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From biomass burning in Eastern Europe

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Air pollution in the Nordic countries

From biomass burning in Eastern Europe

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This report describes the effects on air quality and possible vegetation damage in Northern Fennoscandia due to a combination of biomass burning in Eastern Europe and unfavorable weather conditions. A pollution episode in the spring of 2006 is described in detail. These situations can be avoided in the future with the right political actions. Here, the following recommendations are given to policy makers in Russia, EU and Fennoscandia:

- to develop the legislation, law enforcement and management responsibilities of authorities concerning the use of fire on agricultural and pasture lands, as well as on abandoned agricultural lands;
- to promote alternatives to agricultural burning through the development of consulting service for farmers;
- to institute subsidies for supporting the crop production sector in agriculture to apply alternative technologies, following the examples of subsidies in the European Union.

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Summary

Polluted air with impacts on human health and ecosystems in the Nordic countries, is transported with the winds over very long distances. Large-scale biomass burning is an important source for polluted air over the northern hemisphere. During the spring of 2006, biomass burning occurred on approximately 2 Mha (20 000 km2) forest and agricultural land in Russia and neighbouring countries. Due to the anti-cyclonic high pressure weather situation, this highly polluted air was transported towards north-west across northern Europe, from Scotland to Finland and even all the way to Iceland and Svalbard. High air concentrations of black carbon and ground level ozone as well as high deposition of nitrogen were measured in forests in mid- and north Fennoscandia. Furthermore, high air concentrations of particulate matter causing health problems were documented from Edinburgh, Stockholm and southern Finland.

Monitoring with e.g. remote sensing methods have shown that large-scale wildfires in Russia have continued until today and that the area burnt in 2006 was not exceptionally high as compared other recent years. However, in order to severely affect the air quality in the Nordic countries, the biomass burning in Russia have to coincide an anti-cyclonic, high pressure weather system over Russia which favours northwards transport. Also, when the air masses are not subject ot precipitation, the atmospheic life time of the particles is much longer.

In Russia alternative utilizations of agricultural residues are seldom applicable due to the weak economic state of agricultural enterprises. Existing governmental subsidies for agricultural producers are very small in comparison with those available in the European Union. There is legislation existing in the Russian Federation pertaining to the prohibition of burning agricultural waste. In practice, the enforcement of the ban is very lax, and there is practically no control over agricultural fires. Furthermore, there are decreased fire management capabilities as a consequence of the transition of national economies.

The Nordic countries, as well as other EU member countries, have to support Russia and neighbouring countries in order to increase their efforts to restrict the widespread wildfires. The most important activities include preventing the burning of agricultural waste as well as fire-prevention activities in the forests and providing acquisitions of fire-prevention equipment.

1. Introduction

Emissions from the large-scale biomass burning represent an important component of the northern hemispheric air pollution. During the last decade there have been several large-scale biomass burning events in Eastern Europe, in particular in southern Russia, with severe consequences for the human health of the local population as well as for the local ecosystems.

In addition to local impacts, the large-scale biomass burning also has substantial consequences for the air quality and ecosystem impacts in the Nordic countries due to long-range transport of the polluted air. The Nordic council of Ministers (NMR) initiated a study in 2011, NitrOzNor, with the aim to describe the impacts of the eastern Europe biomass burning on the nitrogen deposition to northern ecosystems (Karlsson et al., 2013). Furthermore, NMR initiated this policy-oriented article with the aim to give an overview of the impacts on the air quality and northern ecosystems caused by the long-range transport of polluted air from large-scale biomass burning.

2. Background

Over the past decade, improved remote sensing has permitted a more accurate assessment of the annual fires in Russian boreal forest, revealing that Russia in general has the largest area burned among boreal forests. Annual estimates of burned areas over the Russian Federation are presented in Figure 1. The mean annually burnt areas range 8-10 Mha for total land and 4-6 Mha for forest land. The between-year variation is large. Furthermore, it can be seen that the area burnt in 2006 was not exceptionally high as compared to e.g. 2003 and 2008.

The extent to which the polluted air from Eastern Europe biomass burning is transported to the Nordic countries depend on the prevailing wind directions, which in turn depend on the large-scale

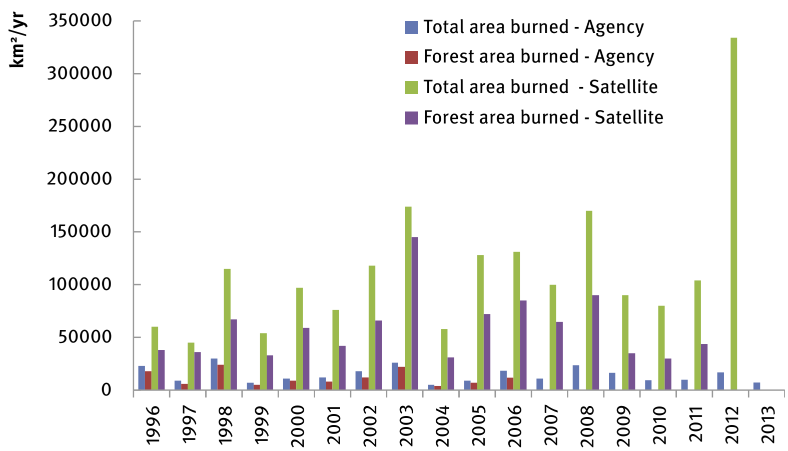


Fig. 1. Annual estimates of burned areas over the Russian Federation derived from three different sources, separated for total land and for forest land. Data for 1996-2006 were from Goldammer et al. (2013), in turn based on Russian Agency reports (Avialesookhrana of Russia) and satellite-derived data (NOAA AVHRR). The second source based on Agency reports from 2007-13 was from JRC 2014. The third source with satellite-derived information from Landsat and MODIS data from 2007-2011 was from Bartalev et al. (2013). The satellite derived information for 2012 was based on Goldammer et al. (2013) and include only the Siberian/Asian part of the Russian Federation.

weather situation. Hence, in order to severely affect the air quality in the Nordic countries, large intensities of biomass burning in Russia have to coincide with air mass transport patterns from Russia towards northwest, i.e. when there is a anti-cyclonic, high pressure weather system over Russia.

During the pollution episode in April/May 2006, the Icelandic low dominated the circulation over the northern North Atlantic and a prominent anticyclone was located over northeastern Europe (Stohl et al., 2007). This pressure configuration corresponds to a positive phase of the North Atlantic Oscillation (NAO) weather pattern, which is known to enhance pollution transport into the Arctic (Eckhardt et al., 2003). Air from the European continent was channelled into the Arctic between the two pressure centres. The situation in 2006 was unprecedented, leading to record high air temperatures and pollution levels in the Norwegian Arctic (Stohl et al., 2007). However, predictions for the future of the NAO is still highly uncertain since the NAO is related to the tracks of Atlantic storms, noisy mid-latitude phenomenon, and predictions of storminess changes are also currently uncertain (Hurrell, 1995).

3. The impacts of the 2006 large scale biomass burning in eastern Europe

3.1 Transport of the polluted air
In May 2006 severely polluted air from large scale biomass burning was transported from eastern European countries towards northwest, all the way to Spitsbergen (Stohl et al., 2007, Figure 2). Snow at a glacier on Spitsbergen became discoloured due to the soot in the polluted air. The air concentrations of black carbon and ground level ozone at Svalbard and Iceland were the highest ever recorded.

3.2 Contribution to the levels of black carbon
Black smoke is one important component of the Short Lived Climate Forcers, SLCF. The polluted air from the large-scale biomass burning that passed over mid-Sweden in the April and May 2006 contained unusually high levels of black carbon (Figure 3).

3.3 Nitrogen deposition to forests in mid-Sweden
The polluted air passing over mid-Sweden during the spring and summer 2006 caused a record high measurement of ammonium deposition to Norway spruce forests at two observation plots with the Swedish Throughfall Monitoring network (www.krondroppsnatet.ivl.se) (Figure 4). The elevated monthly value for ammonia deposition was estimated to have exceeded 1 kg N/ha. The normal deposition of inorganic nitrogen (NO3+NH4) in this region is 1-2 kg N/ha/yr and the critical load for nitrogen deposition to coniferous forest is Sweden is set to 5 kg N/ha/yr (3 kg N/ha/yr in mountain areas). Hence, a monthly deposition of 1 kg N/ha represents a substantial addition to the load of nitrogen to these northern forest ecosystems.

3.4 Tropospheric ozone
On May 6th 2006 the information concentration threshold above which the EU directive requires the general public to be informed,

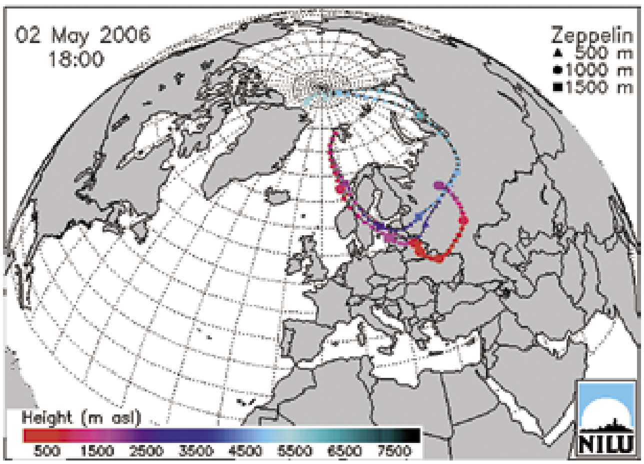


Fig 2. Trajectory analysis for air masses arriving in the afternoon on May 2nd 2006 at Zeppelin on Svalbard Trajectories calculated using the Flextra model were derived from NILU (http://www.nilu.no/projects/ccc/trajectories/).
Triangles show trajectories for air arriving at the destination at between 0 and 500 m above ground, circles 500-1000 m above ground and squares at 1000-1500 m above ground. The colour shows height above ground during air mass transport.

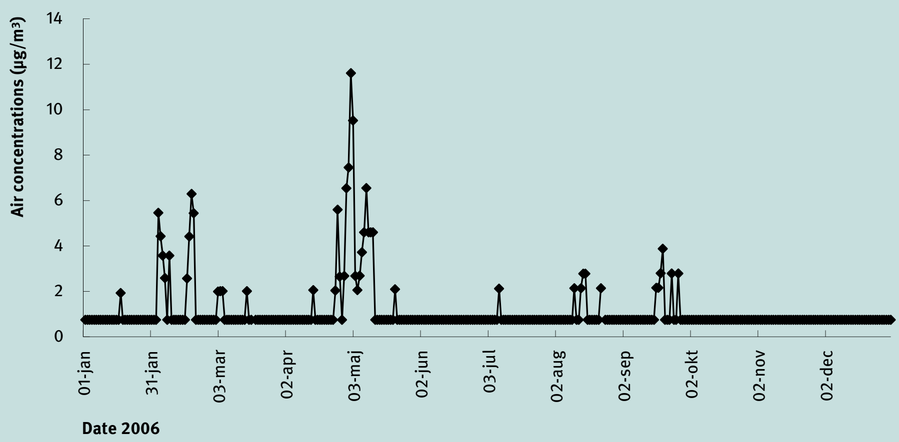
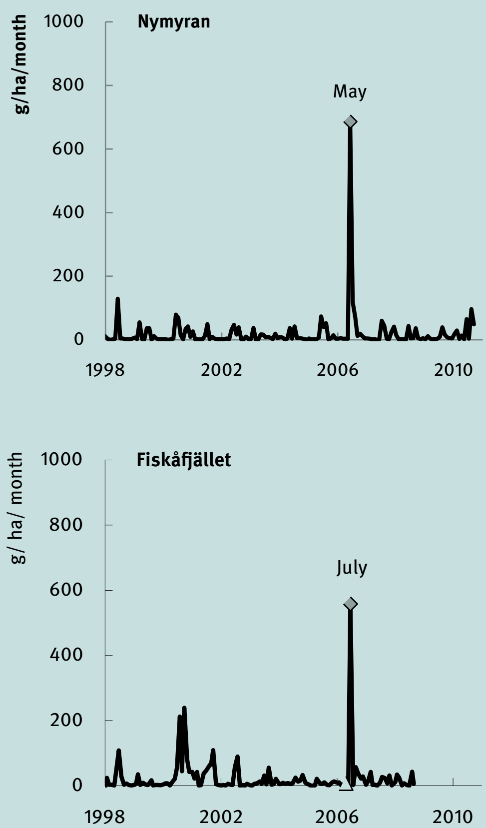


Fig. 3. Daily mean air concentrations of black smoke during 2006 for the EMEP monitoring site Bredkälen, positioned in the middle of the county of Jämtland, Sweden. From Karlsson et al., 2013.



was exceeded at Aspvreten on the southeast coast of Sweden (Figure 5). Trajectory analysis confirmed that the polluted air with the ozone precursors originated from eastern European countries. During the same period, record high ozone concentrations were measured on Iceland and Spitsbergen, with the polluted air also originating from eastern European countries (Stohl et al., 2007).

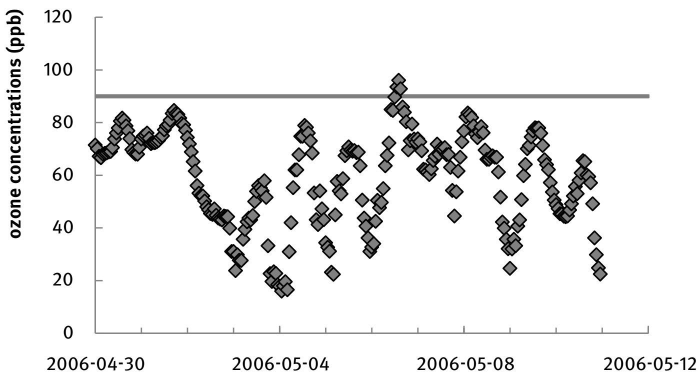
The exceedance of the EU information concentration threshold for ozone is a relatively rare event in Sweden, so this event during May 2006 received a lot of attention in Swedish media, even though it was not recognized at that time that the polluted air originated from eastern European biomass burning.

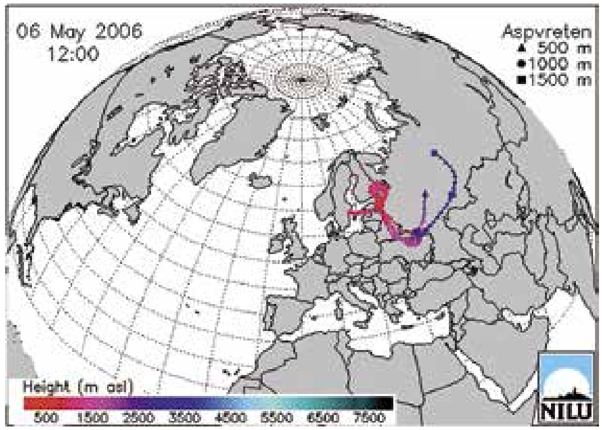
3.5 Particulate matter

The polluted air from the eastern European countries biomass burning caused high concentrations of PM in several northern European cities, among them Stockholm, Figure 6. The particle size with the largest impacts on human health is the PM2.5, and these concentrations were substantially elevated in the Stockholm

Fig. 4. Monthly ammonia deposition in throughfall to Norway spruce forests in the county of Jämtland in mid-Sweden. A, the low altitude site Nymyran, 75-year-old Norway spruce forest at an altitude of 300 m a.s.l., B, the high altitude site Fiskåfjället (600-800 m a.s.l.). From Karlsson et al., 2013.

Fig. 5. Hourly ozone concentrations measured at Aspvreten in south-east Sweden. Also shown with a horizontal line is the information concentration above which the EU directive requires the general public to be informed. Furthermore, the trajectory analysis for air masses arriving in mid-day on May 6th 2006 at Aspvreten is shown. Finally an example from a major Swedish newspaper from 7th May 2006, with headlines stating that "Sunny, spring weather conditions resulted in dangerously high ozone levels".



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area in the beginning of May 2006. The WHO air quality guidelines state that the concentrations of PM2.5 should not exceed 25 µg/m3, as a 24-hour mean concentration, and this level was clearly exceeded in the Stockholm area during the air pollution episode in the beginning of May 2006.

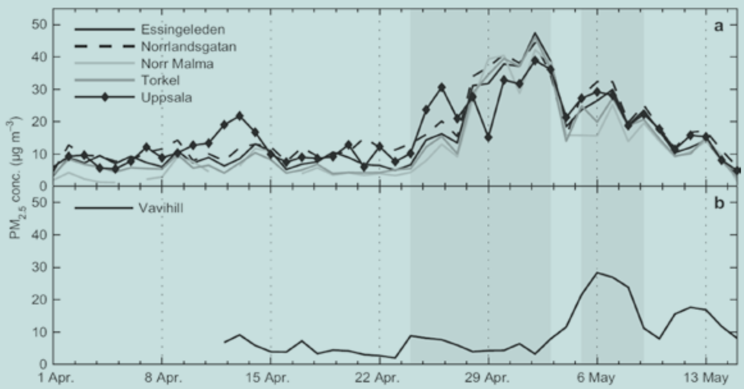


Figure 6. Daily PM2.5 mass concentrations at sites across Sweden. a, Stockholm area; b, southern Sweden. Shaded areas indicate the influence from polluted air from the eastern European countries biomass burning. From Targino et al, 2013.

4. Nitrogen and ozone vulnerability combined with climatic change in the northern latitude ecosystems

4.1 Vulnerability

Atmospheric nitrogen (N) deposition together with ozone might be a threat to biodiversity and ecosystem function. Critically, even low dose N deposition has been shown to have large impacts on plant community development of N-limited ecosystems, which are typically found at higher latitudes (Phoenix et al. 2012). Effects of climatic warming on cold hardiness in northern woody plants and trees have been reported (Ögren 2001). The combination of N pollution and a climatic or a disturbance event can cause major shifts in community composition across multi-trophic levels (Power et al. 1998). Moreover, plants have been reported to be more drought and frost susceptible at sites with higher N deposition (Carrol et al. 1999, Vinebrooke et al. 2004) potentially exacerbating vulnerability to winter temperature fluctuations. Arctic ecosystems are clearly threatened by multiple stressors like winter warming followed by frost chill periods (Bokhorst et al. 2012,) which combined can enhance species responses (Vinebrooke et al. 2004) or lead to unexpected outcomes (Bjerke et al. 2014). Contrasting responses to extreme winter warming events have been reported between deciduous versus evergreen shrubs (Bokhorst et al. 2011), lichens versus mosses (Bjerke et al. 2011). The impacts of N pollution typically include decreases in cryptogams and increases in vascular plants (Nordin et al. 1998, Gordon et al. 2001, Phoenix et al. 2012). A situation with increased nitrogen deposition through precipitation in nitrogen poor vegetation may create favourable living conditions for vascular species. During the winter 2005- 2006, winter warming events occurred (Bokhorst et al. 2012b) on northern Fennoscandia. Additionally, the spring started early in May with subsequent frost chills in mid-May which in combination with the mid-winter warming can have resulted in an increased susceptibility for wooden plants and trees and hence foliar injuries (Mortensen 1999) such as reported in Manninen et al. 2009 and Karlsson et al. 2013.

4.2 Arctic ecosystems

Payne et al. (2013) assessed the critical loads of nitrogen on acid

grassland species throughout Europe and they found the even small loads of nitrogen could harm different species. Change points (reduced biodiversity) strongly converged at an N deposition of 14.2 kg N ha–1 y–1, indicating a community-level ecological (critical) threshold of 15 kg N ha–1 y–1. Approximately 60% of the species change points occur at or below the range of the currently established critical load of 10 to 15 kg N ha-1 h-1. Based on these results they could not rule out ecological impacts from even relatively small increases in reactive N deposition in such ecosystems. Recently, Street et al. (2015) uniquely assessed the potential for tundra heath to recover from N deposition and the influence of phosphorus (P) availability on recovery based on an experimental site in Svalbard. The empirical critical load of N for tundra is set at 3-5 kg N ha-1 yr-1 (Bobbink & Hettelingh 2011). The experiment was established in 1991, in which N was applied at rates representing atmospheric N deposition in Europe (10 and 50 kg N ha–1 yr–1; 'low' and 'high', respectively) for 3-8 yr. They found that Arctic ecosystems are strongly nutrient limited and exhibit dramatic responses to nitrogen (N) enrichment up to 18 years after the treatment, hence the reversibility of which is unknown. High N, with and without P, has many lasting impacts. Importantly, N + P has caused dramatically increased moss abundance, which influences nutrient dynamics. Street et al. (2015) finally concluded that Arctic ecosystems are slow to recover from even small N inputs, particularly where P is not limiting. Hence, fragile and nutrient limited ecosystems in mountains and in the Arctic and Polar regions should be considered as vulnerable and included in future monitoring systems. On the other hand, the amount of nitrogen deposited in northern Fennoscandia has not the yet reached the critical load for nitrogen deposition for most species and types of Arctic vegetation, 5-20 kg N ha-1 yr-1, and is not expected to increase significantly in the future (Bobbink et al., 1998; Aerts and Bobbink, 1999, Hole and Enghardt, 2008).

5. What are the causes for the large-scale biomass burning in eastern European countries?

5.1 Europe without Russia

Regarding fire causes for the large-scale biomass burning there are not consistent or overall annual statistics back in time covering both Europe and Russia. Wildfires caused by burning of crop remnants (arson), carelessness e.g. incorrectly extinguished fires of hikers, berry pickers and illicit agricultural fires are the main causes in East Europe (JRC 2014). For the whole Europe, 60% of the fires in 2006 (JRC 2007) were due to the burning of crop remnants (arson) and 15% were unintentional. Regarding unintentional fires, main reasons are inadequate agricultural and forest management (40%) such as use of fire for cleaning and elimination of forest and agricultural residues. Cigarettes and matches abandoned in sensitive areas constitute 31.7% of fires of unintentional origin (JRC 2007). Natural fires represented 3% of the total number of fires in 2006 and mostly attributed to lightning (JRC 2007).

Although, arson is still the main cause there is a slight tendency to reduction in previous years. The identification of the fire cause is, however, extremely complex and, often, it is not possible to distinguish elements or proofs (JRC 2007, 2014). This explains the large number fires with unknown cause that in 2006 represented 21% of the total number of fires in Europe (JRC 2007). Amongst arson fires, the most important motivation was profit (more than 40% of arson causes).

5.2 Russia

Arson is a widespread practice within modern arable farming in Russia (Goldammer et al. 2013, Shevchenko 2013). The current excessive and unnecessary practice of agricultural burning is recognized as one of the main sources of wildfires. These fires spread to forests and other areas. On average, 30% of large forest fires in Russia around 2006 arise due to agricultural burning (JRC 2007). In 2013, however, agriculture burning was a cause of 4.2% of fire, in comparison with c. 11% in 2012 (JRC 2014). On the other hand, carelessness was the cause of 36.7% of the total number of fires in 2013, which is an increase of 1.2 times compared with the data of 2012 (JRC 2014). Wild fires caused by lightning was very active in 2013 and caused 25.4% of total forest fires, up 2.3 times in comparison to 2012 (JRC 2014). In 2006, 33.7% of fire causes were unknown, but the majority of them was considered to be caused by carelessness (JRC 2007).

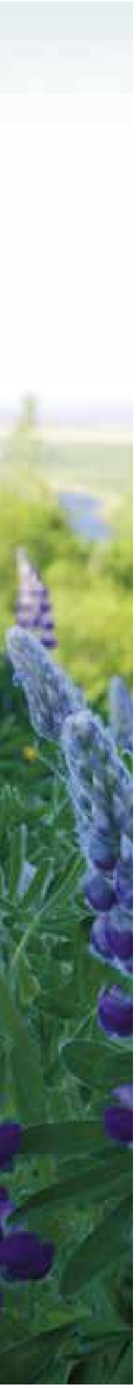
There is a lack of legislative regulation in Russia and there is no clear definition of public responsibility for fire management on various lands, especially at the intersections of natural areas, residential areas, and agricultural lands. Weakened capacity over forestry and decreased fire management capabilities in Russia – as a consequence of the transition of the national economy, often associated with the uncontrolled or illegal forest use and increase of related wildfires (Goldammer et al 2013).

6. How can large-scale biomass burning in eastern European countries be prevented?

The burning of crop remnants continues unaltered due to the fact that it is challenging to effectively use agricultural waste, and lack of viable business models to harvesting, transportation, and storage. At the international level, there are approaches to the utilization of agricultural resides that serve as alternatives to their burning. However, in Russia these alternatives are seldom applicable and cannot be realized due to the weak economic state of agricultural enterprises. As it stands, Russia is not able to use more than half of its annual agricultural wastes. As a result, burning seems to be the only economically appropriate way of utilizing crop residues. Today's governmental subsidies per ha for agricultural producers are very small (€ 15-20 per ha) in comparison with those available in the European Union. Furthermore, there are no structures for the sharing of agricultural knowledge, nor is there the capacity to support the use of methods other than burning.

In addition to the various methods of embedding of crop residues into the soil (for example, ploughing under, low and zero tilling of the soil (no-till)), there are also other alternative methods available, such as the burning of straw in boilers in order to obtain heat energy, the processing of straw in order to obtain biocoal, and etc. However, all of these methods require additional investments into more sophisticated techniques of soil treatment, additional expenses for fertilizers, and more fuel for technical equipment. Moreover, it is necessary to set up and finance consultation services for farmers in order to help them with the implementation of these methods. In order to use straw as a biofuel, it will also be necessary to invest in the industrial production of boilers.

The regulations of Russian Federation pertaining to the prohibition of burning agricultural waste responsible for air pollution are set by the Rules establishing Fire Prevention Regime, ratified by the Decree of the Government of the Russian Federation of 25 April 2012, № 390 "On the Fire Prevention Regime." Clause 218: "Burning of stubble and crop residues and lighting fires on fields is prohibited". Whereas "the questions of environmental protection and ecological security are placed under the joint authority of the Federation and its subjects" (Art.72 of the Constitution of the Russian Federation), the superior legislative bodies of the subjects of the Russian Federation have the right to adopt their own legal acts containing regulations for burning agricultural waste (grass, stubble) and assuming legal responsibility in the case of violation of these regulations. Some regions in Russia has own legislation for ban of agricultural burning. Despite the existing legislative ban on agricultural burning, in practice enforcement of the ban is very lax, and there is practically no control over agricultural fires. This is due weak or non-existent delegation of responsibility between the different agencies. In the other



European countries, information to the public in order to prevent fires seem to be an important measure since the main causes for the wild fires seem to be carelessness and illicit agricultural burning.

In order to reduce the negative impact on the environment, human health and climate, the extent of unnecessary burning in agricultural, pasture and steppe ecosystems in Russia should be prevented by applying the following actions:

- to develop the legislation, law enforcement and management responsibilities of authorities concerning the use of fire on agricultural and pasture lands, as well as on abandoned agricultural lands;
- to promote alternatives to agricultural burning through the development of consulting service for farmers;
- to institute subsidies for supporting the crop production sector in agriculture to apply alternative technologies, following the examples of subsidies in the European Union.

The international exchanges of experiences in preventing wildfires could help to improve situation as well.

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This report describes the effects on air quality and possible vegetation damage in Northern Fennoscandia due to a combination of biomass burning in Eastern Europe and unfavourable weather conditions. A pollution episode due to wild fires in the spring of 2006 is described in detail. These situations can be avoided in the future with the right political actions. This policy brief recommends the Nordic countries to support neighbouring countries in restricting the widespread wildfires. The most important activities include preventing the burning of agricultural waste as well as fire-prevention activities in the forests and providing acquisitions of fire-prevention equipment.

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