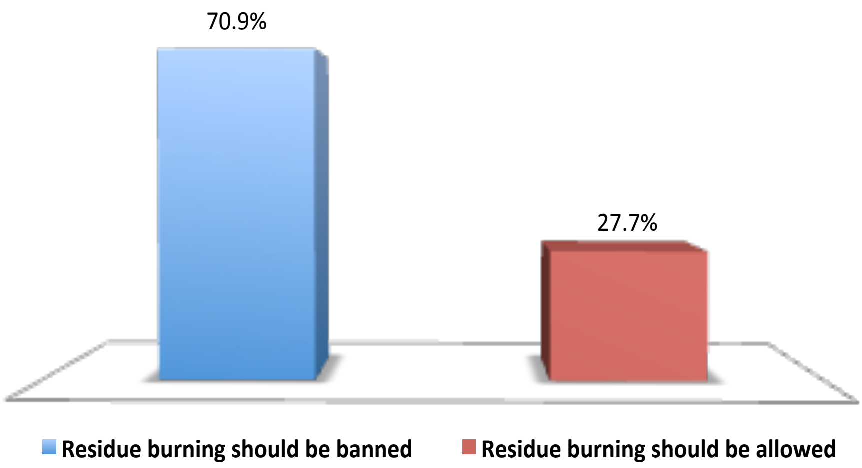


Figure 13: Farmers preferences regarding residue burning (n=300

[17]There is an additional statistically significant split in WTP, within the small farmer group – notably amongst farmer with less than 3 hectares and farmers with 3 to 5 hectare. We have averaged across these two groups to derive a WTP figure for farmers with less than 5 hectares.

4.2.5 Aggregate societal benefits from the choice experiment results

In estimating the benefits of banning burning and protecting remaining windbreaks to farmers over a 10-year time horizon, we use farmers' own elicited preferences on how much they would need to be compensated in the case of loss of existing windbreaks.

With regards to the protection of windbreaks, it was shown in section 3 that if business as usual continues, remaining windbreaks would be lost within less than 10 years. On the contrary, if a policy is enforced to ban residue burning, windbreaks are likely to remain within the time horizon of this study and beyond. Table 5 shows that farmers would need to be compensated (to be equally well off as today) if remaining windbreaks were to disappear. Thus, the benefit of implementing a law to ban burning is the avoided 'welfare loss' (negative of WTA compensation) associated with loosing windbreaks in the business as usual (BAU) scenario (Equation 8). The BAU scenario involves a continuous and incremental degradation of remaining windbreaks. Protecting them therefore requires an immediate policy response. The avoided loss to farmers is estimated as of year 4 (t=3), when more than 50% of remaining windbreaks risk being lost according to predicted wildfire hazards (see Table 2). The expected annual net benefit of preventing this loss is calculated as shown in Equation 11.

Eq 11 $$NPV_{protection\ of\ windbreaks} = \sum_{t=3}^{9} \frac{-\text{WTA per ha}_t}{(1+r)^t}$$

Where:
t=3, fourth year
WTA/ha=-10
r=4%

An effective ban of residue burning could be implemented almost immediately. The benefits from banning burning (Equation 11) are therefore estimated for almost the full accounting period (t=1 to t=9). The benefit of banning crop residue burning is calculated as shown in Equation 12. The aggregated benefits of banning crop residue burning and protecting remaining windbreaks are shown in Table 7.

Eq 12 $$NPV_{banning\ of\ burning} = -\sum_{t=1}^{9} \frac{\text{WTP per ha}_t}{(1+r)^t}$$

Where:
t=1, second year
r=4%

Table 6: WTP for a ban on burning for small and large farmers

Interaction variables	% of population	WTP	EANB per ha (GEL/year)	NPV per ha cultivated
Farmers with less than 5 ha	46%	41	38	306
Farmers with 5 hectare or more	54%	39	36	295

4.3 Benefits from enhanced yields from crop residue integration

In deciding not to burn, farmers have two choices as to what to do with the straw residues. Either they can collect and use or sell them; or they can be shredded during crop harvest using a combi-harvester[19] and

[19] Combined grain-harvesting and residue shredding machine

subsequently be integrated into the soil through use of a disc cultivator to allow for better incorporation of residues into the soil[20].

Crop growth simulations from Section 3.5.2 show that the termination of crop residue burning and the subsequent integration of residues into the soil will enhance cereal yields, benefiting farmers by increasing the amount of cereal crop they can sell at any given year.

As shown in Table 4 above, pronounced yield increases will manifest themselves three years after farmers stop burning. Yields can be expected to increase by 11% for farmers who otherwise burn occasionally; and by 23% on land that otherwise was burned annually. The actual expected impact on yields for small and large farmers, using data from the valuation survey are shown in Table 7.

Table 7: Soil enhancing benefits from left-over residues 3 years after burning stops

PRACTICE		BAU	IF BURNING STOPS	
Cereal yields		Average farmer	Farmers otherwise burning occasionally	Farmers otherwise burning every year
Farmers with less than 5 ha	t/ha	1.8	2.0	2.3
Farmers with 5 ha or more	t/ha	2.5	2.7	3.0

Whilst the yields will increase, the farmer will incur an additional cost associated with renting a combi-harvester as opposed to a traditional harvester. Combi-harvesters ensure that residues are shredded simultaneously with harvesting, allowing for easy integration of the residues into the soil.

Cost of machine rental		Traditional Harvester	Min – max	Combi harvester with residue integration	Min - max	Additional cost
Farmers with less than 5 ha	GEL/ha	70	40-125	110	50-130	40
Farmers with 5 ha or more	GEL/ha	70	30-120	100	50-120	30

As shown in Table 8 combi-harvesters are more expensive than traditional soviet harvesters. Furthermore, the valuation survey revealed that small farmers (<5 ha) pay on average GEL 10 more per hectare for the rental of a combi-harvester relative to large farmers (≥ than 5 ha). Since most farmers rent a tillage machine after harvest to prepare the soil for a new cropping season, the actual integration of residues into the soil does not represent an additional cost and neither additional time (and opportunity costs) to the farmer.

Table 8: Additional costs associated with shredding residues

4.3.1 Net-benefits associated with shredding and integrating residues

The benefits of yield increases to farmers are valued using farmgate market prices for wheat. Yield increases are not to be expected before year 3, whereas the additional costs of renting appropriate machinery are incurred as of the first year. The additional costs of integrating crop residues are subtracted from the additional revenue to derive the Net Present Value per hectare of integrating residues for small and large farmers using Equation 13.

Eq 13
$$NPV_{\text{crop residue integration}} = -C_0 - C_1 + \sum_{t=2}^{9} \frac{\Delta Y_t \times P_t - C_t}{(1+r)^t}$$

Where:

Ct is the additional cost in year t of renting a harvester that can chop residues simultaneously to harvesting

ΔYt is the additional yield in year t to farmers that stop burning and integrate residues instead (from t=2 to t=9)

[20] Farmers who burn crops also use a rotary cultivator after burning to prepare for the planting season (revealed in the valuation survey). So the rotary cultivator does not lead to increased costs for the farmer who decides not to burn.

Pt is farmgate market price of wheat 440 GEL/ton
r is the real interest rate of 4%

Since small and large farmers burn with different frequencies – some occasionally, others every year - the average per hectare NPV benefit of ending burning is furthermore calculated for the two farmer segments using Equation 14.

Eq 14 $$\text{NPV}_{\text{adjusted}} = \text{NPV}_{\text{annual}} * P_b + \text{NPV}_{\text{occasional}} P_{oc}$$

Where:
Pb is the proportion of farmers that burn residues annually and Poc is proportion of farmers that burn occasionally. For small farmers Pb=0.4 and Poc=0.6. For large farmers Pb=0.54 and Poc=0.46.

Table 9 demonstrates that there are significant net-benefits associated with retaining straw in the soil as opposed to burning it. Small farmers can expect a Net Present Value benefit of GEL 632 per ha, equivalent to an expected net annual benefit of GEL 78 per ha per year[21]. This implies that for every additional 1 GEL they invest in integrating straw residues, they can expect 3.7 GEL of benefits. The benefit cost ratio for large farmers is even greater (GEL 5.2 of benefits for every GEL 1 invested) since they face lower crop residue integration costs and higher yields.

Table 9: Benefits and costs to the farmer of integrating crop residues

		Unit	Small farmer (range)	Large farmer (range)
Wheat prices (2016)		GEL/ton	440	440
Occasional burning → no burn	Yield (from year 3)	t/ha/yr	0.2	0.3
	EANB	GEL/ha/year	52	60
Annual burning → no burn	Yield (from year 3)	t/ha/yr	0.4	0.6
	EANB	GEL/ha/year	117	145
Burning → No burn	**EANB**	**GEL/ha/year**	**78**	**105**
Adjusted according to the frequency of burning amongst small and large farmers	**Net Present Value**	**GEL/ha**	**632** (580-680)	**854** (815-893)
	BCR	**GEL/ha**	**3.7**	**5.2**

4.3.2 Marketable benefits from collecting and selling straw

Unprocessed crop residues or straw have productive uses for animal bedding or supplementary forage, but whether it makes sense for farmers to collect straw or not depends on the cost of collecting and storing straw and the price at which straw can be sold or would otherwise need to be bought.

The costs associated with collecting straw and compressing it into bales are also shown in Table 10. These include, per hectare rental costs of machinery and the opportunity cost of time that could be spent on other productive activities during the harvesting season. Machinery rental costs are significantly different for small and large farmers. Furthermore, small farmers face significantly lower farmgate market prices for straw bales. This can possibly be explained by absence of access to storage space and/or lower negotiation power.

It should also be highlighted that the farmgate price for straw is variable from year to year. In years with good rain and decent temperatures, crop, straw, hay and forage yields are high. Under these circumstances, straw becomes less valuable and the price at which it can sell is low. With an increasing incidence of dry-spells or uptake of straw residue integration, the supply of straw is likely to become more

[21] Also called the annuity value, equivalent to the present value the average annual additional income generated over the 10-year accounting period.

restricted in years to come. In 2015, straw prices were high right after the burning season because of the uncontrolled fires that made straw in low supply. Therefore, in evaluating the benefit of collecting and selling straw we used the 'lower range' of 2015 farm gate market straw prices, with a mean selling price of GEL 0.6 per bale for small farmers and GEL 1 per bale for large farmers (Table 10). These prices are consistent with those of previous years according to the Georgian GIZ field officer (Amiran Kodiashvili, personal communication 2016).

Given straw yields (Qt), straw prices and straw collection costs, we are able to calculate the per hectare net present value benefits of not burning and producing straw bales in Dedoplistskaro as shown in Equation 15.

Eq 15 $$\mathrm{NPV}_{straw} = \sum_{t=0}^{9} \frac{Q_t \times P_t - C_t}{(1+r)^t}$$

Where:

Qt is the quantity of straw that may be collected per hectare in year t

Ct is the per hectare cost of renting the straw collection and baling machine and compressing the bales in year t.

Pt is the farmgate price at which straw sells

r is the real interest rate of 4%

T=10 years (t=0 to t=9)

Table 10: Benefits of collecting and selling straw

Variable	Unit	Small farmers	Large farmers
Yield of straw per ha*	tons/ha	2.8	3.7
Effective collection of straw per ha**	tons/ha	1.9	2.8
Price per bale (2015 farm gate prices, lower range)	GEL/bale	0.6	1
Price per ton (27 approx. 80 bales in 1 ton)	GEL/ton	48	80
Machine rental cost associated with collecting and compressing bales	GEL/ha	100	80
Expected net annual benefit (EANB)	**GEL/ha**	**-5**	**147**
Net Present Value (NPV)	**GEL/ha**	**N/A**	**1196**
Benefit Cost Ratio (BCR)	**GEL/ha**	**0.9**	**2.4**

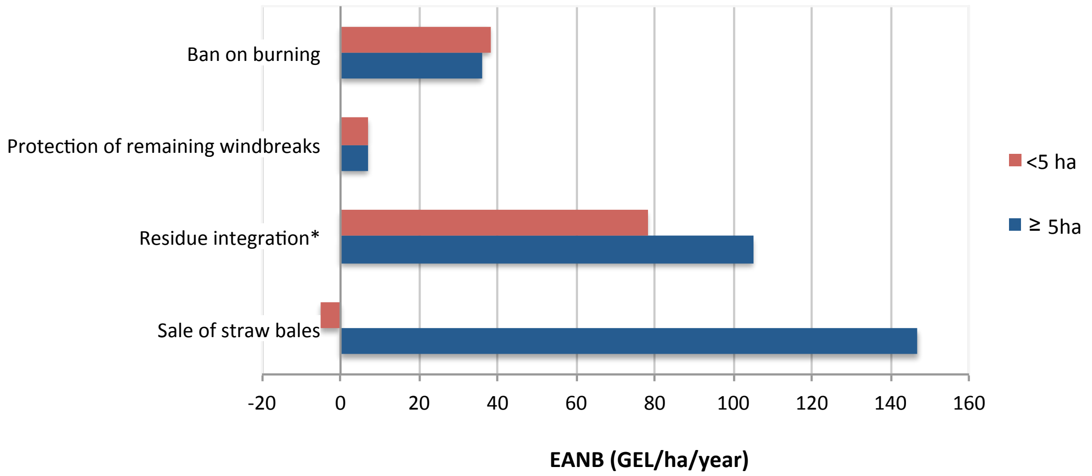
*We have used a conservative estimate of approximately 1.5 t of straw per 1 kg of wheat

**Approximately 70% of all straw can be collected.

As shown in Table 10, the expected net annual benefit of collecting and selling straw for the large farmer is in the order of GEL 147 per ha per year over 10 years using a 4% discount rate. Small farmers, however, face higher straw collection prices and lower yields relative to large farmers, which makes it uneconomical for them to collect and sell straw bales. The benefit cost ratio of 0.9 reveal that at current farmgate market prices and machine rental costs, the average small farmer would lose GEL 0.1 for every GEL spent. Of course, if small farmers were able to improve their agricultural yields and negotiate prices differently, they could earn positive net-benefits from straw collection and sale.

4.4 Farm level net-benefits

The expected annual net benefits per hectare from above valued ecosystem services and policy options analysed above are shown in Figure 14. The figure highlights that if a ban on burning were to be implemented, it would be most rational for small farmers to integrate all straw into to the soil. Large farmers could choose to do mixture of straw residue integration and straw collection to diversify income sources.



*Averaged for farmers burning yearly and occasionally

Figure 14: Expected annual net benefit per hectare of 'not burning' for small and large farmers

4.5 Societal level benefits and cost

4.5.1 Benefits of reduced greenhouse gas emissions

GHG emissions from wildfires generate a global externality, since the climate changes caused by them have worldwide economic and societal consequences. The benefits from reduced emissions associated with the prohibition of burning in Dedoplistskaro municipality are therefore not specific to Georgia, but rather global. The benefits of reduced emissions are valued using the Social Cost of Carbon (SCC).

The SCC is often used to evaluate regulatory policies affecting greenhouse gas emissions. The SCC estimates the discounted value of the damage associated with climate change impacts that would be avoided by reducing carbon dioxide (CO_2) emissions by one metric ton in a given year (Anthoff et al., 2009). SCC estimates are calculated using Integrated Assessment Models (IAMs) of climate and the economy, which estimate the damage resulting from greenhouse gas emissions over a period of 100 or 200 years or longer. The damages include decreased agricultural productivity, damage from rising sea levels and harm to human health.

There are a number of different Integrated Assessment Models. In these models, the SCC depends on expectations of future economic growth and ethical viewpoints about weighting welfare levels between different generations, amongst other issues. Moreover, the SCC is sensitive to the categories of monetary and non-monetary climate change effects that are being considered in IAMs, and to assumptions made about uncertainties and extreme scenarios of climate change (Montenegro et al., 2007). As a result, different Social Cost of Carbon estimates are found in the scientific literature. Some of the most known studies are shown in Table 11. In this report we employ one of the more conservative estimates (USD 37/ton[22]). This estimate is used by the US EPA (EPA 2015) and has been devised by the American interagency working group (White House, 2013). It combines the three most common IAM models (DICE, FUND and PAGE).

[22] Equivalent to 94 GEL in 2016. Calculated using an inflation factor of 1.15 (USD 2007 to USD 2016) and an exchange rate of 1 USD=2.2 GEL in 2016.

Table 11: Estimates of the social cost of carbon

Study	SCC per ton CO2
Nordhaus (2008)	$6(a)
Anthoff et al. (2011)	$8 (b)
Stern (2007)	$85 (a)
Hope (2013)	$106 (b)
Moore et al (2015)	$202 (b)
EPA (2015)	$37 (c)
Van den Bergh and Botzen (2014)	$125 (b)

a) 2000 dollars; b) 2010 dollars; c) 2007 dollars

On the basis of carbon balance estimates presented in section 3.4 we estimate the Present Value benefits of implementing a ban of burning using equation 13. The present value benefit represents the avoided global damage costs over 10 years (2017-2026). Using equation 16, these amounts to GEL 4.4 million.

Eq 16 $$\text{PV benefit of avoided emissions} = \sum_{t=0}^{9}\left[(CO_2e_{BAU_t} - CO_2e_{\text{ban on burning}_t}) * SCC_t \,/\, (1+r)^t\right]$$

Where:

CO_2e BAU = Tons of CO_2 equivalent emissions year by year in the BAU scenario

Where CO_2e policy = Tons of CO_2 equivalent emissions year by year in the ban-of burning scenario

r=4%, the real Georgian interest rate.

SCC= 94 GEL/t CO_2e eq[23] in the first year and gradually rising up to 116 GEL/t CO_2e in 2026.

Table 12: Avoided damage from the SCC (r=4%)

Year	**Tonnes of CO2 equivalent emissions from** deforestation of windbreaks and crop residue burning			**SCC GEL per CO_2eq** **1 USD=2.2 GEL**	**Total avoided damage cost SCC** **GEL**
	BAU	**Ban on burning**	**Difference**		
2017	8,706.4	870.6	5,222.9	94	855,740
2018	3,867.9	386.8	2,320.3	96	375,427
2019	6,024.1	602.4	3,613.8	99	577,025
2020	1,893.7	189.4	1,136.0	101	178,886
2021	10,480.1	1,048.0	6,286.9	104	975,706
2022	5,311.8	531.2	3,186.5	106	487,110
2023	3,237.9	323.8	1,942.4	109	292,303
2024	2,254.1	225.4	1,352.2	111	200,215
2025	3,018.6	301.9	1,810.9	114	263,670
2026	1,666.7	216.6	1,299.4	116	185,970
Total	46,461	4,646	28,171		**GEL 4,392,054**
EANB					**GEL 541,487**

[23] USD 37 in 2007 dollars amounts to GEL 94 in 2016. We have used the official inflation factor of 1.15 to convert USD 2007 to USD 2016 values. We subsequently applied the 2016 commercial exchange rate of 1 USD=2.2 GEL to convert USD to GEL.

4.5.2 Costs of implementing a policy to ban crop residue burning

There will be costs involved in implementing a law that prohibits burning of crop residues. At the very minimum, public authorities would need to finance awareness-raising campaigns including the distribution of leaflets, newsletters and broadcasting across radio and television networks. The Georgian Ministry of Environment has provided a detailed breakdown of expected expenses shown in Table 12 (Source: Weigel, 2016).

Within the first two years after the ban has been implemented, fire patrolling would also be necessary. Fire patrollers should also be given the legal mandate to fine arson and conduct forensic wildfire investigations. The costs of these services are estimated on the basis of GIZ's prior fire patrolling experience and shown in Table 13. Taken together, these awareness-raising and enforcement costs sum up to approximately GEL 95,000 in present value terms over the 10-year accounting period for Dedoplistskaro municipality alone.

Lastly, one could also foresee the possibility that these services are complemented with extension services to facilitate the farmer's ability to transition away from crop residue burning towards more sustainable land management practices. A minimal level of enforcement costs after the first two years is probably also advisable, especially during the harvesting season. Farmers themselves, however, claim that the openness of the valley makes it virtually impossible for any farmer to hide arson. Though this claim hold less true during night. In either way, a fair air degree of collective self-enforcement of the law is foreseeable in the case that most farmers understand and uphold an interesting in avoiding fires.

Accounting for these additional costs, the Maximum Present Value costs of implementing and enforcing the policy to ban crop residue burning amount to GEL 122,200 using Equation 17 and information in Table 13.

$$\text{Eq 17} \quad \text{PV Public Costs} = \sum_{t=0}^{9} [\text{Implementation and Enforcement Costs}/\ (1+r)^{t}]$$

Where:
r=4%

Table 13: Implementation and enforcement costs

Lower-bound implementation and enforcement costs for Dedoplistskaro		Year	Cost (GEL)
Awareness and information raising costs in the first year incurred by MoE	10,000 brochures	1	2,000
	Information desks and banners	1	2,000
	Logistics, including transportation of banners and all other materials	1	1,000
	Rent for the meeting spaces for two meetings per district	1	500
	Graphic informative clip for TV and other social media resources	1	6,000
	Newspaper with comprehensive information, to be released over several editions in the summer.	1	500
	SUB-TOTAL	1	12,000
Fire patrolling and fining	700 GEL/month/person for 6 months (May-October). Two patrols	1 – 2	8,400 per year
4x4 Vehicle	Suitable for off-road	1	48,000 (one-off)
Fire patrolling Fuel cost	Patrolling of 2000-3000 km per month (for 6 months)	1 – 2	9,000 per year
Lower bound discounted cost		**1-2**	**95,650 GEL**

Upper-bound implementation and enforcement costs		Year	Cost (GEL)
Extended fire patrolling	2 patrols for one month per year (700 GEL/year each)	3 - 10	1,400 per year
Fire patrolling fuel cost	Patrolling of 2000-3000 km per month (11 month)	3-10	1,000 per year
Extension services in SLM	Workshops and individual farm-level support. Two extension service provider 4 months per year (700 GEL/month)	1 - 3	5,600 per year
Sub-total discounted cost		1-10	26,310
Upper bound discounted cost			**122,200**

Table 14: Present value implementation and enforcement cost

Parameter	Present Value (GEL)
PV implementation and enforcement costs (min)	95,650
PV implementation and enforcement costs (max)	122,000
Maximum Expected Annual Net Cost (EANC)	15,040

4.6 Making alternative uses of Straw: Pellet producing facility

Straw pellets are widely used in daily life, for animal bedding, feed for animals, and fuel for heating for home and industry use. Turning raw straw or straw bales into pellets offer great opportunities for easily transporting and using pellets in households and industrial appliances. In its ‘unprocessed state’ one m^3 of raw straw weighs 50 kg. In contrast, pellets are very dense, offering 800 kg of straw material per m^3 (figure 15). In this light, it is of interest to analyse the scope for developing an economically viable straw pellet production facility in Dedoplistskaro.

Figure 15: Density of raw straw, straw bales and straw pellets

4.6.1 Straw for animal fodder

Straw is a low quality feedstuff, but it can be utilized as an alternative to hay if properly supplemented with minerals, vitamins, and grain (Rossi 2009; Hall 2009). In order to infer the potential value at which straw pellets for fodder can sell in Dedoplistskaro, we have compared the protein content of straw with that of hay - a major feed-source in Dedoplistskaro. This is because protein is a major determinant of feed prices (Rossi 2009), explaining for example the high prices on soybean (43% protein content), currently selling on international markets for 100 USD/t (Ragan 2016). Thus, on the basis of the protein content of straw and sale price of hay, we have inferred the possible selling price of straw pellets.

Table 15: Hypothetical price of straw on the basis of protein content

	Protein	Hay	Straw
Dry matter in 1 ton		900 kg	900 kg
Total digestible nutrients in 1 ton		550 kg	430 kg
Crude Protein in 1 ton		170 kg	36 kg
Price per bale (in 2015)		1.8 (1.3)	1.324
Price per ton (in 2015)		145 GEL/ton	104 GEL/ton
Inferred feed price on the basis of protein content in Hay (146 GEL/170 kg)	0.85 GEL/kg	145 GEL/kg [25]	30 GEL/ton

With a protein content of only 3.6%, it can be seen from Table 15, that the sale price of straw as a source of feed is not economically viable. Straw bales currently sell for more than their 'feed equivalent' content. Clearly, straw is valued for animal bedding or something else than fodder in Dedoplistskaro. There is no viable business model in converting straw into straw pellets for feedstock.

4.6.2 Using straw for fuel pellets

Straw pellets can be used as fuels burning in pellet boilers, pellet stoves and other pellet appliance in households. Straw pellets are also used in central power plants, co-firing with traditional fuels, such as coals, oil and others.

There is significant demand for fuelwood in the Dedoplistskaro district. According to Helbig (2016), the mean consumption of firewood is 9 m^3/household/year in Dedoplistskaro municipality, resulting in a total annual demand of 51,000 m^3/year in Dedoplistskaro. The majority of households spend between GEL 350 per year – and GEL 700 per year for firewood, which corresponds to 1-2 months of the average household income (GEL 350).

A lot of the fuelwood is illegally sourced and as restrictions on supply are enforced, the price of fuelwood might rise. But with a higher price premium, the incentive to continue unsustainable sourcing of fuelwood will persist. At the same time, it is the principal means for heating of households in Dedoplistskaro. In this context, it is relevant to analyse the case for substituting fuelwood with pellets from straw. Such a scenario, however, would require investments into a pellet producing facility and households would need to buy stoves suited for pellets, so as to maximize the benefits of pellet burning. Because of the fuel's consistency and the combustion mechanics of new pellet stoves, they burn more efficiently[26] and more cleanly than wood - giving off 80% less particulates relative to woodstoves, improving indoor climates[27]. Pellet burning stoves can also burn in normal fuelwood, but creates a lot of ash that way[28].

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[24] A price range of 0.9 GEL/ton and a higher price range of 1.6 GEL/ton (from GIZ valuation survey 2016)
[25] Weigh per bale (10-15 kg)
[26] Pellet stoves are very efficient -75 percent to 90 percent overall efficiency - and have a BTU output content four to five times higher than cord wood or wood chips. Pellet stoves can be vented through a small hole in the wall, rather than a whole chimney. www.hometips.com/buying-guides/pellet-stove-advantages.html
[27] http://www.treehugger.com/clean-technology/pellet-stoves-vs-wood-stoves-which-is-greener.html
[28] In order to help households finance the purchase of a pellet stove, intelligent arrangements can be made, whereby the pellet producing facility would sell stoves to households at discounted prices, zero-interest loans or in return for straw.

The following section focuses on analysing the economic feasibility of installing a large-scale fuel pellet production facility. Data sources and references underlying the analyses are found in Appendix 4. In undertaking a feasibility study, we have considered:

- **The demand side:** What is the annual demand for fuelwood in Dedoplistskaro district and at what price are consumers purchasing this fuel?
- **The supply side:** What is the magnitude of wheat and straw produced in the Shiraki valley and at what price are farmers currently selling straw?
- **The production side:** What is the capital and operating costs of the facility? At what price would fuel-pellets need to be sold for the production facility to be economically viable?

Demand side

The maximum current sale price of pellets on the basis of its energetic equivalent value is 109 GEL/t (Table 16). This was calculated using local fuelwood prices from Dedoplistskaro (RECC, 2016; Helbig, 2016) and secondary data on energy content of fuelwood and straw. Data sources underlying the analysis are shown in Appendix 6.

Table 16: Calculation of the energy equivalent value of a ton of straw pellets

Price (GEL) per m^3 fuelwood	Mega Jules (MJ) per m^3 fuelwood	Price per Mega Jules (GEL/ MJ)	MJ/ ton of straw	MJ equivalent value of ton of straw
63	9360	0.0067	16,200	GEL 109

Supply side

On the supply side, the estimated annual production of straw in Shiraki valley is 82,000 t.

In 2015, straw was sold for an average of between GEL 75 per ton (lower range price equivalent to GEL 0.9 per bale) and GEL 136 per ton (upper range equivalent to GEL 1.7 per bale). The prices were particularly high in 2015 because of low supply of straw.

If crop residue **burning continues to be allowed** and is coupled with an increasing prevalence dry-spells due to changing climates, the price of straw is likely to reach regular price hikes above 75 GEL/t.

For the financial feasibility analysis we have developed two scenarios. Under the **BAU scenario** we assume that there are price hikes from GEL 75 per ton to GEL 100 per ton one in three years (due to fires or droughts coupled with low supply of straw).

If residue **burning were to be prohibited**, straw will be in more abundant supply. In this case, input prices of GEL 70 per ton is likely to be guaranteed in most years. We have therefore assumed a price hike of 100 GEL/ha only one in five years.

In both scenarios, it is assumed that the sales price for straw pellets increase from GEL 80 per ton to GEL 110 per ton within four years after start of operations.

In the BAU scenario we assume that the that the facility operates at 70% capacity utilization (37600 t/year) and at 80% (43700 t/year) in the 'ban on burning' scenario, because there is a greater likelihood of a stable supply of straw if burning is prohibited.

Assuming average annual wheat yields of 2 tons per hectare, the Shiraki valley produces an estimated 80,000 tons of straw per year. Ensuring a steady supply of straw for the facility throughout the year would require good storage facilities. These assumptions are outlined in table 17.

Table 17: Assumptions underlying the cash-flow analysis

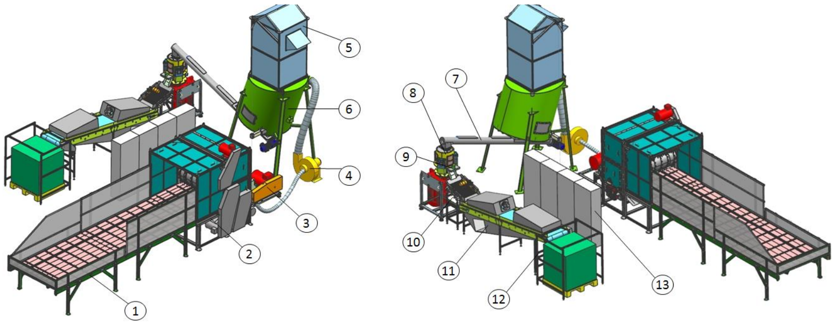
	Low price (GEL/ton)	High Price (GEL/ton)	Frequency of price hikes	Tonnes of straw processed per year	Capacity utilisation of the pellet machine
BAU	75	100	1 year out of 3	37600	70%
Prohibition of burning	70	100	1 year out of 4	43700	80%

Production side

The costs of installing a facility that match the straw that can be supplied in Dedoplistskaro have been sourced from a detailed offer from a reliable German company, MÜNCH Edelstahl GmbH[29]. The straw pelleting production line includes:

1. The straw pelleting line includes Material receiving, bale shredding
2. Milling, intermediate storing
3. Humidity regulation, pelletizing, cooling, screening
4. Bagging, storing
5. Control system, electrical equipment, automation

Figure 16: Components of pellet production facility



1. Input conveyor
2. Separator
3. Grinder
4. Fan for air transporter
5. Dust filtration
6. Buffer silo
7. Dispensing equipment to press
8. Press
9. Vapor and dust extraction fan
10. Separating vibratory conveyor
11. Cooling conveyor
12. Holder for big-bag
13. Main electrical panel
Control panel

Figure 16 provides a more detailed breakdown of all the components that are part of a pellet production facility. The total cost of these production elements, including the building of a storage facility and the purchase of a vehicle, amounts to 3.6 million GEL as shown in Appendix 8 featuring the cash flow. The lifetime of the machinery is more than 20 years if well maintained. We have assumed an 20-year lifetime of the machine, although according to an interview with the CEO of MÜNCH (the supplier of the machinery), the lifetime of the machine could be much longer if well maintained. As it was not possible to obtain estimates of maintenance costs, these have not been integrated in the cash-flow analysis and as a

[29] MUNCH webpage: http://www.muench-edelstahl-gmbh.de/index.html

consequence we have maintained a hypothesis of a 20-year lifetime of the machinery. The machinery has a total production capacity of 7.5 tons per hour, or 52,000 t of pellets per year assuming it is in operation 80% of the time.

4.6.3 Results

Under the BAU scenario, where use of fire is allowed, investing in the pellet producing facility would be risky. With an insecure supply of straw at varying prices, the business would only just make break-even. According, to the feasibility and assuming an interest rate of 4% and over 20 year timeline the BCR is 1.02 and the NPV is GEL 800,000. The internal rate of return is 7%.

In case that the burning of straw is prohibited, input prices are likely to be more stable. In this case, a net present value benefit of GEL 6.4 million can be realized if straw pellets are sold approximately 35% above the price at which straw is bought from the farmer. If there would be regular and consistent demand for straw, it is likely that prices lower than GEL 70 per ton of straw can be negotiated with farmers, especially amongst the larger once which have lower straw collection costs and higher yields, relative to the small farmers.

In that case the profitability of the pellet producing enterprise could be higher. The present value outflows and inflows for the two scenarios are demonstrated in Figure 17 and 18.

Table 18: Main results from financial feasibility analysis of the pellet producing facility(r=4%, t=20 years)

	Reliable supply of straw (when burning is banned)	Unpredictable supply of Straw (BAU)
Net Present Value	GEL 6,400,000	GEL 800,000
BCR	1.11	1.0
IRR	17%	7%

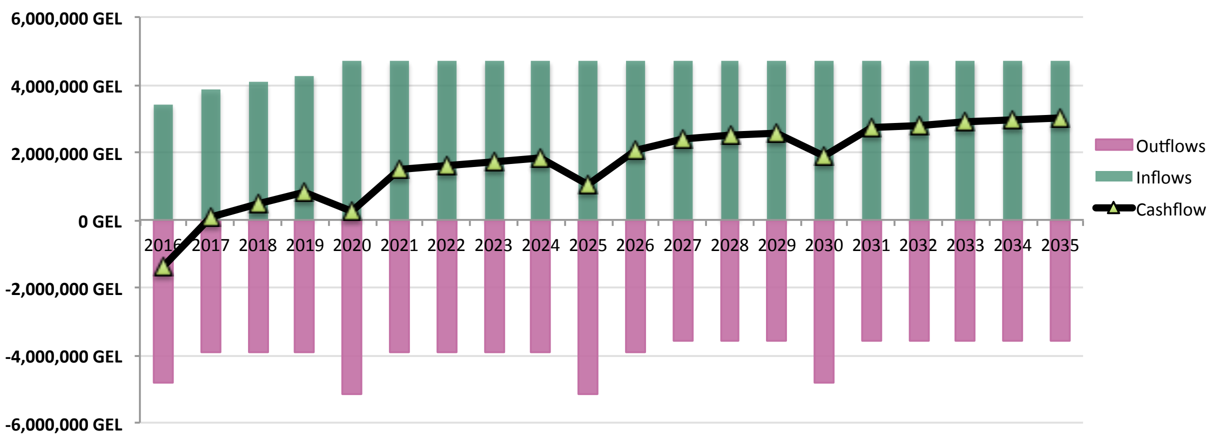


Figure 17: Cash-flow of pellet producing machine under 'ban on burning'

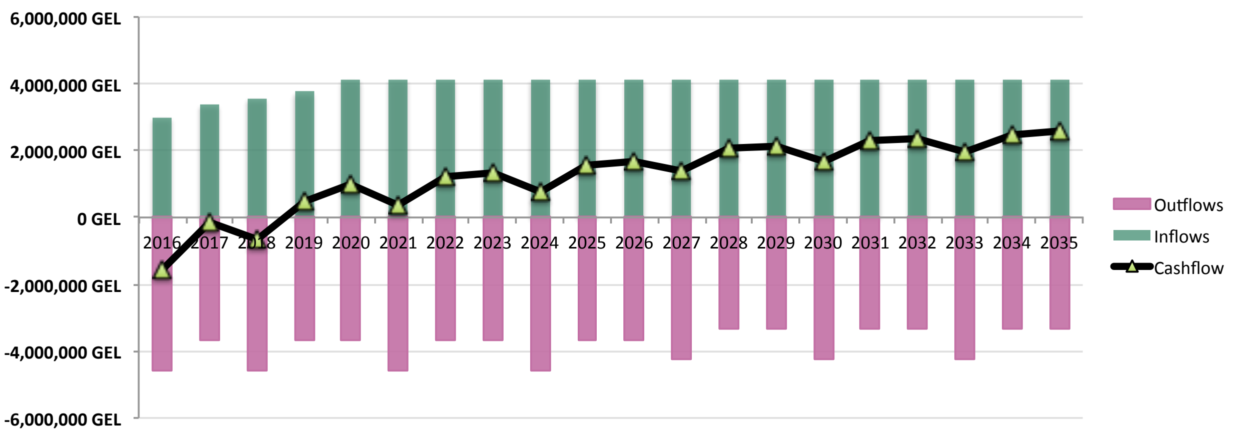


Figure 18: Cash-flow of pellet producing facility under 'BAU'

5. Aggregate cost benefit results

5.1 Assumptions and land use context

This chapter draws together all of the results presented in previous chapters to understand the overall societal and farm-level impact of ending crop residue burning. In order to do so, we first consider the share of the land within Shiraki valley that is cultivated by large and small farmers. Using the results from the valuation survey, we find that the 141 small farmers cultivate a total of 367 hectares. In contrast the large farmers cultivate 4,509 hectares in total (excluding one farmer with 2,500 hectares of land who is not representative for the general large farmer population). From this data, it may be deduced that approximately large farmers cultivate 92% of the 20,000 hectares of cropland dedicated to cereal crops. We have confidence in this estimate since the share of large and small farmers (at 5 ha split) within our survey is consistent with official statistics from the Dedoplistskaro municipality.

Table 19 : Proportion of land cultivated by small and large farmers in the Dedoplistskaro district.

Typology	Farmers with	Number of farms	Total farmland area	Proportion of farmland
Small farmers	Less than 5 ha	141	367	**8%**
Large farmers	5 ha and more	149	4,509[30]	**92%**

Secondly, we have estimated the net-benefits and benefit cost ratios for small and large farmers (table 20a and table 20b) in Dedoplistskaro under the ban the **ban on burning scenario**, relative to a simple continuation of BAU. .In doing so, we have assumed that burning in the farming sector is prohibited by law and that the law is effectively implemented and enforced. The resulting benefits include the protection of remaining windbreaks, avoided damages from carbon emissions, welfare benefits from a comprehensive ban on burning, enhanced yields from crop residue integration and marketable benefits from selling straw, minus the costs of doing so to farmers and the costs to public authorities from enforcing the law. Given the relative proportion of land cultivated by small and large farmers (from table 19) per hectare estimates are scaled to Dedoplistskaro municipality in Table 21, for a 10-year period using the Georgian real discount rate of 4%.

5.2 Results

Table 20a and 20b shows the impact of a ban on burning on respectively small and large farmers. As can be seen, under current machine rental prices, it is significantly more advantageous for small farmers to shred and integrate straw[31] during harvest using combi-harvesters (NPV of GEL 630 per ha) compared to collecting, using and selling straw bales (NPV of GEL -40 per ha)

It is thus rational for small farmers to integrate straw in the soil provided they are aware of the long-term benefits of doing so. For large farmers, the collection and sale of straw is highly worthwhile. However, if all large farmers would collect straw bales this would likely put a downward pressure on prices. Moreover, the price of straw bales varies according to supply and

[30] This figure excludes one large farmer with 2,500 hectares of land. There are a total of 4,820 farmers in Dedoplistskaro municipality, amongst which there are 3 very large farmers as known to the GIZ project with 2,500 ha of land. Since one of these three farmers, is represented in the sample of with only 300 households, we believe there is reason to think that this super-large farmer type is overrepresented within the sample. In order for our sample to be representative of super-large farmers in the valley, there would need to be 4820/300 = 16 of them in the valley. That is not realistic, since they alone would be cultivating near 34,000 ha of land. Hence, in calculating the proportion of land cultivated by respective small and large farmers, we have excluded one very large farmer.

[31] When straw has been shredded it can easily be integrated into the soil when ploughing the soil.

demand conditions inducing a risk to farmers. To mitigate this, it is worthwhile for large farmers to also integrate the residues in the soil, so as to reap the ecosystem service benefits of enhanced soil fertility and soil moisture.

By integrating straw in the soil, **large farmers** may expect an additional GEL 5.2 in revenues, for every GEL 1 spent on required farm machinery (notably, combi harvesters). **Small farmers**, my earn an additional GEL 3.7 for every additional 1 GEL spent (table 20a)

When accounting for the welfare benefit of ensuring a legally enforced ban of burning, the benefits to farmers and society alike are even more pronounced. The stated preference results from the choice experiment exercise shows that farmers would be willing to pay a higher land registration fee to ensure that burning is effectively prohibited. Over a 10-year period, the NPV amount to approximately GEL 300 per hectare, for both small and large farmers. This implies that farmers overall have a preference for using cohesion to enforce an ending of crop residue burning, as opposed to leaving it up to farmers own voluntary decisions. Voluntary action does not protect the individual farmer against the negative externalities associated with neighboring farmers burning their fields. As mentioned in section 6.1 however, there is reason to interpret Willingness to Pay results, for such policy-oriented questions with some caution.

The choice experiment also revealed that farmers would also suffer a welfare loss with the disappearance of remaining windbreaks. The NPV welfare benefit of protecting remaining windbreaks over the 10-year period is GEL 56 per hectare for both large and small farmers.

Accounting for the benefits of integrating straw and selling in addition to farmers' own stated preferences for a ban on burning and the avoided destruction of remaining windbreaks - the total NPV benefits to small farmers in the Dedoplistskaro district is GEL 0.8 million and between GEL 16 and GEL 17.5 million for large farmers over a 10-year period. Overall, small farmers can expect GEL 5 of benefits for every GEL 1 they spend and large farmers, while large farmers can expect between GEL 3 and GEL 7 of benefits for every GEL 1 they spend, depending on what they do with the straw residues. It is reasonable to expect that large farmers will eventually do a mixture of residue integration and straw collection to minimize risks.

In that case, the Net Present Value benefit of implementing a ban on burning in the Dedoplistskaro distrist, amount to GEL 16.8 million for the Georgian society over a 10-year period. It is assumed that law enforcement costs of GEL 120'000 are borne by Georgian authorities. Accounting furthermore for the benefits of enhanced carbon sequestration, global net-benefits are in the order of GEL 21 million.

Table 20a: EANB (GEL), NPV (GEL) and Benefit-Cost Ratios (BCR) for small farmers under a ban on burning scenario (T=10 years, r=4%, cereal cultivation=20,000 ha, land burned=10,000 ha).

Small farmers	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	489600	N/A*
Protection of remaining hedges	6.8	56	89600	N/A*
Aggregate net-benefits				
Burning banned and all residues are integrated in the soil	**123**	**994**	**1.1 million**	**5.2**

**Assuming that government authorities bear the costs of enforcing a ban on burning, there is no cost involved for farmers.

Table 20b: EANB (GEL), NPV (GEL) and Benefit-Cost Ratios (BCR) for large farmers under a ban on burning scenario (T=10 years, r=4%, cereal cultivation=20,000 ha, land burned=10,000 ha)

Large farmers	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	1196	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**	**1206**	**15.8 million**	**6.9**
Burning banned and all straw collected and sold	**190**	**1547**	**17.4 million**	**2.9**

*Averaged across farmers that burn residue on an occasional and a yearly basis.
**Assuming that government authorities bear the costs of enforcing a ban on burning, there is no cost involved for farmers.

Table 21: Societal estimates for EANB (GEL), ENAC (GEL), NPV (GEL) and Benefit-Cost Ratios (BCR) for farmers, the Georgian and global society. (T=10 years, r=4%, cereal cultivation=20,000 ha, land burned=10,000 ha)

Global benefits	EANB district-wide		NPV district-wide	
Avoided damages from enhanced carbon sequestration	541,500		4,390,000	
Cost to public authorities	**ENAC district-wide**		**NPV cost district-wide**	
Enforcement and Implementation Costs	15,050		122,000	
Aggregate societal net-benefits	**EANB/ha**	**NPV/ha**	**NPV district wide**	**BCR**
Farmers as a whole	**166**	**1343**	**16.9 million**	**3.8**
Georgian society			**16.8 million**	**4.4**
Global society, including carbon sequestration			**21.2 million**	**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 integrating the other half,,

5.3 District-wide present value benefits and costs from ban on burning

In figure 20, shows **aggregate** present value benefits and costs for all farmers, associated with a ban on burning in the Dedoplistskaro district over a 10-year accounting period with a 4% discount rate. As can be seen, the benefits associated with integrating residues (GEL 9.2 million) in the soil and collecting and selling straw bales (GEL 5.5 million) are significantly larger than the present value costs associated with doing so (between GEL 1.1 and 3.7 million)

There are not many windbreaks left in Dedoplistskaro. Remaining windbreaks protect only some 5% of farmland (derived on the basis of farmer's own estimates, Table A4.4 Appendix 4). With few windbreaks left to protect, the present value benefit of protecting these is rather low, equivalent to a present value benefit of GEL 1.1 million. Finally, the legal enforcement and implementation costs (GEL 0.1 million) are minimal compared to the benefits generated to the farming population from invigorating a 'ban on burning' (GEL 16.9 million) and avoided carbon emissions (GEL 4.4 million)

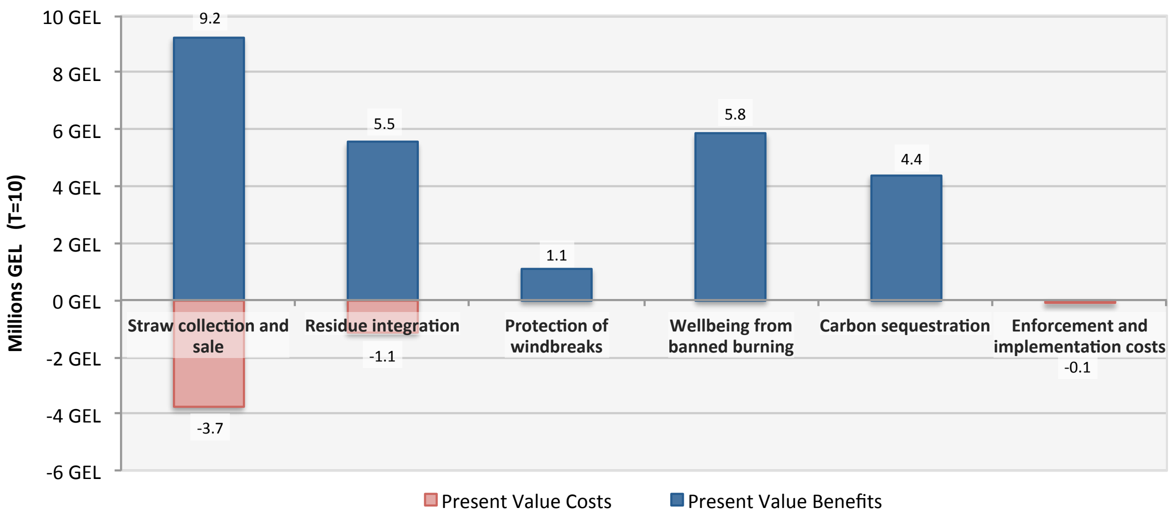


Figure 20: Aggregate PV benefit and PV costs in million GEL from a legally enforced ban of crop residue burning (r=4%)

6 Discussion

The results presented in table 20a and table 20b lend themselves to the conclusion that crop residues should be used productively and integrated into the soil, as cash-constrained farmers can earn a good return on every Georgian Lari invested in crop retention. However, if crop residue burning was to be prohibited by law and effectively implemented, the final strategy adopted by farmers would most likely be a mixture of crop residue integration into the soil and collection of straw. If farmers realise that significant benefits can be made by integrating residue into the ground, at little additional cost, most farmers will choose that strategy. As that happens and supply of straw is reduced, the farmgate market price for straw will increase and more farmers may decide to collect straw as opposed to integrate it. Thus, over time, and provided perfect knowledge amongst farmers regarding the benefits of integrating residues, it can be expected that the net-benefits from either of these strategies will converge. This will of course also depend on the evolution of the livestock sector in Dedoplistskaro and the potential demand for straw from other industries, e.g. for pellet production.

One may also question why do farmers not voluntary decide to integrate residues, or sell the straw, if the outcome of doing so is as beneficial as our results demonstrate? Aside from prevailing misperceptions about fires controlling pests and fires being good for the ground, there is a crucial issue of timing and acess to capital that intervenes. At the moment when farmers harvest, their financial resources are scarce because they have not yet sold their crop harvests. It is therefore difficult for a small, cash constrained farmer to legitimize the additional costs associated with hiring a combi-harvester and in particular a machine to collect and compress straw into straw bales. This obstacle could be overcome, if rural financial markets were well established or if there were effective cooperatives that could pool resources for the purchase of farm machinery.

Additionally, there is significant scope for improving farmers' knowledge about sustainable land management practices. Mono-cropping and zero-rotation is common amongst farmers. Cultivating the same crops year after year results in a higher prevalence of pests and diseases and rapid spread where a uniform crop is susceptible to a pathogen. Mono-cropping also adversely affects overall soil fertility. Thus, other measures – in addition to prohibiting burning - including integrated pest management, conservation or no-tillage and frequent crop rotations may be adopted to improve soil fertility levels.

Indeed, lack of extension services and in particular information about the long-term negative repercussions on farm systems from burning is hindering progress on uptake of SLM approaches in Georgia. Furthermore, many farmers do not have long-term tenure security to their land, as they are renting from other farmers. This reduces their incentives to invest into soil fertility over the long term.

Despite these challenges, the valuation survey in Dedoplistskaro has revealed that the fires of 2015 have created understanding and urgency around the dangers of fires, especially with regards to their impacts of windbreaks. It is an opportune moment for Georgian society to create further awareness around about risks of burning (whether to clear land for weeds or residues), as well as the impacts of burning and the economic benefits that straw can bring!

6.1 Limitations of the study

The stated preference results assessed in section 4 should be interpreted with some caution. The potential presence of hypothetical bias, is known to lead to overstatements of true WTP in stated preference methods, and will potentially lead to the overestimation of welfare measures for the specific scenarios (Harrison, G.W., Rutström, E.E., 2008). There are different sources of hypothetical bias, but considering the relatively high WTP estimates for a ban on burning in this study, it is possible that the estimate is a reflection of farmers interest in influencing political outcome (i.e. strategic bias), as opposed to their true Willingess to Pay for a ban on burning. Meta-analysis conducted by List and Gallet (2001) and by Murphy et al., (2005) suggests that mean hypothetical values can be about 2 to 3 times greater than actual cash payments. In this study, we have no proof of whether political or strategic bias has been a source of inflated willingness to pay for a ban on burning. Independently of that, the net-benefits of integrating crop residues and collecting and selling straw (aggregate NPV of GEL 10 million from table 20a and 20b) provides a safe lower bound estimate of the benefits of banning burning to farmers.

But these results should nevertheless be treated as lower bound estimates of the true benefits of prohibiting fires. We have not valued the additional benefits, accruing to:

- health benefits from improved air quality;
- the protection of biological pest control functions that windbreaks offer;
- the likely reduced fire suppression costs to public authorities;
- and the enhanced protection of perennial farm systems such as vineyards.

These benefits are likely to be significant. Furthermore, there are uncertainties regarding how some of the parameters used in the analysis will evolve in the future, for example the prices for straw. We have therefore used conservative estimates where possible, so as to produce lower bound benefit estimates.

7 Conclusion

Crop residue burning has proven to be an inexpensive and convenient way of managing excess straw. But the significant energy embedded in straw can profitably be exploited for fuel instead of going up in smoke. Alternatively, if left in the ground, crop residue can provide a protective layer for soil erosion by wind or water, can increase the organic matter and water holding capacity of the soil, and can provide 'feed and forage' for earth worms. When crop residue is burned all of those benefits are lost, and other damages, e.g. to perennial farm systems and windbreaks are done. Moreover, without residue on the soil surface, the ground is now susceptible to erosion and organic matter is depleted (Fasching, 2001). Thus, although there may be some short-term cost savings to crop residue burning there is a slow, steady and sure reduction in soil health including microbial activity, carbon and nitrogen pools and moisture content, that will eventually result in reductions in productivity that cannot be overcome with increased additions of mineral fertilizers.

The agronomic and economic results from this study confirm these findings and clearly demonstrate that there are multiple long-term economic and social benefits associated with ending crop residue burning once-and-for-all within the Dedoplistskaro district. Moreover, the farming population itself demonstrates significant welfare benefits from and preferences for a ban of burning. Because fires easily spread across fields, their impacts cannot be effectively mitigated if farmers unilaterally decide not to burn. It is a collective action problem that has to be dealt with by leveraging effective institutional powers.

Finally, in the context of an increasingly imminent climate crisis there are reasons to prioritize changes to how we manage land. The agricultural sector is characterized by a large technical carbon mitigation potential, offering comparably more cost effective mitigation options than other sectors of the economy (FAO 2013). When adequately targeted, GHG mitigation in agriculture is closely linked to benefits for climate change adaptation and food security (as shown above). 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.

Appendix 1 – Remote sensing of fires[32]

The objective of the analysis of fires in the Dedoplistskaro valley were two fold, 1) to characterize in time and space the fire regimes in the Shiraki valley and Dedoplistskaro municipality over the last 16 years, and 2) provide monthly and yearly estimates of cropland (agricultural land) area burnt for input into the future projections of fires to support the economic valuation study. In the following we present the main figures from the analysis as well as information about where the data came from and how it was generated.

Agricultural fire intensity and extent within the Dedoplistskaro district 2000 to 2015

Figure A1.1 shows the number of times a given pixel-area within the Dedoplistskaro district has burned over from 2016. The zone in which there is fire activity is aligned with the boundaries of the Shiraki valley. Most places within this zone has burned 2-3 times over the past 16 years, but there are some hotspots that have burned up to 8 times over the last 16 years.

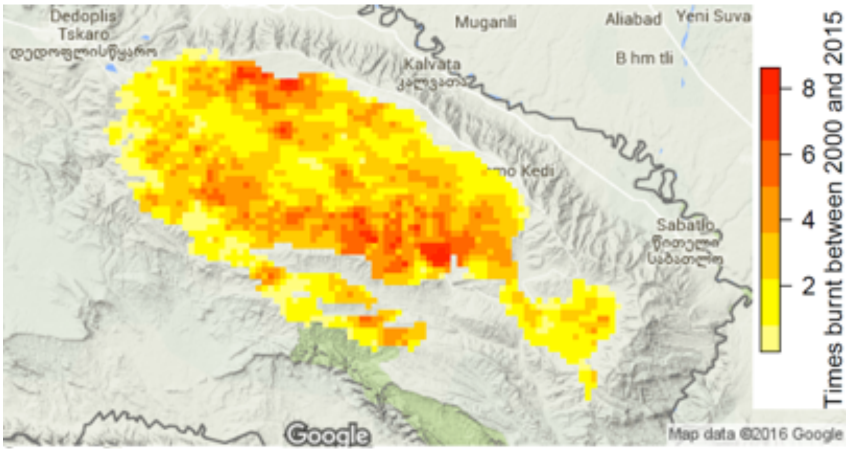


Figure A1.1 Fire intensity within the Dedoplistskaro district between 2000 to 2015

Figure A1.2 shows the average number of hectares burned per month between January and December for the last 16 years, the standard deviation and the 95% confidence interval for the mean[33]. Fire activity begins in May, but end of July, early August is the time where fire activity peaks with an average of 3,000 ha burned per year.

[32] The data and figures provided in this section have been elaborated by Luis Costa, an Altus Impact associate.
[33] There is a 95% certainty that the true population mean (burned area) lies within the indicated light grey zone.

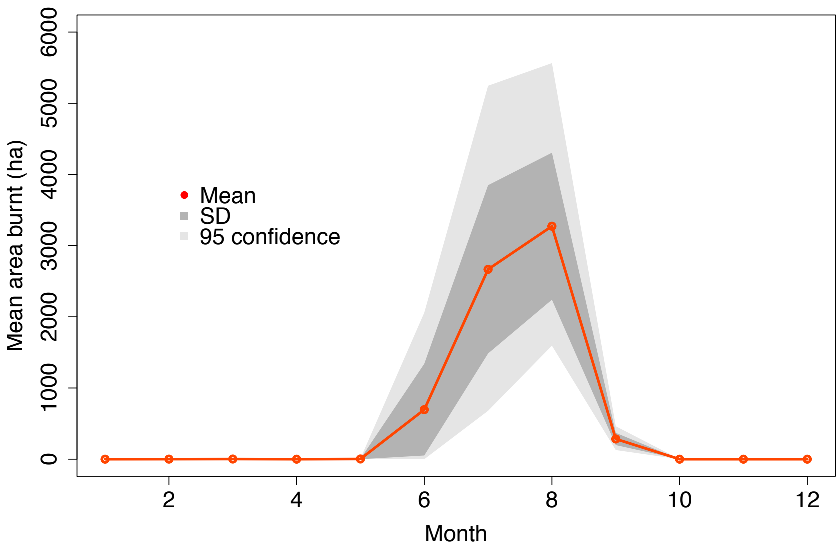


Figure A1.2 Bootstrapped distribution of average area burned by calendar month within the Shiraki valley (average over 2002-2015)

Figure A1.3 shows the share of grassland burned vis-à-vis cropland for the year of 2002 to 2014. In general, burning of cropland represents a larger share (from 50 to 80%) of fires recorded by MODIS relative to grassland (from 10 to 40%) in any one year.

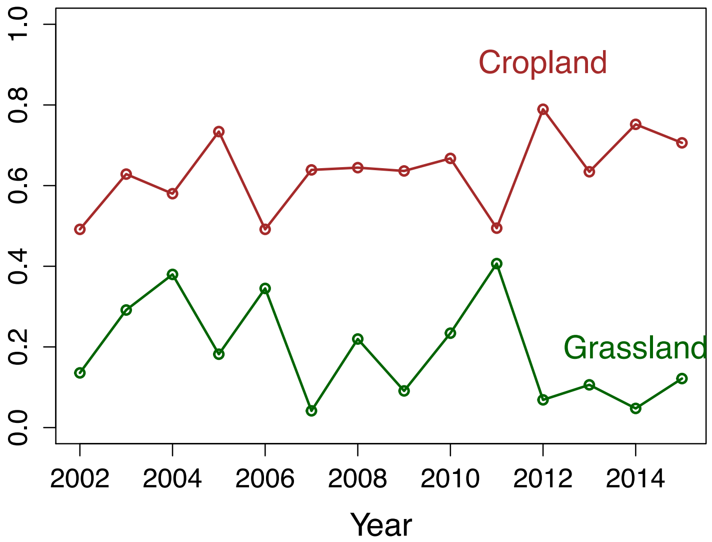


Figure A1.3 Fraction of total burned area by land use category by year

Figure A1.4 shows the total area burned in Dedoplistskaro municipality as a whole and for the Shiraki valley between 2002 to 2014. The figure shows that fire in the Shiraki valley account for the vast majority of fire activity in Dedoplistskaro municipality. This is in accordance with the previous figure, showing that the majority of fires recorded are on cropland.

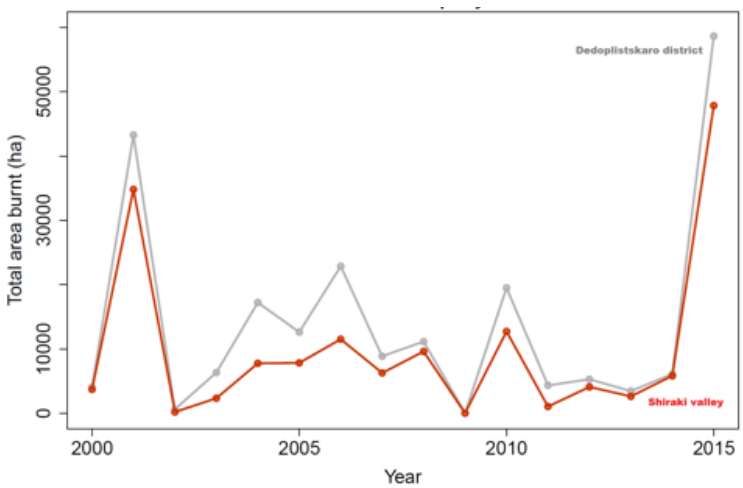


Figure A1.4 Total area burned in Shiraki and Dedoplistskaro per year

Background on data and methods used for the analysis of fires

The above shown fire analysis for the Shiraki valley and Dedoplistskaro municipality was conducted using the datasets summarized in Table A1.1 as the main inputs.

Unless noted otherwise, all spatial analysis was conducted with the R free software[34] environment for statistical computing. The first step of the analysis consisted in extracting the information from both MODIS products for the regions of interest. Accordingly, the geographic delimitation of the Dedoplistskaro district and the Shiraki valley was overlaid with the raster's containing information of area burnt and land-cover, this was done for all the time series that were available (2000 – 2015). The end result of this process is two time series of raster data for each investigated location. The time series of area burnt is composed by a total of 192 raster files, each representing one month (16 years x 12 months), and containing the dates of burning. The time-series of land cover is composed by 12 raster files (2001-2013), each containing the land-cover classification for the respective year.

Table A1.1 - Overview of the input data used for the fire analysis in the Dedoplistskaro district and Shiraki valley

Information	Time frame	Type	Spatial resolution	Time resolution	Source
Delimitation of the Dedoplistskaro district	Present	Shapefile	-	-	Global Administrative Areas v2.5[35] retrieved in February 2016
Delimitation of the Shiraki valley	Present	Shapefile	-	-	Klein 2015, Satellite based fire-monitoring of 2015's burned area in Shiraki, Georgia, GIZ Report
Land cover (classes)	2001-2013	Raster	500m	Yearly	MODIS product MCD12Q1[36] retrieved in February 2016
Burnt area (date of burning per pixel)	2000-2015	Raster	500m	Monthly	MODIS product MCD45A1[37] February 2016

[34] https://www.r-project.org/
[35] http://www.gadm.org/
[36] https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd12q1
[37] https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd45a1

Area burnt estimates are obtained by summing all pixels identified as “burnt” in the raster time series according to the respective day of burning. For example, all pixels coded with 1 (one) in the time series are summed up in order to obtain the total are burnt (over the 16 years of data) for the first of January. The process is repeated for all days of the year, 1-365. Fires occurring in leap-days (February) are ignored. The monthly and yearly estimates of area burnt are simply obtained by corresponding aggregation of the daily results previously described. So far these results refer to the total area burnt in the two regions analysed. In order to distinguish fires taking place in cropland from others taking place elsewhere (see Objective 2), the raster depicting area burnt were overlaid with the raster files containing information on land-cover. Given the differences in time resolutions (monthly vs. annual) of the data sets the following assumption was made: area burnt as cropland in year *x* is determined using the land-cover information of year x-1. E.g., we assess the area burnt of cropland in the year 2001 using the land-cover information of the year 2000. This is done to establish a time buffer for the vegetation to re-establish itself from the fire season taking place the previous year.

Finally, a fire density map is also produced for the Dedoplistskaro district and the Shiraki valley. The map was obtained by counting how many times the same pixel was identified as burned in the MODIS dataset between 2000 and 2015.

Appendix 2: ELD Georgia pre-valuation and post-valuation workshop outcome document

The following document summarises the outcome of national and local workshops that were held in the lead-up to and during the finalisation of the ELD valuation study in Georgia. The first two workshops were crucial to defining the direction of the study the ecosystem services to be valued and issued that merited special attention. The final workshops served to provide critical feedback and validation of the results of the study.

ELD Georgia re-valuation workshop outcome

In the lead up to the economic valuation assessing the case for banning crop residue burning in Georgia, two workshops were conducted at the end January 2016. One at the national level, in Tbilisi, where stakeholders from Ministry of Environment, ministry of agriculture, the Academy of Sciences and representatives of farmers and shepherds associations, were represented and another one, in the Dedoplistskaro municipality, where farmers, herders and decision makers from the municipality and the local parliament were present. A summary of the main outcomes of relevance to the valuation study is provided in the following.

Pre-valuation workshop at the National Level, Tbilisi, 25th of January 2016

The three main themes that were discussed in the workshop, concerned the main impacts of wildfires, why farmers engage in crop residue burning and what can be done at the national and local level to incentivize a change away from current land use practices.

In terms of the most negative impacts of wildfires escaping the from the fields where the fire was lit, most workshop participants pointed towards the devastating financial implications, including the burning down of perennial systems such as vineyards and fire-windbreaks and unharvested wheat from adjacent farmland. One participant claimed that of thousands of unharvested wheat were burned last year in Dedoplistskaro. A representative from the National Forest Agency also highlighted the grave consequences of fires escaping into forests and protected areas - destroying areas of cultural and recreational importance and undermining progress on implementing international environmental conventions.

There were different views about why farmers choose to burn their residues, as oppose to integrating them into the soil and/or collecting the residues. The dominant view was that farmers do it simply because they have no other options and cannot afford to shred or integrate, collect and compress residues. Amongst participants from the Ministry of Agriculture there was a concern or a belief that farmers are not be ready to stop crop residue burning. Some participants also claimed that farmers perceive burning as being good for the soil.

There was general consensus amongst all workshop participants that farmers lack an understanding of the long-term implications of their practices on-site (their farm) and off-site. It was thus acknowledged that any policy on crop residue management has to be accompanied with education and training of farmers.

Most important of all, workshop participants were preoccupied with the need for alternative uses of crop residues to be available to farmers. One participant from the MoA stated: *If we prohibit the burning of residues we need to offer farmers something in the way of compensation… We can say that fire damages fertile soil but what can we do to stop these processes if there is no alternative to burning?* [38]

Alternative uses of residues, such as bio composting, for construction material, animal fodder and the transporting of residues to Turkey for processing were mentioned, as well as the need to assess of the financial viability of these options.

[38] Eka Sanadze from MoA

The final stage of the workshop served to elicit what the workshop participants considered as the most important and urgent policy priorities, so as to deal effectively with the increasing incidence of wildfires originating in the farming sector. The exercise also served to understand the importance that workshop participants attributed to the development of 'alternatives' relative to other policy priorities, such as enforcing and banning residue burning.

Each participant was given two votes, most important and second most important. The final outcome demonstrated that there was more support for developing immediate alternative uses of residues from which farmers can derive and income – rather than the actual ban on residue burning. The workshop was finalised by leaving participants with an open question: Is it likely that alternative economic uses of residues will develop as long as the cheap option - residue burning is allowed? Maybe an actual banning of burning will help create a real push for the development of alternative technologies?

Key outcomes of relevant to the valuation study

The main outcomes of the workshop that has direct relevance to the valuation study include the following observations:

- The main concerns of fires are their direct and indirect damage to 'unharvested wheat fields, vineyards and windbreaks. These need to be assessed in the valuation study. Lost cultural heritage and recreational values also need to be considered and if not valued then at least given recognition as another cost associated with poor wildfire management.
- It is important to learn more about farmer's true preferences over residue management and how much they would need to be compensated to forego the burning of crop residues. A stated preference valuation exercises may be undertaken for this purpose.
- It is important to include a financial assessment of potential uses of residues in the valuation study. This assessment should be as close as possible to any realistic investment that could materialize in the Shiraki valley. Otherwise it will lack relevance and credibility.

Pre-valuation workshop at the district level, Dedoplistskaro municipality, 26th of January 2016

The workshop in Dedoplistskaro included farmers, shepherds, representatives from the Forest Policy Service, the fire brigade, the APA Vashlovani protected area, the local municipal administration and parliament. All participants were attentive and interested in the questions that were discussed.

At the outset of the workshop, participants provided some background on weather related trends. Pastoralists and farmers alike highlighted the increasing incidence of very warm summers, stating that when they started farming one year out of five would be 'abnormal i.e. very hot with low precipitation levels' and now that ratio had been inversed. The consequences of the aggravating weather patterns are less productive pastures compounded by overgrazing, low agricultural yields and the increasing likelihood of uncontrollable wildfires, like the one seen in the summer of 2015.

The most negative impact of the 2015 fires as perceived by farmers is the damage they have done to windbreaks. One farmer said, *"I have 5 hectares of farmland and all the windbreaks have burned down. There are no windbreaks left to protect in the landscape now".*

As for the impact of burning on the soil, another farmer said: "*Everybody knows that burning is not good, but the alternatives are too expensive. An efficient harvester and residue shedding machine cost 120 GEL/ha to rent, double that of a traditional harvesting machine".*

In general, there was wide agreement within the room that handling residues appropriately is prohibitively expensive for farmers. Other factors which compound this situation, were mentioned, namely:

1) Before the wheat has been harvested and sold farmers have no cash. It is therefore not an appropriate moment to pay for the rental of disk plowing, combined harvester and shedder or tractors to collect and compress residues.
2) The company that rents out the modern tractors is state-owned and is therefore likely to be earning monopoly rents, resulting in higher rental prices than what would happen in a competitive market for farmland machinery.
3) The moment at which the residues should be integrated into the soil or collected is around the same time that farmers are processing and sell their wheat harvests. The opportunity cost of time is therefore high at this moment of the year.
4) Farmers in the Shiraki do not have access to accurate weather data. Timing of harvest or burning is therefore not necessarily optimal (I need a bit more info on this to understand this)

The many disincentives to stop burning and manage residues differently, led to calls for finding financially interesting uses of the residues. Participants argued that with appropriate investments in processing facilities, residues could be used for/as:

- Fertilizers and mulching
- Construction material
- Input into mushroom production
- Heating
- Forage for animals.

However, in all of these cases outside investments may be necessary, though it appears that are some financially and socially interesting opportunities. For example, livestock owners in the room mentioned that if the straw residues were milled into edible residues they would buy it during winter months for their animals. The fact that pastures are overgrazed and livestock owners in the Shiraki valley purchase imported foodstock makes this a particularly interesting option to analyze as part of the valuation study.

Key outcomes of relevant to the valuation study

The main outcomes of the workshop that has direct relevance to the valuation study include the following observations:

- At the local level, there is a good understanding of the direct and indirect problems caused by crop residue burning and there is an interest among farmers (at least those present in the workshop) to manage residues differently. These attitudes stand in contrast to the perception that national workshop participants from the MoA had about farmers, arguing: 'They are not ready for change'. In case there is a significant divergence between farmers' attitudes and what the government officials perceive, it is of relevant to rectify these through the valuation survey. Efforts will thus be made to understand the true preferences of farmers regarding alternative land use and residue management scenarios as well as the minimum compensation demanded to accept a legislative ban of residue burning.

- It is prohibitively expensive for farmers to rent the equipment needed for shredding, collecting or integrating residues in the soil. In order for farmer to justify or afford such expenditures, it is of key interest to finding and developing alternative uses that can allow farmers to earn a margin on the crop residues. The need to investigate the feasibility of alternative residue uses is in agreement with outcomes from the workshop at the national level.

A heated discussion at the workshop in Dedoplistskaro

Participants at the pre-valuation national level workshop

#	Name	Organization	Position
1.	Maka Manjavidze	Land Resource and Water Protection Service, MENRP	Chief Specialist
2	Tamar Loladze	Waste and Chemicals Management Service, MENRP	Chief Specialist
3	Neli Korkotadze	Environmental Supervision Department, MENRP	Chief Inspector
4	Natia Iordanishvili	Maintenance and Reforestation Department, National Forestry Agency	Head of Department
5	Lika Giorgadze	Forestry Policy Service (FPS)	Specialist
6	Lasha Khizanishvili	Forestry Policy Service	Chief Specialist
7	Teona Kerashvili	Forest Policy Service (FPS)	Assistant
8	Eka Sanadze	Ministry of Agriculture	Head of Soil Department
9	Jimsher Koshadze	Ministry of Agriculture	Legal specialist
10	Giorgi Gambashidze	Scientific Research Academy of Georgia	Head of Laboratory Soil Fertility Research Service
11	Gela Gligvashvili	Scientific Research Academy of Georgia	Professor
12	Sopiko Akhobadze	RECC	Executive Director
13	Ana Bokuchava	Georgian Farmer Association	Project Coordinator
14	Olga Weigel	GIZ	Advisor
15	Hannes Etter	ELD Initiative	Scientific Desk Officer
16	Lindsay Stringer	University of Leeds	Expert
17	Stacey Noel	Stockholm Environmental Institute	Expert
18	Vanja Westerberg	ALTVS Impact	Expert
19	Malkhaz Adeishvili	UNIDO	Economic expert
20	Nanuli Chkoidze	Interpreter	Interpreter

Participants at the workshop at the district level

#	Name	Organization	Position

1	Hannes Etter	ELD Initiative	Scientific Desk Officer
2	Stacey Noel	Stockholm Environmental Institute	Expert
3	Lindsay Stringer	University of Leeds	Expert
4	Vanja Westerberg	ALTVS IMPACT	Expert
5	Benashvili Giorgi	Ministry of Agriculture	Local representative
6	Kikilashvili Giorgi	Farmer	Farmer
	Topchishvili Besik	Farmer	Farmer
7	Nateladze David	Farmer	Farmer
8	Cherkezishvili Vazha	Vashlovani Friends Association	Head of Association
9	Tavadze Dachi	Vashlovani Friends Association	Member of Association
10	Gaprindashvili Pridon	Association “Tushi Shepherds”	Head of Association
11	Metreveli David	Association “Tushi Shepherds”	Member of Association
12	Rekhviashvili Nikoloz	Association “Tushi Shepherds”	Member of Association
13	Malkhaz Merabishvili	Dedoplistskaro Municipality	Head of Coordination Department
14	Javakhishvili Zviad	Dedoplistskaro Municipality	Chairman of Dedoplistskaro Municipality
15	Kodiashvili Amiran	GIZ	Field Coordinator
16	Weigel Olga	GIZ	Advisor
17	Martkoplishvili Ilia	Journalist	Journalist
18	Giorgadze Lika	Forest Policy Service	Specialist
19	Chkoidze Nanuli	Interpreter	Interpreter

ELD Georgia post-valuation workshop outcome

Post-valuation workshop at the District Level, Dedoplistskaro, 1st of June 2016

A lot was learned from the post-valuation workshop in the Dedoplistskaro district. The workshop started out with a presentation of the preliminary results from the valuation study. It covered:

- A presentation of basic socio-demographic and attitudinal information of the 300 farmers that had been interviewed as part of the valuation survey.
- The main results of a choice experiment study undertaken as part of the valuation survey. This included survey respondents expressed Willingness to Pay to enforce a ban of burning, and their willingness to accept compensation to forgo the protection of remaining windbreaks.
- An exposition of the marketable value of straw and the benefits of integrating straw into the soil. The additional costs to farmers associated with handling residues differently than burning was also taken into account.
- Finally, a basic cash-flow analysis an economic feasibility assessment of installing a fuel pellet producing facility was presented. This included all relevant aspects on the ‘demand side, the supply side and the production side’ of such installing such a facility.

Getting through the presentation took one hour longer than initially anticipated. The audience vividly engaged in what was presented and that included a fair amount of confrontation with regards to specific data that was presented.

Several reasons can explain this, including the following:

- Powerpoint slides were not correctly translated which caused some confusion.
- The translator did not stick to simply translating what the presenter said, but rather engaged in the discussion and provided her own views. This made the presentation unnecessarily long.
- For the ease of the valuation study, price data on straw was converted from ‘straw bales’ into ‘tons of straw’. This made it difficult for farmers to evaluate the legitimacy of what was being presented.

- For the ease of valuation, some figures were converted from their ‘local unit’ to ‘internationally recognized units, such as tons of straw instead of straw bales. This made it difficult for the critical part of the audience to quickly evaluate the legitimacy of the numbers provided.
- The presentation was comprehensive and covered all the ecosystem services and costs that had been valued as part of the study. Some of the results were not directly relevant to farmers. In the light of a long presentation compounded by above-mentioned factors, it would have been more appropriate to leave out those costs and benefits that did not directly speak to farmers.
- One of the figures presented, namely price-information on straw bales, was questioned by the audience.
- All these were compounded by the presence of one particularly controversial individual in the audience.
- In trying to explain the behavior of that individual, interviewers from RECC argued that that the farmers who were present in the workshop had participated in several related workshops by that time and were fed-up with “talking”. They wanted action now. As one farmer argued during the workshop: “We know burning is not good, but give us alternatives now”. RECC interviewers highlighted that farmers in rural villages (outside the city of Dedoplistskaro itself) would have benefited significantly more from this kind of workshop as they had very little knowledge of the problems associated with crop residue burning.

Despite above-mentioned difficulties, several important lessons of relevance to the valuation study were learned from the workshop in Dedoplistskaro. These includes:

- The discovery of issues associated with inconsistent data entry of the valuation questionnaire and subsequent rectification of results
- The incorporation of additional costs into existing cost benefit estimates. In particular, costs associated with crop residue collection were upward adjusted to account for the opportunity cost of time - in the valuation study itself.
- There was also a farmer within the audience who had 3 years of experience with not burning. He shared his experience with the other farmers, bringing the results of the study to live.

Overall the workshop offered a number of useful lessons for everyone, including ideas and recommendations about ‘what to avoid’ or be careful about in similar workshops with local stakeholders in the future.

After the workshop - a pleasant visit of a married couple who has constructed a house using straw.

Post-valuation workshop at the National Level, Tbilisi, 3rd of June 2016

In comparison to the workshop at the local level, the workshop with national decision makers ran smoothly. The workshop started out with a presentation of the valuation study. Simultaneous translation ensured smoothness and good understanding of the study results and the overall process by the audience. As a result there were few (or any at all?) requests for clarification by the audience.

It was highlighted in the discussions after the presentation that it would be important to disseminate the report and the results as widely as possible in Georgia. Notably, that every municipality should have a policy brief and the full report.

Giorgi Ghambashidze, head of laboratory at the Soil Fertility Research Service in Georgia presented his results of the agronomic analysis that he had done of soils that have been burned and not burned. His presentation highlighted the complexity of soils and how their functions and structure change as a result of burning. Through his presentation he made it clear, that integrating residue, does not only help build up organic matter and nitrogen content, but also reduces the capacity of soils to retain water and the level of biological activity which is fundamental to help build organic matter.

Following Giorgi's detailed and interesting presentation a range of different issues were discussed, including:

- How to help farmers those farmer who would like to avoid burning to access more expensive farm machinery which can allow for residue shredding. It was highlighted that at the time when grain is harvested, it has not yet been sold and so farmers have limited financial means. Discussions over pricing with the state owned company Mechasinatory ltd were deemed necessary and justified, given that it is in the State's interest to help improve on livelihoods and the environment in the Dedoplistskaro district.
- The code of waste management, which prohibit the burning of waste and farm waste. It was questioned, why is it necessary to implement a new law to ban burning of crop residues, when there is already an existing legal mechanism. No conclusion was drawn on this.
- Whether it would be possible to obtain funding from the carbon market from avoided burning. This was considered rather limited given that the voluntary carbon market is currently flooded in carbon credits and other carbon trading market Joint Mechanism and the CDM under the Kyoto protocol are no longer in operation. It was nevertheless, highlighted that there could be scope for exploring financing opportunities through Land Degradation Neutral Fund of the Global Mechanism. There was however no further deliberation on this point.

In general, there was consensus within the room that the burning of crop residue should come to an end. One participant, Mr. Jimsher Koshadze, from the MoA however claimed that banning of crop residue burning would ultimately hurt farmers. That was not a popular claim amongst the remaining participants, and so much of the discussions were focused on countering his claims.

Finally, although there was no clear course of direction in the deliberation following the presentations on the valuation study and the agronomic study the workshop certainly served as an important platform for brainstorming on the minds of the stakeholders that were present.

Participants at the post-valuation workshop in Dedoplistskaro

#	Name	Organization	Position
1	Hannes Etter	ELD Initiative	Scientific Desk Officer
2	Vanja Westerberg	ALTUS IMPACT	Expert
3	Olga Weigel	GIZ	Advisor
4	Kodiashvili Amiran	GIZ	Field Coordinator Dedoplistskaro region
5	Zaza Badurashvili	GIZ	Project Assistant
6	Manana Kodiashvili		Interpreter
7	Lika Giorgadze	FPS, MoE	Specialist
8	Giorgi Arabuli	REC Caucasus	Biodiversity Monitoring Specialist
9	Evgenia Mekhtievi	REC Caucasus	Socio-economic group leader
10	Iago Khochiashvili	Ministry of Agriculture	Farmer
11	Giorgi Ghambashidze	Scientific Research Center of Agriculture	Head of Laboratory of Soil Fertility Research Service
12	David Nateladze		Farmer
13	Vazha Cherkezishvili	Vashlovani Friends Association	
14	Malkhaz Merabishvili	Dedoplistskaro Municipality	
15	Omar Tedoradze	Ministry of Agriculture	Deputy Head of Sectoral Development Service
16	Giorgi Benashvili	Ministry of Agriculture	Head of ICC
17	Dachi Tavadze	Vashlovani Friends Association	
18	Giorgi Kikilashvili		Farmer
19	Martkoplishvili Ilia	Newspaper Shiraki	Journalist
20	Nodar Kharnauli		Operator

Participants at the post-valuation workshop at the national level

#	Name	Organization	Position
1	Maka Manjavidze	Land Resource and Water Protection Service, MoE	Chief Specialist
2	Nino Chikovani	Land Resource and Water Protection Service, MoE	Head
3	Irma Gurguliani	Waste and Chemicals Management Service, MoE	Deputy Head
4	Neli Korkotadze	Department of Environmental Supervision, MoE	Chief Inspector
5	Maia Chkhobadze	Department of Environmental Supervision, BCD MoE	Head of BCD Dep.
6	Natia Iordanishvili	NFA	Deputy Head
7	Jimsher Koshadze	MoA	Legal specialist
8	Giorgi Ghambashidze	SRCA	Head of Laboratory Soil Fertility Research Service
9	Sopiko Akhobadze	RECC	Executive Director
10	Evgenia Mekhtievi	RECC	Socio-economic group leader
11	Giorgi Arabuli	RECC	Biodiversity Monitoring Specialist
12	Carlo Amirgulashvili	FPS, MoE	Head
13	Amiran Kodiashvili	GIZ	Local coordinator
14	Olga Weigel	GIZ	Advisor
15	Hannes Etter	ELD Initiative	Scientific Desk Officer
16	Vanja Westerberg	ALTUS Impact	Expert
17	Lika Giorgadze	FPS, MoE	Legal Specialist
18	Christian Gönner	GIZ	Team Leader
19	Nana Chkhoidze		Translator
20	Konstantin	Department of Environmental Supervision	Head of Integrated

	Khachapuridze		Environmental Control Service
21	Natia Kobakhidze	GIZ	Senior advisor

Appendix 3 – Conditional logit model with interactions (from the choice experiment)

The model shown in Table A3 is presented in section 4.1.1. The model shows how preferences towards the protection of windbreaks or banning of burning vary between different farm-household characteristics. The implications of the model results are mentioned in section 4.1.3 and 4.1.4.

Table A3.1: Conditional Logit Model with interactions

Parameter	Estimate	Std Error	Significance	WTP / WTA
Alternative specific constant	21.14	806.46		
Loss of remaining windbreaks	-0.10	0.11		-2 GEL
Loss of remaining windbreaks*farmers with windbreaks	-0.67	0.22	***	-26 GEL
Moderate restoration of windbreaks (20% to 50%)	0.89	0.08	***	37 GEL
Large-scale restoration of windbreaks (20% to 100%)	1.48	0.09	***	63 GEL
Ban of residue burning	0.86	0.09	***	56 GEL
Ban of residue burning*affected by 2015 fires	0.41	0.12	***	+14 GEL
Ban of residue burning*first generation of farmers	-0.47	0.19	***	- 28 GEL
Price	-0.02	0.00	***	
****Significance at the 99 pct. level of confidence*				

Table A3.2: Conditional Logit Model with interactions including one split on farm size

choice	Coef.	Std. Err.	z	P>z
Alternative Specific Constant	20.6	601.6	0.03	0.973*
Loss of remaining windbreaks	-0.2	0.1	-2.38	0.017
Moderate restoration of windbreaks (20% to 50%)	0.9	0.1	10.96	0
Large-scale restoration of windbreaks (20% to 100%)	1.5	0.1	17.3	0
Ban of residue burning, farmers >= 5 ha	1.0	0.1	9.59	0
Ban of residue burning, farmers < 5	0.04	0.1	-0.33	0.739*
Price	-0.02	0.0	-20.95	0

*Insignificant, because amongst farmers with less than 5 ha of land, there is one group (0.5-2.9 ha) who have a WTP of 20 GEL/ha, and another group (3 ha – 4.9) whose WTP is greater than 60 GEL/ha.

Appendix 4 - Baseline household demographics and farm data

In this section the main socio-demographic and economic characteristics of the farming households in Dedoplistskaro are presented. The data is based on the valuation survey implemented in March and April of 2016.

Socio-demographic and economic household characteristics

Table A4.1 and **A4.2** show the basic SDE characteristics of the sample that was interviewed. As can be seen, the majority of the household heads have grown up in Dedoplistskaro and almost half of them hold a university degree. Interesting, only 22% claim to have received any training in farming although farming represents the main livelihood activity for 90% of the sample and more than half of the farmers started farming more than 20 years ago.

Table A4.1 Basic household characteristics (n=300)

Variable	Mean
Gender of household head (=Male)	94%
Household head grew up in district	88%
Any household member with a university degree	46%
Household head with university degree	39%
Household has received training in farming	22%
Household head has grown up in a family of farmers	88%
Households with an annual income above 5000 GEL/year	46%
Farming as the main livelihood activity of HH	90%
Animal husbandry as the main livelihood activity	3%
Employment as the main livelihood activity	7%
Household head began farming >20 years ago	56%
Household head began farming < than 5 years ago	3%

Table A4.2 Basic household demographics

	Obs	Mean	Median	Std. Dev.	Min	Max
Age of household head	300	51.8	52	13.3	24	82
Household size	300	4.2	4	1.9	1	13
Nr of HH members below 18 years	300	0.8	1	1.0	0	5
Nr of HH members above 60 years	300	0.7	0	0.8	0	3
Annual Household income (GEL)	**300**	**7,152**	**4,000**	**27,000**	**0**	**400,000**

Farm characteristics

As shown in **Table A4.**3 most of the farming households in the same have obtained their land through state allocation (55%). This is followed by ownership acquired by purchase (22%) and inheritance (10%). Only 3% of farmers belong to a cooperative, and even less belong to environmental farmer association. Interestingly however, up to 66% consider joining a cooperative. And of those who responded, *no - I do not consider joining a cooperative*, the principle reason was because there were no cooperatives within their vicinity.

Table A4.3 Land ownership and farm characteristics

	Mean

Land under ownership acquired through inheritance	10%
Land under ownership acquired through state allocation	55%
Land under ownership acquired through purchase	22%
Households using or renting land only (no ownership)	13%
Household belonging to an environmental farmer association	1%
Household belonging to a cooperative	3%
Farmers considering joining a cooperative	66%
Not joined a cooperative because there are none	9%
There is no need to join a cooperative	13%

Table A4.4 testifies the rareness of windbreaks in Dedoplistskaro. Only 27.5% of all farmers claim to have their land partially protected by windbreaks. The average proportion of land protected by windbreaks is 5%.

Table A4.4 Farm characteristics and windbreaks (n=300)

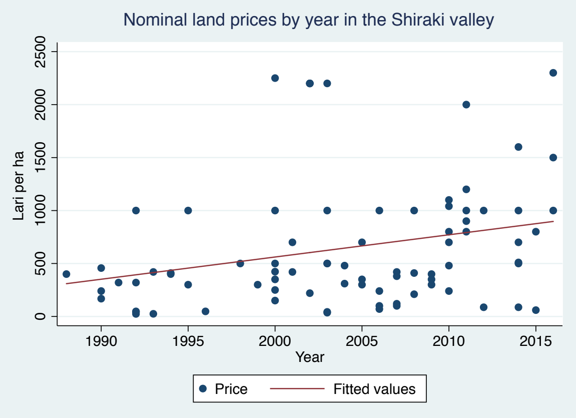
Is your farmland protected by windbreaks ?	Mean
Yes	0.3%
Partially	27.5%
No	72.1%
Average share of farmland protected by windbreaks	5%

As shown in Table **A4.3** 22% of farms have purchased land. **Table A4.3** shows what year the land was purchased in and at what price. From 1990 to 2015, nominal land prices (not adjusted for inflation) have gradually increased. The real price of land has therefore not risen at the same pace.

Table A4.5 Farm characteristics (n=300)

Variable	Mean	Median	Std. Dev.	Min	Max
Land used for farming (ha)	25.5	5	151.6	0.5	2,500
Plots of land used for farming	2.7	2	2.7	0	30
Last time land was purchased	2004	2005	7.6	1988	2016
Price per hectare land when purchased	647	422	595	24	2,300
Rental price per hectare (2015)	103.3	87	31.0	84	300
Hectares cultivated with wheat	9.3	2	30.4	0	250
Output of wheat (tons)	37.1	2.8	248.8	0	4,000
Yield (tons/ha)	2.2	2	1.2	0.12	7.5

Figure A4.1 Land prices (not adjusted for inflation) (n=300)



As can be seen in **Table A4.6**, farmers cultivate principally wheat and barley. The average farmer has 9 hectares of land as judged by the mean and 3 hectares of land as judged by the median.

Table A4.6: What is grown (n=300)

Farmer's land cultivated with	Mean	Median	Std. Dev.	Min	Max	Pct share
Wheat	9.3	2	30.4	0	250	49%
Barley	5.5	1	20.0	0	300	29%
Wheat and barley	14.9	3	27	0	300	58%
Sunflower	0.7	0	3.5	0	50	4%
Pastures	3.4	0	24.8	0	271	18%
Vineyards	0.1	0	0.7	0	10	1%
Other/fallow	6.3					
Total	**19.1**	**3**	**58.3**	**0**	**590**	**100%**
	Share	**Total ha**				
% dedicated to wheat and barley out of total arable land	**60%**	20,562				
% dedicated to wine and sunflower out of total arable land	**3%**	11,82				

In terms of distribution of farm sizes, **Table A4.7** shows that about 48% of farmers cultivate less than 5 hectares of land, and remaining have 5 hectares or more.

Table A4.7: Distribution of farm sizes (not ownership) in Dedoplistskaro

Distribution of farm sizes (land cultivated, not ownership)	Number	Percent %	Cumulative %
Less than 1 ha	4	1.4	1.4
1 ha to 1.9 ha	33	11.4	12.3
2 ha-2.9 ha	41	13.7	26.0
3 ha-3.9 ha	34	11.3	37.3
4 ha-4.9 ha	32	10.7	48.0
5 ha-6.9 ha	32	10.7	58.7
7 ha - 9.9 ha	25	8.3	67.0
10 to 14.9 ha	28	9.3	76.3
15-19.9 ha	17	5.7	82.0
20-29.9 ha	22	7.3	89.3

>30-100 ha	21	7.0	96.3
>100 ha	11	3.7	100.0

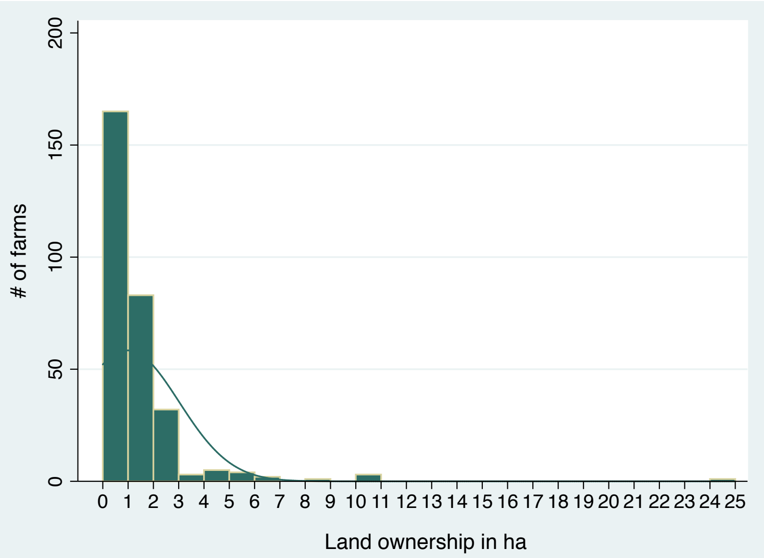


Figure A4.2 land ownership (n=300)

Agricultural yields

As shown in **Figure A4.8**, average yields (tons/ha) in Dedoplistskaro vary between less than 1 ton per hectare and up to 3.5 ton per hectare depending on the source. It is interesting to note however, that average yields estimated from the valuation survey in 2015 are lower than yields provided by ICC and Klein. That is probably because the valuation survey captures both ineffective and effective farmers, because of the representative sample size, whereas estimates from ICC and Klein are based on data from a much smaller subset of farmers. It is thus more reasonable to expect that average yields are in the order of 2.2 tons/ha in 2015 and not above that. Figure **A4.3** however, shows that some farmers were able to fetch up to 6-7 tons/ha in 2015, whilst others had less than 0.5 tons/ha!

Figure A4.3 gives an indication as to what determines yields. In this case, we clearly see that smaller farmers with less than 5 ha of land have lower yields than larger farmers (with >5 hectares of land).

Table A4.8 Yields (tons/ha) in the Dedoplistskaro district from different sources

Year	ICC	Klein (n=15)	Camacho et al., 2015 (n=census)	Westerberg (n=300)
2010	.	2.6	.	.
2011	.	2	.	.
2012	2.1	3	1.8	.
2013	1.8	2.8	.	.
2014	2.7	0.7	.	.
2015	3.5	3.2	.	2.27 ± 0.2
Average	2.5	2.5	1.8	2.2

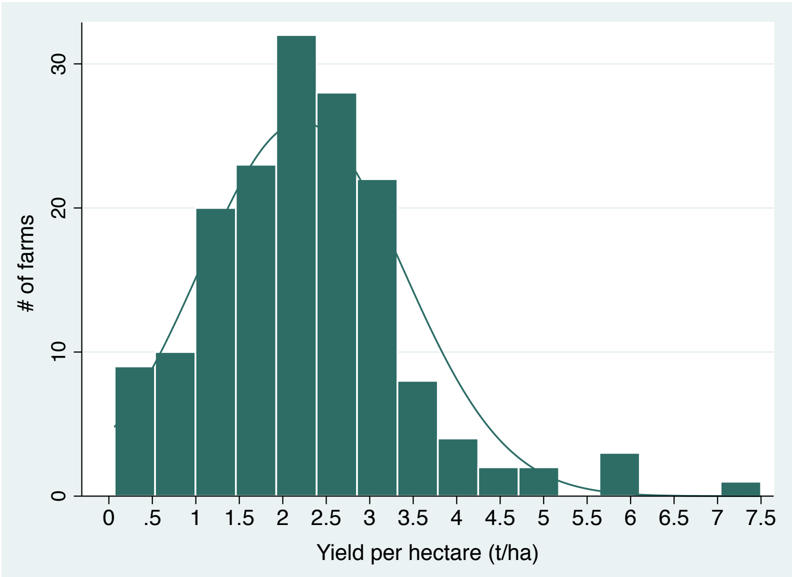


Figure A4.3 Distribution of yields in 2015 from the valuation survey

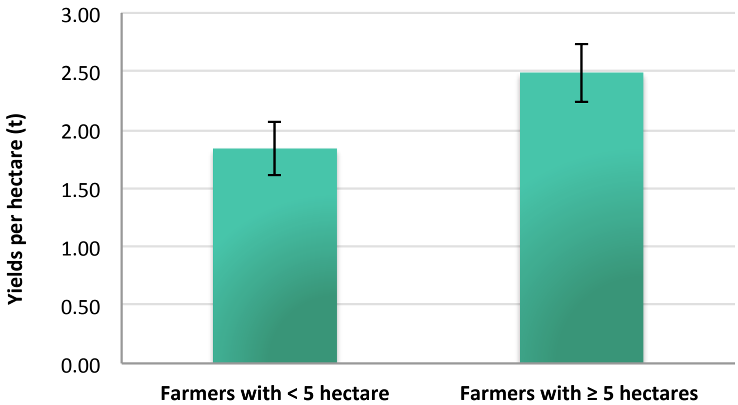


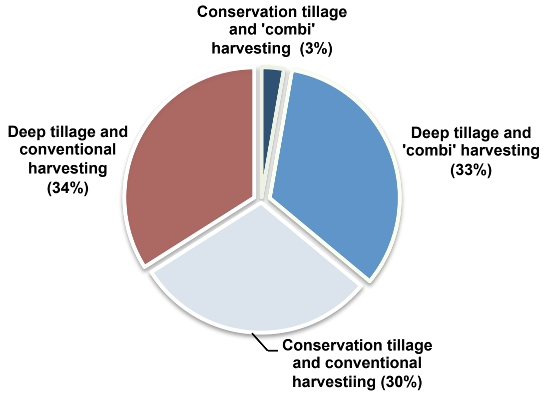
Figure A4.4: Crop yields in Dedoplistskaro from different sources

Land under sustainable land use management practices

In terms of uptake of conservation tillage and residue management, Table A4.9, 3% of farmers in Dedoplistskaro cultivate with both light discs and a 'combi' harvester that shreds crop residues during harvest. Remaining farmers use heavy machinery for cultivation and/or harvest.

Table A4.9: Uptake of Sustainable Land management practices

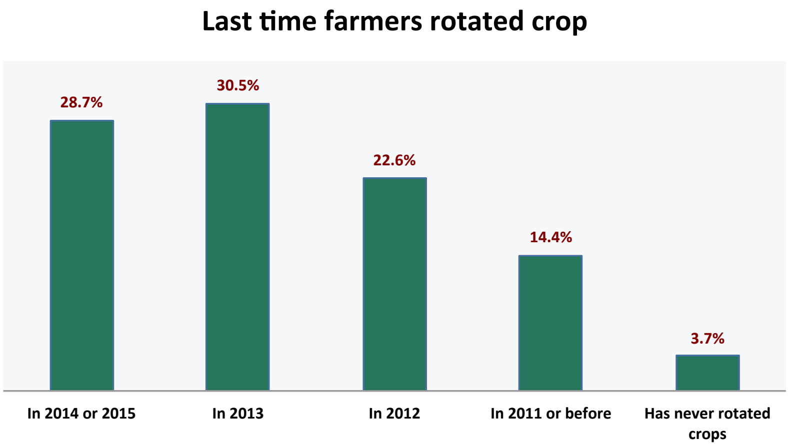
Share of farmland (harvested with SLM equipment)				
Soil management practices	Share of farmers	Ha	Std dev	Share of land
Pure conservation practices				
Cultivation with light discs and COMBI harvesting	3%	0.4	4.7	3%
Crop residue mulching	0.3%	0.05	0.6	0.4%
Conservation and conventional farm practices		**Ha**		
Cultivation with heavy discs and COMBI harvesting	23%	4.4	17.9	33%
Cultivation with light discs and conventional harvesting	19%	3.9	33.7	30%
Conventional farm practices only		**Ha**		
Cultivation with heavy discs and conventional harvesting	45%	4.4	14.6	34%



Amongst the different possible kinds of improved agronomic practices, crop rotation is the only major practice undertaken by farmers. Consulting Table **A4.10,** it can be seen that 28% of all cereal fields have been cultivated/rotated with other crops within the last 2 years.

Table A4.10: Last time farmers rotated crop

Crop rotation	Obs	Share of farmers	Hectares of land	Share of land
Farmer has last time rotated crop in 2014 or 2015	84	30%	18.1	28%
Farmer has last time rotated crop in 2013	89	31%	16	25%
Farmer has last time rotated crop in 2012	66	23%	14.5	23%
Farmer has last time rotated crop in 2011 or before	42	14%	11.6	18%
Farmer has never rotated crops	11	4%	4.1	6%


Last time farmers rotated crop
28.7%
30.5%
22.6%
14.4%
3.7%
In 2014 or 2015
In 2013
In 2012
In 2011 or before
Has never rotated crops

Appendix 5 – Results of the soil laboratory analysis

This appendix presents the results of the laboratory analysis of the soils that were sampled in Dedoplistskaro municipality during spring of 2016. The differences in soil characteristics between Site 1 and 2 are described in section 3.5.2 in the report. Findings from the remaining sites are described below.

Table #1. Site 1

Site 1
Current usage: Arable
Crop: Winter barley
Plot size: 10 ha
Management practice: No burns of crop residues (at least last 3 years);
Crop residues incorporation to soil after harvest: Yes
Use of synthetic fertilizer: No (at least last 3 years)

Parameter	**Result of Analysis**
pH (in water extract)	8.22
Calcium carbonate (%)	0.75
Organic matter (%)	3.84
Loss of organic matter at 150°C (%)	0.27
Loss of organic matter at 250°C (%)	2.28
Nitrogen (N) % (total)	0.11
Phosphorous (P_2O_5) % (total)	0.07
Potassium (K_2O) % (total)	0.62
Exchangeable Calcium (Ca) mg.eq./100 g	45.17
Exchangeable Magnesium (Mg) mg.eq./100 g	6.57
Exchangeable Sodium (Na) mg.eq./100 g	0.38
Bulk density g/cm^3	0.96
Hygroscopic water (%)	6.38

Particle size distribution* (%)	fraction (mm)						
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
	0	2	20	8	17	53	78

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %)

Site 2
Current usage: Arable
Crop: Winter wheat
Plot size: 15 ha
Management practice: annual burn of crops residues (at least last 3 years);
Crop residues incorporation to soil after harvest: No
Use of synthetic fertilizer: Yes (at least last 3 years)

Table #2. Site 2

Parameter	**Result of Analysis**						
pH (in water extract)	7.87						
Calcium carbonate (%)	0.00						
Organic matter (%)	3.13						
Loss of organic matter at 150°C (%)	0.18						
Loss of organic matter at 250°C (%)	2.28						
Nitrogen (N) % (total)	0.11						
Phosphorous (P_2O_5) % (total)	0.08						
Potassium (K_2O) % (total)	0.64						
Exchangeable Calcium (Ca) mg.eq./100 g	47.01						
Exchangeable Magnesium (Mg) mg.eq./100 g	8.15						
Exchangeable Sodium (Na) mg.eq./100 g	0.37						
Bulk density g/cm^3	1.09						
Hygroscopic water (%)	6.38						
Particle size distribution*	fraction (mm)						
	1-0.25	0.25-	0.05-	0.01-	0.005-	<0.001	<0.01
	0	3	17	10	17	53	80

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %

Site 3
Current usage: Windbreak
Current status: burned in 2015;

Parameter	**Result of Analysis**						
pH (in water extract)	8.19						
Calcium carbonate (%)	0.38						
Organic matter (%)	4.70						
Loss of organic matter at 150°C (%)	0.14						
Loss of organic matter at 250°C (%)	3.42						
Nitrogen (N) % (total)	0.09						
Phosphorous (P_2O_5) % (total)	0.09						
Potassium (K_2O) % (total)	0.65						
Exchangeable Calcium (Ca) mg.eq./100 g	51.45						
Exchangeable Magnesium (Mg) mg.eq./100 g	6.43						
Exchangeable Sodium (Na) mg.eq./100 g	0.35						
Bulk density g/cm^3	0.91						
Hygroscopic water (%)	6.61						
Particle size distribution* (%)	fraction (mm)						
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
	0	7	18	9	17	49	75

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %)

Site 4
Current usage: Arable
Crop: Winter barley
Plot size: 6 ha
Management practice: No burns of crop residues (at least last 2 years);
Crop residues incorporation to soil after harvest: No
Use of synthetic fertilizer: No (at least last 2 years)

Table #4. Site 4

Parameter	**Result of Analysis**						
pH (in water extract)	7.95						
Calcium carbonate (%)	0.76						
Organic matter (%)	3.49						
Loss of organic matter at 150°C (%)	0.00						
Loss of organic matter at 250°C (%)	2.83						
Nitrogen (N) % (total)	0.10						
Phosphorous (P_2O_5) % (total)	0.07						
Potassium (K_2O) % (total)	0.40						
Exchangeable Calcium (Ca) mg.eq./100 g	45.66						
Exchangeable Magnesium (Mg) mg.eq./100 g	5.98						
Exchangeable Sodium (Na) mg.eq./100 g	0.47						
Bulk density g/cm^3	0.81						
Hygroscopic water (%)	7.07						
Particle size distribution* (%)	fraction (mm)						
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
	0	2	17	9	19	53	81

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %)

Site 5
Current usage: Windbreak
Current status: unburned

Table #5. Site 5

Parameter	**Result of Analysis**
pH (in water extract)	8.18
Calcium carbonate (%)	1.89
Organic matter (%)	4.80
Loss of organic matter at 150°C (%)	0.09
Loss of organic matter at 250°C (%)	3.81
Nitrogen (N) % (total)	0.09
Phosphorous (P_2O_5) % (total)	0.08
Potassium (K_2O) % (total)	0.37
Exchangeable Calcium (Ca) mg.eq./100 g	67.36
Exchangeable Magnesium (Mg) mg.eq./100 g	5.63
Exchangeable Sodium (Na) mg.eq./100 g	0.37
Bulk density g/cm^3	0.82
Hygroscopic water (%)	6.84

Particle size distribution* (%)	fraction (mm)						
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
	0	3	15	9	21	52	82

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %)

Site 6
Current usage: Arable
Crop: No winter cereals were sown during sampling
Plot size: 50 ha
Management practice: No burns of crop residues (at least last 5 years), burned accidentally in 2015;
Crop residues incorporation to soil after harvest: Yes
Use of synthetic fertilizer: Yes (at least last 5 years)

Table #6. Site 6

<table>
<tr><th colspan="4">Parameter</th><th colspan="4">Result of Analysis</th></tr>
<tr><td colspan="4">pH (in water extract)</td><td colspan="4">8.43</td></tr>
<tr><td colspan="4">Calcium carbonate (%)</td><td colspan="4">1.89</td></tr>
<tr><td colspan="4">Organic matter (%)</td><td colspan="4">3.25</td></tr>
<tr><td colspan="4">Loss of organic matter at 150°C (%)</td><td colspan="4">0.25</td></tr>
<tr><td colspan="4">Loss of organic matter at 250°C (%)</td><td colspan="4">2.45</td></tr>
<tr><td colspan="4">Nitrogen (N) % (total)</td><td colspan="4">0.14</td></tr>
<tr><td colspan="4">Phosphorous (P_2O_5) % (total)</td><td colspan="4">0.08</td></tr>
<tr><td colspan="4">Potassium (K_2O) % (total)</td><td colspan="4">0.34</td></tr>
<tr><td colspan="4">Exchangeable Calcium (Ca) mg.eq./100 g</td><td colspan="4">52.62</td></tr>
<tr><td colspan="4">Exchangeable Magnesium (Mg) mg.eq./100 g</td><td colspan="4">4.28</td></tr>
<tr><td colspan="4">Exchangeable Sodium (Na) mg.eq./100 g</td><td colspan="4">0.37</td></tr>
<tr><td colspan="4">Bulk density g/cm^3</td><td colspan="4">0.95</td></tr>
<tr><td colspan="4">Hygroscopic water (%)</td><td colspan="4">5.93</td></tr>
<tr><td rowspan="3">Particle size distribution* (%)</td><td colspan="7">fraction (mm)</td></tr>
<tr><td>1-0.25</td><td>0.25-0.05</td><td>0.05-0.01</td><td>0.01-0.005</td><td>0.005-0.001</td><td><0.001</td><td><0.01</td></tr>
<tr><td>0</td><td>5</td><td>20</td><td>10</td><td>20</td><td>45</td><td>75</td></tr>
</table>

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %)

Site 7
Current usage: Arable
Crop: Winter wheat
Plot size: 100 ha
Management practice: No burns of crop residues (at least last 2 years), burned accidentally in 2015;
Crop residues incorporation to soil after harvest: Yes
Use of synthetic fertilizer: Yes (at least last 2 years)

Table #7. Site 7

Parameter	**Result of Analysis**						
pH (in water extract)	8.19						
Calcium carbonate (%)	3.75						
Organic matter (%)	2.66						
Loss of organic matter at 150°C (%)	0.00						
Loss of organic matter at 250°C (%)	2.39						
Nitrogen (N) % (total)	0.11						
Phosphorous (P_2O_5) % (total)	0.07						
Potassium (K_2O) % (total)	0.50						
Exchangeable Calcium (Ca) mg.eq./100 g	51.94						
Exchangeable Magnesium (Mg) mg.eq./100 g	4.09						
Exchangeable Sodium (Na) mg.eq./100 g	0.41						
Bulk density g/cm^3	0.99						
Hygroscopic water (%)	6.16						
Particle size distribution* (%)	fraction (mm)						
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
	0	5	17	9	22	47	78

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %)

Site 8
Current usage: Arable
Crop: Winter wheat
Plot size: 52 ha
Management practice: No burns of crop residues (at least last 5 years), burned accidentally in 2015;
Crop residues incorporation to soil after harvest: Yes
Use of synthetic fertilizer: Yes (at least last 5 years)

Table #8. Site 8

<table>
<tr><th colspan="4">Parameter</th><th colspan="4">Result of Analysis</th></tr>
<tr><td colspan="4">pH (in water extract)</td><td colspan="4">8.04</td></tr>
<tr><td colspan="4">Calcium carbonate (%)</td><td colspan="4">0.38</td></tr>
<tr><td colspan="4">Organic matter (%)</td><td colspan="4">3.27</td></tr>
<tr><td colspan="4">Loss of organic matter at 150°C (%)</td><td colspan="4">0.26</td></tr>
<tr><td colspan="4">Loss of organic matter at 250°C (%)</td><td colspan="4">2.37</td></tr>
<tr><td colspan="4">Nitrogen (N) % (total)</td><td colspan="4">0.11</td></tr>
<tr><td colspan="4">Phosphorous (P_2O_5) % (total)</td><td colspan="4">0.14</td></tr>
<tr><td colspan="4">Potassium (K_2O) % (total)</td><td colspan="4">0.46</td></tr>
<tr><td colspan="4">Exchangeable Calcium (Ca) mg.eq./100 g</td><td colspan="4">45.25</td></tr>
<tr><td colspan="4">Exchangeable Magnesium (Mg) mg.eq./100 g</td><td colspan="4">8.37</td></tr>
<tr><td colspan="4">Exchangeable Sodium (Na) mg.eq./100 g</td><td colspan="4">0.38</td></tr>
<tr><td colspan="4">Bulk density g/cm^3</td><td colspan="4">0.99</td></tr>
<tr><td colspan="4">Hygroscopic water (%)</td><td colspan="4">6.61</td></tr>
<tr><td rowspan="3">Particle size distribution*
(%)</td><td colspan="7">fraction (mm)</td></tr>
<tr><td>1-0.25</td><td>0.25-0.05</td><td>0.05-0.01</td><td>0.01-0.005</td><td>0.005-0.001</td><td><0.001</td><td><0.01</td></tr>
<tr><td>0</td><td>1</td><td>17</td><td>11</td><td>16</td><td>55</td><td>82</td></tr>
</table>

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %)

Site 9
Current usage: Arable
Crop: Winter barley
Plot size: 13 ha
Management practice: No burns of crop residues (at least last 5 years), burned accidentally in 2015;
Crop residues incorporation to soil after harvest: Yes
Use of synthetic fertilizer: Yes (at least last 5 years)

Table #9. Site 9

Parameter	**Result of Analysis**					
pH (in water extract)	8.12					
Calcium carbonate (%)	6.38					
Organic matter (%)	3.01					
Loss of organic matter at 150°C (%)	0.26					
Loss of organic matter at 250°C (%)	2.45					
Nitrogen (N) % (total)	0.08					
Phosphorous (P_2O_5) % (total)	0.14					
Potassium (K_2O) % (total)	0.60					
Exchangeable Calcium (Ca) mg.eq./100 g	50.65					
Exchangeable Magnesium (Mg) mg.eq./100 g	4.26					
Exchangeable Sodium (Na) mg.eq./100 g	0.34					
Bulk density g/cm^3	0.97					
Hygroscopic water (%)	6.16					

Particle size distribution* (%)	fraction (mm)					
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
	0	1	17	12	21	49	82

* based on physical clay fraction content (<0.01 mm) soil texture is medium clay (physical clay content 75-85 %)

A5.1 Comparative analysis of soil characteristics amongst site 3-9

Unlike Site 1 and 2, Site 3 and Site 5 represents the windbreak areas and therefore cannot be compared to these. Site 3 was totally burned in 2015 and Site 5 was remained unaffected. Organic matter content on Site 3 is slightly lower (by 0.1%), than on Site 5, which might be result of the fire, but such small differences can be caused by non-homogeneity of soil too. Site 3 and Site 5 more differs by their bulk density, where Site 3 has higher value, which might be caused by burning of fresh organic matter and plant residues.

Site 4 is an arable land unaffected by fire, which shows higher organic matter content compared to other arable lands (Site 2, Site 6, Site 7, Site 8, Site 9) except Site 1, and has lower bulk density than any other arable land.

Site 6, Site 7, Site 8 and Site 9 have similar management practice with no burns and incorporation of residues after harvest, but all of them were accidentally burned in 2015. They show a lower organic matter content compared to Site 1, which can be influenced by fire, but also by other factors. Bulk density of the soils from these sites are very similar and vary between 0.95-0.99 g/cm3 and fall in the same range as for Site 1 (0.96 g/cm3).

Appendix 6 – Data input into the feasibility analysis of a pellet producing facility in Dedoplistskaro

Table A5.1: Assumptions, data and data sources used for the economic feasibility assessment of the pellet producing facility.

Demand for energy in Dedoplistskaro	Unit	Mean value	Values/source
MJ of energy in 1 m3 of fuelwood	MJ/m3	9,360	Biomass energy centre[39]
Energetic content of straw pellets	MJ/ton	16,200 (2.8)	19 MJ/kg,13 MJ/kg, 15 MJ/kg, 18 MJ/kg [40]
Annual demand for fuelwood per household	m3/HH	9	Helbig 2016
Annual demand for fuelwood	m^3	51,525	Helbig 2016
Annual total demand for fuel in MJ equivalents	MJ	482.3 millions	Calculated
Annual total demand for fuel in pellet equivalents	tons	29,770	Calculated
Economic value of fuel	**Unit**	**Mean value (sd)**	**Values/source**
Price of fuelwood	GEL/m3	63 (14)	44, 60, 70 and 76 GEL/m^3 depending on the size of truckload delivery (REC, GIZ 2016)
Implicit price per MJ of energy	GEL/MJ	0.0067	Calculated
Sale price per ton of pellets on the basis of the energy equivalent value	GEL/ton	109.0	Calculated
Total potential supply of wheat straw	**Unit**	**Mean value (sd)**	**Values/source**
Arable land	ha	34,000	Klein (2015)
% of farmland dedicated to barley and wheat cropping	%	60%	Valuation survey
Wheat and barley fields, Dedoplistskaro	ha	19,000	Inferred from valuation survey

[39] http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,20041&_dad=portal

[40] http://www.factory.lt/en/production/pellet-presses/straw-shredding-and-pellet-producing-equipment; http://www.appletonlemoors.co.uk/docs/calorific_values.PDF; http://www.agripellets.com/Docs/AWSPA.pdf; Helberg (2016)

Appendix 7 – Main parameter values for small and large farmers used in the cost benefit analysis

Table A7: Main parameter values for small and large farmers used in the cost benefit analysis
*Denotes statistically significant differences at the 95 pct. Level of confidence, based on both parametric on non-parametric tests.

Price per ton of wheat (GEL)	N	mean	median	sd	min	max
Less than 5 ha	75	476.1	450	99.1	310	750
5 ha or more	105	449.4	430	71.6	325	700
Price per ton of straw* (GEL/ton)	**N**	**mean**	**median**	**sd**	**min**	**max**
Less than 5 ha	28	56.4	48	24.5	28	160
5 ha or more	34	91.4	80	34.3	44	200
Price per bale of straw* (GEL/ton)	**N**	**mean**	**median**	**sd**	**min**	**max**
Less than 5 ha	28	0.7	0.6	0.3	0.35	2
5 ha or more	34	1.1	1	0.4	0.55	2.5
Rental straw collection cost* (GEL/ha)	**N**	**mean**	**p50**	**sd**	**min**	**max**
Less than 5 ha	47	116.3	120	35.6	56	220
5 ha or more	40	97.7	100	38.2	44	220
Effective collection of straw *(ton/ha)	N	mean	**median**	sd	min	max
Less than 5 ha	69	1.9	1.8	1.0	0.63	6.3
5 ha or more	94	2.6	2.6	1.2	0.63	6.3
Yield of straw* (ton/ha)	**N**	**mean**	**median**	**sd**	**min**	**max**
Less than 5 ha	69	2.8	2.6	1.4	0.9	9
5 ha or more	94	3.7	3.7	1.7	0.9	9
Yield of wheat* (ton/ha)	**N**	**mean**	**median**	**sd**	**min**	**max**
Less than 5 ha	69	1.9	1.75	0.9	0.6	6
5 ha or more	94	2.5	2.5	1.1	0.6	6
Rental price of soviet harvester (GEL/ha)	**N**	**mean**	**median**	**sd**	**min**	**max**
Less than 5 ha	80	73.8	70	19.2	40	125
5 ha or more	69	69.3	70	20.3	20	120
Rental price of combi harvester* (GEL/ha)	**N**	**mean**	**median**	**min**	**max**	
Less than 5 ha	28	103.9	110	17.1	50	130
5 ha or more	46	96.8	98	13.5	60	120

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