**Guidance Document on the Reduction of Agriculture Residue Burning**

DRAFT Informal Document \*

Developed by the Task Force on Techno-Economic Issues (TFTEI) in cooperation with the Task Force on Reactive Nitrogen TFRN

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|  *Summary*  |
| The development of a guidance document on reduction of emissions from agricultural residue burning was included in the work plan 2020-2021, as item 2.2.2. by decision of the Executive Body (EB), at its 37th session in December 2019. The task was assigned to the Task Force on Techno-economic Issues (TFTEI), as leading body in collaboration with the Task Force on Reactive Nitrogen (TFRN). The document will be discussed, as official document, by the Working Group on Strategies and Review (WGSR), at its 59th session in 2021 for submission and adoption by the Executive Body at its 41st session in 2021.   |

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# Introduction

The Executive Body (EB) of the Convention on Long-range Transboundary Air Pollution (CLRTAP) adopted the workplan 2020-2021 for the implementation of the Convention, at its thirty-ninth session (Geneva, 10-13 December 2019). The EB, in Workplan Item 2.2.2, tasks the TFTEI, as leading body, to develop a guidance document on reduction of emissions from agricultural residue burning, in collaboration with the Task Force on Reactive Nitrogen. At the special thematic day on agricultural opening burning, held back to back to the 5th annual meeting of TFTEI (Ottawa, 21-23 October 2019), experts presented background on definitions and best practices related to open burning, and agreed to develop a draft document, to be prepared by the International Cryosphere Climate Initiative (ICCI) experts. This document provides an initial draft and structure for such as Best Available Techniques (BAT)/ Best Available Practices (BAP) report, for presentation by the co-chairs of the TFTEI at fortieth meeting of the Working Group on Strategies and Review, where the Parties’ experts will be invited to provide their feedback/comments on the document . The document will be further refined in consultation with Parties experts, until achieving a consolidated and agreed text within the WGSR, at its 59th session in 2021. The final document is expected to be adopted by the Executive Body at its 41st Session in December 2021. The main objective is that of reducing the emissions of air pollutants and short-lived climate pollutants (SLCP), especially black carbon (BC), and their impact on human health, environment and climate change, from this sector.

*The guidance document includes:*

* *Scope involves all use of fire in agriculture as practiced in the UNECE region on cultivated lands (e.g, not including wildland management fires)*
* *Report to include descriptions of monitoring and characterizing set agricultural fires and their emissions and measures to limit such emissions*

*Time schedule of work on the document: [this list serves as a memo to the reviewers and will be deleted in the final official document]*

*1) Receiving* *comments/amendments/contributions from Convention experts,* ***on voluntary basis****, (by 31st of August 2020)

2) Discussion of the revised draft report at the 6th annual TFTEI meeting (22-23 October 2020, Warsaw, Poland)

3) Further review and improvement of the draft report, including the outcomes of the 6th annual TFTEI meeting, and taking into account of the further comments from the experts (received within the 30th of November 2020)

4) Finalization of the document by TFTEI co-chairs and ICCI experts in December 2020 and January 2021

5) Submission of the final draft, as official document, to the UN Secretariat, by end of January 2021, for consideration of WGSR at its fifty-ninth session (2021).

6) Final adoption is expected by the Executive Body, at its the 41st session, in December 2021.*

# II. Subject Matter and Scope

 The purpose of this document is to provide the deliverable related to item 2.2.2. in the Work Plan 2020-2021, for the implementation of the Convention, consisting of this guidance document on reduction of emissions from agricultural residue burning. The document will focus on the following issues:

* Guidance document on good practice and measures for the reduction of emissions from use of fire in the agricultural sector
* Best Available Techniques (BAT) and Practices (BAP) for fire-free agriculture alternatives. As regards BAP, this document also includes additional policy measures that can contribute to the reduction of emissions and impacts from use of fire in agriculture, such as subsidies for fire-free practices and loan support for alternative equipment, as useful background (section IV.C). Section II.E also provides a brief survey of existing regulatory and supportive measures that may contribute to adoption of best available practices and technologies, with respect to reducing fire use in the agricultural sector, as adopted in some UN-ECE countries with good success.

 This document also fills a need to inform Parties to the Convention on Long-Range Trans-boundary Air Pollution and other stakeholders, even outside the United Nations Economic Commission for Europe (UNECE) region, about the available best practices and technologies for fire-free agricultural approaches and alternatives.

**A. General Background**

 Open burning in agriculture is a practice with deep historical roots. Farmers burn for a variety of reasons, and rarely simply as a tradition. The practice for example occurs to cheaply remove excess straw that might otherwise snare or break plows; to remove insect pests and weeds; or to “fertilize” the soil with ash (a common misconception due to the black appearance of charred earth).

 Open burning exacerbates impacts of tillage and erosion by making the soil more brittle. Soil is left bare and particles are prone to wind and water erosion, losing organic matter to burning in the surface horizon, which is the richest layer. Not only stubble or grass burns, in other words; also the organic matter in the soil is lost. This makes use of fire in agricultural systems a cause of net loss of carbon, either as Carbon Dioxide (CO2)or methane. Loss of soil organic matter due to its combustion carries other consequences, such as decrease in soil fertility (organic matter carries nitrogen, phosphorus, etc.), reduction in soil infiltration rate and many other tangible economic impacts to the farmer. In addition, a quarter of all living organisms exist in the soil; so global biodiversity is also impacted.

 This “burned off” loss of fertility must be countered by greater use of expensive fertilizers to maintain crop yields, accompanied by greater erosion and soil run-off caused by the more brittle burned soil structure. Additional impacts of burning therefore include degradation of local water systems from added fertilizer and soil incursion, and greater need for water resources for irrigation, at a time when such resources already are under stress from climate change and glacial loss. Additional use of fertilizers also implies additional emissions of air pollutants such as ammonia (NH3), causing secondary particle formation. These negative environmental impacts are accompanied by negative direct human health impacts from air pollutant emissions and smoke, which in some cases can be extreme (such as New Delhi, 2017, 2019).

 In contrast, no-burn methods not only eliminate emissions of Particulate Matter 2,5 (PM2.5 ), Volatile Organic Compounds (VOCs), black carbon and greenhouse gases (GHGs), but also provide some level of adaptation and resilience to climate change and extreme weather events. This is particularly the case for low-till and especially, no-till methods, especially when combined with use of cover crops and injected manure (a suite of agricultural methods termed “conservation agriculture” or CA). Other no-burn methods also aid sustainable development, for example use of straw stubble for bio-energy or cook stove fuel to preserve local forest resources.

 The negative impacts of burning, especially crop yield loss and increased fertilizer costs, translate into decreased income for farmers and puts into danger food security. Once demonstrated, this impact of burning on profits -- not initially understood by many farmers, who burn only because they believe it necessary – eventually drives demand for alternatives. In many regions of Latin America with large agri-businesses – Argentina, Brazil, eastern Bolivia – this transition to no-burn methods already has occurred entirely for economic reasons. In Western Europe and North America, human health impacts (including traffic accidents caused by residue burning) together with regulatory measures and incentives have driven this transition more quickly, which often require some initial investment in no-burn equipment, methods and training. With European Union accession, Poland and the Baltic nations decreased burning by 90% in just five years, showing that a transition to no-burn methods can occur rapidly with such supports (a combination of phasing in increasingly-strict EU regulations, with farmer subsidies to ease the transition). However, in a number of LRTAP Parties, including the EU and North America, farmers still make use of open burning for a variety of purposes. In a warming climate, such use of fire has led to extensive wildfires, especially in southern Europe, in recent years.

**B. Human Health Impact**

 Of greatest relevance in the air quality context, studies demonstrate that on a global basis, open biomass burning causes 5-10 percent of air pollution deaths (approximately 250,000 deaths annually). Recent studies[[1]](#footnote-1) [[2]](#footnote-2)note that PM2.5 from agricultural sources, primarily fires, is the main contributor to premature mortality from air pollution for East and Southeast Asia, the eastern U.S., Europe and Russia/Ukraine.

 The summer 2010 fires in European Russian showed the degree to which smoke from open agricultural burning significantly and negatively impacts human health, with Russian authorities estimating that 25,000 to 54,000 additional deaths occurred that summer in Moscow alone from a combination of air pollution from fires and high temperatures[[3]](#footnote-3). In Delhi, during the November 2017 fire emergency, PM2.5 levels sometimes peaked over 1000 (parts per million) ppm, well above rates with documented acute and severe health effects, especially among the very young and very old.

 More recently, authorities have focused on the longer-term impacts of smoke exposure, even to a single exposure, over a longer fire period. Much of this research interest has come due to more frequent wildfires in a drier and warmer climate, especially in the western U.S., for example measured as emergency room visits for respiratory distress and lasting at least a year after the fire event, with monitoring continuing.[[4]](#footnote-4) This indicates how the effects of a single exposure incident may be long-term, with the very young (<4), the elderly and those with existing respiratory conditions most seriously affected. Consistent evidence from a review of more than 50 peer-reviewed articles from Asia, Australia, Europe, and North America that smoke exposure from biomass burning leads to respiratory morbidity in general, with specific exacerbations of asthma and Chronic Obstructive Pulmonary Disease (COPD). [[5]](#footnote-5)

Accidents and direct fire-related injury and death comprise an additional health impact of open burning[[6]](#footnote-6). Indeed, the OECD (Organization for Economic Co-operation and Development) nations first began addressing open burning due to its impact not only on health from an air quality standpoint, but accident mortality and morbidity. Direct injury and mortality from fires, occurring among both local inhabitants and firefighters is an annually occurring health impact of this practice, which becomes especially acute when set agricultural fires spread to become wildfires in a hotter and drier climate.

 Greater rates of pollution and eutrophication occur in nearby rivers, lakes and waterways, including the Baltic, due to higher needed fertilizer application on burned soils (see section II.D), negatively impacting local populations and water eco-system based services and industries, such as drinking water, fishing and tourism.

**C. Climate Impacts**

 Climate impacts from open burning arise from both Carbon Dioxide (CO2) and other GHG emissions, and those of so-called short-lived climate pollutants (SLCPs). SLCPs in this context refer primarily to the three pollutants methane, BC and ground-level ozone (which is not emitted directly but arises from interactions between sunlight and other emitted pollutants (precursors), especially methane, CO and NOx). SLCPs remain in the atmosphere for a few days to several weeks, with up to 12 years for methane. This means their abatement can have an almost immediate positive impact on climate and temperature.

 BC is an especially potent warming agent when it wafts over or especially, deposits directly on ice and snow, and has been associated with greater rates of snowpack and glacier loss. While emissions from fires not close to cryosphere (snow and ice regions such as the Arctic, Alps or Rocky Mountains) or other highly reflective surfaces might be cooling in the short-term due to co-emitted substances such as light organic carbon or sulfates, close to cryosphere all fires warm regionally due to this albedo feedback; and GHG emissions from fires are of course warming under all conditions. Agro-forestry sector open burning comprises the single largest source of BC emissions globally, at over one-third of the annual total (approximately 2700 Gg or 36%[[7]](#footnote-7)).

 In terms of CO2 emissions, set agro-forestry fires were long considered essentially “carbon neutral,” because it was assumed the same amount of carbon lost to fire would be fixed by the subsequent year’s crop. As understanding of soil carbon cycles has grown however, it has become clear to the vast majority of researchers that due to loss of humus, soil structure and the soil itself, more carbon is lost from the soil annually than can be replaced by any subsequent crop. The amount of carbon lost almost certainly varies between soils and cropping systems; but of note, the heavily burned and cultivated soils of Punjab, India today are essentially devoid of carbon. This is a very active current area of research, also in terms of the degree to which changes in cropping systems might serve as future carbon sinks in more modern, no-burn cropping and forestry systems.

 With field and forest burning no longer seen as carbon neutral, these emissions from open agricultural burning have the potential to eclipse current national GHG emissions estimates. Historically, most countries either have not included, or have underestimated open burning emissions due to the difficulty of tracking fires year-to-year, as well as reporting bias given that many countries have (largely unenforced) laws banning burning, leading to an erroneous emissions estimate of “zero.” However, developments in satellite monitoring technology over the past decade have provided an unusually accurate and neutral method for calculating open burning emissions today. Current Visible Infrared Imaging Radiometer Suite (VIIRS) satellite technology has allowed for increasingly fine resolution not only of fires or burned areas (the older Moderate Resolution Imaging Spectroradiometer (MODIS) technology), but the existing crop prior to burning, allowing for far more accurate emissions estimates of CO2, methane, BC and other species from a given crop burned under given conditions (see Section IV.D).

**D. Agricultural Impacts**

 Open burning primarily decreases soil’s productive capacity by destroying the humus (organic matter) and soil consistency vital to good yields. Studies show that crop yields on burned fields average 20-35% less. Conversely, burned fields require around 25% more fertilizer to hold yields steady. With each successive burn, soils lose more nutrients – not only nitrogen (N) and phosphorus (P), but also carbon.

 Lack of humus and the high heat of burning also compacts the soil, making it more brittle and prone to erosion by both wind and water. Such erosion is most evident on hillsides, but also occurs by wind erosion on flatlands, where soil levels drop each year as burning and plowing cause topsoil levels to diminish. In one comparison between a no-burn farm in Chile and its neighbors that practiced burning, land levels were a full meter higher compared to neighboring burned fields over 30 years of measurement. Similar impacts can be seen on agricultural lands where cement wells and water cisterns, originally dug at soil level or below now sit some meters above the current ground level. Where irrigation is necessary, larger amounts of water must be used to compensate for more brittle soils, further depleting supplies already under stress in a warmer climate.

 After burning and related erosion, whatever remaining fertility naturally remains in the soil comes from the deeper layers under the burned portion; reaching in other words successively deeper and deeper into the earth as soils erode until at some point, no topsoil remains, as can be seen in some portions of the Andes today. Greater fertilizer run-off also occurs from brittle soils less able to maintain the fertilizer in-place. This results in higher supply costs to the farmer.

 These negative impacts hold for all uses of fires in the agro-forestry sector, though of course are greatest where use of fire occurs annually or even two-three times each year; where fire occurs on marginal lands such as those in high boreal regions; or in mountainous regions with only a thin layer of topsoil. Use of fire even once in such ecosystems can limit agricultural use to just a few seasons or crops; after which time the user moves on, leaving a depleted and eroded landscape difficult or impossible to restore to its prior condition.

 This rule also holds for forestry burning used to clear before tree harvest on steep lands with little topsoil. Once the trees are harvested, the remaining land, even if planted with new seedlings, remains much more prone to erosion and landslides, especially in the first seasons after harvest. Pasturelands similarly do not benefit in “fertility” after a burn: while some non-grass and invasive species may be removed, research has shown that the quality and livestock nutrition of such pastures is lessened after each burn unless fertilizer is used, an investment rarely employed by herdsmen especially in developing countries.

 To summarize, while burning may meet certain short-term needs, the overall damage to soil structure, fertility, and even complete loss due to erosion make its use in the agricultural and forestry sectors rarely if ever motivated from any longer-term economic standpoint, let alone those of sustainable agriculture.

**E. Existing Policy and Regulatory Measures**

 Use of fire in agricultural systems has been regulated in some UN-ECE countries since the early 1980’s, often at the sub-national level, in order to deal with specific local conditions and policy goals. These differing underlying motivations often have impacted the scope of such measures, especially as these evolve over time: These include:

* Prevention of wildfire spread, by controlling when burning can occur, e.g. requiring permits to prevent burns under too-dry conditions;
* Visibility concerns for aircraft and ground vehicles, which may require permits per the above, or prevent use of fire near airports or major highways;
* Air quality concerns, often connected to overall PM10 or PM2,5 emissions limit values, including compliance with NEC directive by EU Members States, resulting in such stringent requirements for burning as to comprise a de facto ban;
* Concerns with soil quality and erosion, especially the prevention of large-scale dust storms and loss of topsoil, also comprising de facto bans.

 These varying goals often have led to patchworks of measures, but with evolution over time of policies moving towards de facto bans, due to the large geographic area over which smoke and dust may spread as a result of agricultural sector burning. Nevertheless, such measures are not uniformly enforced and in some countries, broadly ignored by both farmers, and local authorities, especially where farmer support and education (often referred to as agricultural extension services) are weak or non-existent in supporting such transition to fire-free alternative methods.

**III. Definitions**

 ***Open burning in agriculture*** is defined as all intentional burning in the agro-forestry sector, including stubble and pastureland burning and use of fire to clear fallow lands, and the wildfires that spread from such set intentional burning in the agro-forestry sector. It excludes only prescribed burns on wildlands for the prevention of wildfire, or to restore fire-dependent ecosystems.

 ***Conservation or no-till agriculture*** refers to a set of practices that involve no tilling (plowing) of the soil, in concert with other practices, such as use of cover crops.

 ***Low-till agriculture*** involves minimal tilling of the soil (plowing only the very top layer).

 ***Conventional tillage*** involves use of multiple instruments – plows, seeders, rotors, etc. – that deeply work the soil.

 ***Fallow lands*** denote fields once used for agriculture, that have been abandoned with various levels of incursion from vegetation and succession, from weeds to (over periods of many years) scrublands or forest.

 ***Wildlands*** refer to forests and grasslands that have never been used for agriculture, or restored to a natural or wild state from previous agricultural use. Some of these wildlands involve fire as a natural part of the ecosystem.

 ***Prescribed burns***, as used in this document refers only to use of fires in wildlands or to prevent spread of wildfires.

 ***Managed burns***, as used in this document refers to permitted use of fire on agricultural lands.

 ***Bio-energy*** involves use of biomass and other biological material (manure) for production of energy, including fuels such as pellets, biogas and ethanol.

 ***Wildfires*** are fires that either spread unintentionally from human activity, or from factors such as lightning strikes (primarily in high altitude or high latitude boreal regions) or spontaneous combustion under extremely dry conditions. Estimates show that up to 90% of wildfires spread primarily from open agricultural burning, especially when this occurs near forests; but human causes include also trash fires, sparks from electrical transmission lines or human actions such as hot items thrown from highways vehicles or trains.

**IV. Alternative Fire-free Agricultural Methods**

**A. An Integrated Approach**

 It should be noted at the outset that the specific fire-free methods to be utilized will vary dependent on a variety of factors: crop, pasture, forestry or small landowner environments; relative scale of different practices; and availability of alternative equipment, including financing needs. Successful measures have largely taken a “three legs” approach to introduction of fire-free agricultural systems:

1) mapping and monitoring to define the problem,

2) education of farmers, and

3) growing regulation on the heels of or in concert with farmer education and extension services, including at times subsidies or other incentives for adoption of no-burn systems.

Activities may encompass:

i) Satellite and on-ground mapping open burning patterns from the field- to regional-level, including retroactive satellite mapping over a period of at least several years, to identify the largest and most persistent open burning emission sources (see Section D, below);

ii) Education and demonstration of the available solutions to the largest and most relevant open burning practices to farmers through provision of extension services, including local partnerships with entities focused on more sustainable agricultural practices (NGOs, civil society, state and federal extension services, agribusinesses, among others);

iii) Introduction of measures, both regulatory and supportive (subsidies, equipment loan guarantees, etc.) specific to these most relevant uses of fire, in order to both support the transition, and ensure compliance by those who may lag behind. Bringing together experts, policymakers, and progressive farmers for strategic support to discuss and troubleshoot practical solutions through conferences, meetings, and workshops.

 It is important to note that these “three legs” should occur sequentially to ensure the most effective and high-impact (in terms of both emissions, and use of resources) measures. Mapping must occur first to ensure the most important sources are the first addresses. Farmer education and support must occur prior to, or at least in concert with, any regulatory measures. The most significant failures in addressing open burning over the past 40 years (and there have been many) have occurred when authorities introduce burning bans without adequate support and extension services already in place. In general:

* With proper extension/training, alternative methods help farmers save money on manual labor, fuel, and fertilizer; and can equal or improve yields, while also helping to conform to laws banning open burning as well as water management (by requiring less irrigation).
* Informing farmers about the economic benefits of fire-free resource conservation methods versus the economics of conventional fire use can address the issue of open burning, in some examples by 90% or more.
* With the proper resources (human and capital), burning can be all but eliminated at very low or negative costs.

**B. Available Alternatives to Open Burning**

 Although no-burn technology and methods are available for all agro-forestry systems, plots, crops, farmers, and weather conditions may vary considerably from place to place, requiring region-specific approaches. Below are outlined some of the chief methods or systemic approaches. These systems can encompass ***in-situ*** (on-field) and ***ex-situ*** (off-field or off-farm) residue management strategies. In-situ includes reincorporation into soil, conservation agriculture (no-till, minimal till, strip till, etc…), and use for feed and fodder. Ex-situ can involve third parties interested in using residue a primary material for energy production (biogas or other biofuels) or for construction (bricks, pellets, furniture).

**1. Conservation Agriculture**

 Conservation Agriculture (CA) is seen as the most important alternative to conventional burning-tillage agriculture, replacing conventional agriculture globally at the annual rate of some 10 M ha (hectares) of cropland because it offers many benefits to farmers and society. In 2016, CA cropland area covered some 180 M ha globally (12.5% of global cropland). CA systems are ecologically underpinned by three interlinked principles of:

1. No or minimum mechanical soil disturbance (through the practice of no-till, direct seeding and crop establishment and no-till weeding)
2. Maintenance of soil mulch cover (through the practice of retaining crop residue, stubble and biomass from cover crops)
3. Diversified cropping (through the practice of crop rotations or sequences or associations; including use of cover crops involving annuals and perennials such as legumes, which increase soil fertility)

 The main reasons for adoption of CA can be summarized as follows:

(a) better farm economy (reduction of production inputs of seeds, fertilizer, pesticides and water, and lower costs in machinery and fuel, and time-saving in the operations that permit the development of other agricultural and non-agricultural complementary activities);

(b) flexible technical possibilities for sowing, fertilizer application and weed control (allowing for more timely operations);

(c) equal yields or yield increases (depending on the starting level of soil degradation), greater yield stability (as long-term effect) and higher overall seasonal production;

(d) soil protection against water and wind erosion;

(e) greater nutrient use efficiency and retention;

(f) fewer crop protection problems and costs; and

(g) better water-use efficiency and retention, and better water economy including in dryland areas.

 No-till and cover crops can also be used between rows of perennial crops such as olives, nuts and grapes or fruit orchards, and in palm oil plantation systems. CA can be used for winter crops, for traditional rotations with legumes, sunflower and canola and in field crops under irrigation where it can help optimize irrigation system management to conserve water, energy and soil quality, reduce salinity problems and to make fertilizer use more efficient.

 The above principles when put into practice with locally formulated adapted practices, along with other best management practices of integrated crop, nutrient, pest, water, energy, labor and farm power management, have shown in all continents the ability to transition from conventional burn-tillage agriculture.

**2. Low-Till Practices**

 Low-till involves some use of plowing and tillage equipment, but this is minimized and residues are incorporated back into the soil. It shares some of the advantages of full CA, and for many farmers represents an intermediate step from tillage-and-burn agriculture. It also is a necessary tool in some ecosystems where organic matter does not decompose quickly enough or where there is insufficient growing time to deploy cover crops, for example in very cold and dry regions.

 This alternative requires that farmers have access to the appropriate machinery and fuel, as well as the capital to pay for it; but is often the least capital- and labor-intensive of all no-burn alternatives. It also tends to find easier acceptance from farmers, as it simply involves omitting burning from field preparation.

 Provision of or support for higher-quality steel plows that break through thick stubble is enough in these cases to halt burning entirely. Choppers added to harvesting combines, dedicated choppers or simply tractors with improved plows can also better enable stubble to be incorporated into the soil. Where soil has suffered from decades of burning, incorporation may be a necessity simply to restore the soil to a more fertile state, one that requires less fertilizer and irrigation.

 In addition to minimal tillage of entire fields, some farming systems employ strip till, which involves working the soil still to deeper depth, but only in narrow strips where seeds are actually planted.

**3. Alternative Use Practices**

 Alternative *ex situ* use of crop and forest residues range from low-tech, on-farm uses such as animal fodder and bedding, to advanced technologies such as district heating plants using biogas or pellets manufactured from crop or forest residue. Both require additional equipment and investment to gather the residue, and (for the high-tech alternatives) creation of a market value chain and initial high levels of investment in for example, district heating plants. These high-tech alternatives are therefore more long-term in nature compared to in situ best practices and technologies, and also dependent on other market conditions such as costs for fossil fuels or creation of subsidies.

**a. Animal Feed and Bedding**

 Some crop residues can also be used as animal food and bedding. Even if its nutritional value is not the same as residues from pasture, it can be also of great value for small-scale farmers. In some countries, loss of a viable livestock industry has been the proximate cause of increased burning, when this alternative use was no longer needed. Certain crop remnants such as maize have sufficient nutrition to serve as alternate fodder; less digestible residues may be used for bedding.

 **b. Bioenergy**

 Various crop and forest residues can be converted into biochar, pellets, briquettes, and building materials. Compared to open burning, these techniques produce lower emissions of air pollutants, and at the same time can reduce reliance on fossil fuel for energy purposes. The use of agricultural residues for energy, unless it occurs directly on-farm, requires refineries, transportation and a distribution network. Nevertheless, especially with initial subsidies this method is becoming increasingly practiced at both the on-farm and regional level in a number of UN-ECE countries.

 i. **On-farm energy production** most often occurs on farmers with both livestock and crop production, where crop residues are mixed with manure to produce biogas in smaller on-farm “cookers.” The biogas is then burned to provide the farm with energy, and excess may be sold to local distribution networks.

 ii. **District heating** normally refers to heating from pellets produced from crop and forest residues. It is especially used in conjunction with forest understory clearing and timber waste products (see IV.5, below).

 iii. **Production of bio-fuels**

 (a). **Biogas** is normally produced as part of an integrated approach to waste management, often in close proximity to urban areas and where residues are mixed with manure and other organic materials from businesses and households. Producing biogas solely from crop and forest residues is not currently a viable technology, and most biogas technologies can only incorporate 10-20% crop residues in the total biomass used, with manure or food waste being the chief component. The biogas is then used as fuel for a variety of purposes similar to natural gas, from biogas vehicles to stoves and furnaces.

 (b). **Ethanol** can be produced solely from crop residues, in contrast to biogas. However, ethanol as a fuel is rarely in demand in UN-ECE countries.

**5. Forest/Orchard/ Fallow Land Residues**

 Emissions from forest/timber farms, orchard or fallow land residues comprise a potentially large source of emissions in the UN-ECE region, especially when risk of wildfire spread is taken into account. Timber farms produce large amounts of residue through both periodic clearing of underbrush to promote commercial tree growth, and during the harvesting process, when trees are entirely stripped of branches for easier transport. Underbrush or residue from forest harvest can present a fire risk, as well as present barriers for timber growth or re-growth. Orchards similarly require clearing of undergrowth, as well as periodic pruning of branches that need disposal. Fallow agricultural lands placed back into production require clearing of anything from low grass and brush, to removal of larger trees and bushes.

 In all these cases, use of fire presents an easy and cheap method to remove the excess biomass, though often with extreme risk of wildfire spread due to the nature of all these land use types, which by definition are in close proximity to other forests and fields. Risk of wildfire spread has grown as a result of climate change, with more frequent periods of drought and high temperature. Burning under wetter conditions however produces larger amounts of PM2.5 and other pollutants due to the low fire temperature[[8]](#footnote-8).

 Alternative fire-free methods do however exist and are in wide deployment in some UN-ECE countries. In situ methods chop and spread the excess biomass, often with a single large machine, similar to no-till and low-till methods on crop lands. This can be especially useful when clearing fallow lands for new production, or when clearing orchard understory, beginning to build humus and decreasing need for fertilizer.

 On timber farms, excess branches and biomass most often are placed in large piles near timber roadways, where they can most easily be transported for conversion to pellets for district heating; to wood mills where they are mixed with other timber by-products for a variety of uses such as paper; or chipped into mulch.

 Unlike low-till and no-till methods on croplands however, these methods rarely prove negative cost to the producers, except over longer time spans. They therefore may require some level of supportive government economic measures, to varying degrees based on rural economic conditions.

**6. Pastureland Practices**

 Burning of pastures remains a practice in some UN-ECE countries, as well as globally, especially in the annually set savannah fires of sub-Saharan Africa (which might comprise the single largest global source of BC and PM2.5 annually). Just as with cropland burning, pasture fires however decrease soil fertility and ultimately, yields of grass for grazing or hay for harvest. Since pasture often forms part of livestock operations, farmers often spread manure on the surface of both burned and unburned fields in springtime to compensate for loss of fertility, a practice that can result in excess ammonia and eventually, nitrous oxide (N2O), a powerful GHG. Spreading of manure to compensate for nutrient loss from burning also pollutes nearby waterways, especially because the burned fields are more prone to erosion.

 More sustainable and fire-free practices involve gathering of hay without burning on pasturelands not used for direct grazing. Some portion of grass or stubble may be left on the field to decompose, or occasionally turned into the soil. Manure can also be injected, rather than spread onto the field surface.

 A second fire-free practice that reduces the need for fertilizer is rotational grazing, including on fields also used for harvest of hay. Grazing livestock provide a more spread-out application of nutrients into the soil, decreasing or even eliminating need for additional application of fertilizer to maintain soil fertility. Grazing also holds down incursion of non-desirable weeds into the pasture or hayfield, another reason sometimes cited for pastureland burning.

**7. Wildland Management**

 Protection of wildlands (protected forests not used for timber production; protected grasslands or savannah; and protected wetlands, peatlands, fens and bogs) may involve periodic use of fire. This use of fire is not considered “agricultural open burning,” for two reasons:

 - Some wildland ecosystems are dependent on periodic fire events to maintain their natural state, with a number of species actually fire-dependent for seed dispersal, germination or regeneration. Such lands require use of fire for ecological functioning. However, it is noteworthy that this kind of burning is far less frequent than in human agricultural systems, often occurring on mutli-year or decadal scales, rather than the annual (and sometimes, three times annually) burning deployed on some croplands and range/pastoral systems.

 - Reduction of wildfire risk under extremely dry or drought conditions sometimes requires prescribed burns (burning conducted professionally by wildland firefighters, under extremely controlled conditions). Such burning is unavoidable especially when occurring during active wildfires. The need for such burning however can be lessened to some degree by regular proactive clearing of brush by mechanical means and for alternative use, as outlined in IV.5, above.

 For the purpose of decreasing agricultural open burning, it is important that wildland management fire practices not be conflated with other, unnecessary use of fire in agro-forestry systems outlined in sections IV.1-IV.6, above.

**C. Supportive Services and Measures**

 Successful implementation of the above fire-free practices can be aided by a number of supportive services, measures and regulation; especially to enable more rapid adoption to decrease PM2.5 and other emissions even where such measures are economically advantageous to the farmer.

**1. Extension Services – Training and Education**

 Education, training and demonstration plots are key for success of the transition to no-burn, fire-free agriculture. Many farmers remain unaware of the economic advantages of fire-free methods, as well as their implementation. Experience from demonstration projects show high levels of interest and demand for no-burn technologies and approaches once this connection is made. It is therefore important to develop knowledge of no-burn practices among agricultural extension service providers, whether public or private, to address the varying needs of different crop systems. Such services are capable of educating and training farmers in issues related to the new climate-smart agricultural paradigm to generate sustained change.

**2. Equipment**

 Mechanization covers all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorized equipments. Demonstration of conservation agriculture and low-till equipment can help communities make the transition. There are different options according to the size of the farm/plot: manual, animal-driven or tractor-driven; with many manufacturers and options throughout the UN-ECE region. However, this is also a national opportunity to develop national equipment adapted to regional conditions. In addition to potential support for equipment purchase or leasing (see section C.5, below), manufacturer or extension support for troubleshooting and to ensure proper equipment maintenance is key to continued and sustained use.

**3. Communication: Awareness raising, Community Engagement and Advocacy**

 Open burning is also a behavioral problem, and can be addressed through regular social interaction, shifting the mind-set of farmers and society alike by providing timely and required training and information. Constant engagement and updated, timely, and concise knowledge about advancements in the field of agriculture brings changes in attitude and behavior. Involving local institutions such as schools and farmer cooperatives can also effectively address issues around open burning. Other examples of supportive communications measures may include:

- Distribution and publication of residue management manuals for farmers, informative leaflets (e.g. through local post offices);

- Real-time mapping of fire seasons, including spreading to the general public as well as farmers, to better associate negative air quality events as well as wildfire spread with burning in the agro-forestry sector, this emphasizing the current negative impacts as well as potential future benefits such as avoided wildfire damage.

- Media broadcasts, infographic videos and websites, formulation of social media groups;

- Organization of seminars, press tours, and other media support to facilitate accurate solution-oriented coverage of open burning issues;

- Farmers-agronomist meetings, field days with exposure visits to demonstration plots and farms of progressive farmers associated with crop residue management;

- Engagement of institutions such as local administrations, schools and universities, identifying and training of ambassador farmers/opinion leaders.

**4. Market Development**

 A number of academic and commercial start-ups have developed different systems that use straw and/or biomass to produce bio-energy at the community level. For longer-term solutions, value chain creation for use of agricultural and forestry residue might be supported where such energy needs exist through public finance, private entrepreneurship or public/private partnerships.

**5. Financing**

 Farmers often need access, including financial assistance, to purchase or lease appropriate equipment. Government subsidies for locally manufactured farming equipment that helps to avoid burning (among many other benefits) have often proven to be a useful tool.

 Such financing is not a universal barrier and due to the greater crop yields and less fertilizers used, an issue of initial transition only. There are no instances reported of regions that have adopted no-burn, especially conservation agriculture techniques returning to use of fire. Farmers simply save money through higher yields and lower costs for fertilizers and fuel.

 The potential role of direct subsidies for rapid conversion to no-burn methods should not be ignored, much as supports currently exist for leaving some degree of croplands fallow for ecological management purposes. Current satellite technologies (see IV.D, below) could serve a monitoring function for such programs, with subsidies paid out immediately upon planting with a new crop, regardless of the no-burn method chosen. If immediate cessation of burning is desired, this might prove the best initial approach, with more sustainable solutions introduced over time.

 Financial incentives even for larger farms might therefore speed this transition. Medium and small-size farmers are more likely to require initial financial support at some level to make this transition, lacking the capital needed for initial investment in no-burn equipment such as direct seeders, cover crop seeds, or (on a more expensive scale) equipment for electricity, pellet or biogas production from different residues. While some policies to encourage a more rapid transition among large commercial farmers will also be an asset, provision of training and education to farmers of all sizes could be the most desired and effective public financing alternative.

 Additional supported investments could be devoted to equipment to inject manure into the soil (for combined animal husbandry and crop production), harvest pasturelands for hay rather than burning off excess growth, or support purchase of initial cover crops (plants such as clover or legumes planted in-between cash crops, in essence providing a fertilizing function).

**6. Governance and Regulatory Measures**

 In those countries in the UN-ECE region with effective regulation for use of fire in agro-forestry, such measures generally have been introduced successfully only in concert with other farmer-supportive measures, as noted above. Rarely, if ever are across-the-board bans without such supportive measures either effective, or enforced; as they do not address the underlying reasons for the specific use of fire under different ago-ecological conditions.

 Some countries or sub-national regions, rather than support transition to fire-free agricultural methods have instead deployed “managed” or permitted burning on croplands. Such permitted burning however aims only at preventing the spread of wildfire and associated air pollution and infrastructure damage, by prohibiting use of fire under dangerously dry conditions. It does not address the economic dis-benefits arising from soil fertility loss and other negative impacts on the farmer and local communities. Some wildfire spread still can occur with permitted agricultural burning, and satellite studies have demonstrated that emissions in regions that allow managed burns still have approximately twice the level of emissions as those which effectively prohibit use of fire except under exceptional circumstances.

 Specific inclusion of CA (or other no-burn practices) could be added to national or sub-national regulatory mixes, especially in regions where satellite monitoring shows persistent use of fire. By means of the Common Agricultural Policy (CAP) for example, Member States of the EU have been able to provide incentives to farmers to adopt soil and water conservation practices that are also climate-smart.

**D. Monitoring and Evaluation: New Satellite Technology and Support**

 One key aspect to ensuring valid reductions of emissions of PM2.5, black carbon, ground level ozone and VOCs as well as GHGs and related co-benefits is the recent ability to characterize via satellite monitoring the crop vegetation in question, and therefore the related decrease in emissions arising from adoption of fire-free agricultural practices and technologies.

 Current satellite technology (VIIRS, has allowed for increasingly fine resolution not only of fires or burned areas but the existing crop prior to burning than the older MODIS, technology. This allows for both verification of compliance, and calculations of avoided emissions over time. Current resolution was confirmed in 2017 studies as accurate down to the 50m2 level.[[9]](#footnote-9) It may also be an effective way of improving national emission inventories of PM2.5 and BC. Additional fusion approaches from open-source imagery at 30 m (Landsat) to 10 m (Sentinel constellation) allows for field-level verification of VIIRS active fire and generation of burned area at the weekly time scale.

 Although not easily quantifiable, some of these emissions occurred from wildland fires, rather than fires on agro-forestry holdings. However, a large majority of wildfires and related emissions spread from set fires in the agricultural sector or other human activities such as trash burning, with estimates of around 85% in the United States, for example between 1992-2012, based on published government data.[[10]](#footnote-10) Such wildfires, which are occurring with greater incidence given higher frequency of hot and dry conditions, will also be avoided through increased use of no-burn methods in the agricultural sector: an important co-benefit which can also be monitored at the regional and national level as use of fire in the agricultural sector decreases.

 In addition, while negative carbon emissions within agriculture remain difficult to quantify with acceptable uncertainty, ongoing research in this field might make it possible to further characterize or monetize the benefits accruing from no-burn methods over time in terms of carbon drawdown into the soil, especially when conservation agriculture methods are used as the alternative to burning.

**V. Situation in EECCA countries**

 The Eastern Europe, Caucasus and Central Asia (EECCA) Member States and Russian Federation have great potential to decrease emissions from open agricultural burning; which are on average eight-nine times[[11]](#footnote-11) that of other UN-ECE regions due to a variety of factors, often tied to changing agricultural economic conditions. The scale of emissions, if brought to other UN-ECE region levels would easily exceed by many times the reduction levels noted in the revised Gothenburg Protocol for the EECCA region, as well as increase food security and resilience in a changing climate. The needed fire-free practices and technologies are not appreciably different than those deployed elsewhere in the UN-ECE.

 To assist in this transition, some EECCA countries would have access to a number of resources, including potential financing for programs deploying extension services and equipment. This includes the Global Environment Facility (GEF) and Green Climate Fund (GCF) and, potentially also the European Investment Bank.

 For the GCF, support for fire-free BAT and BAP is especially attractive for several reasons related to GCF goals and requirements, because these fire-free approaches combine both adaptation and mitigation. For mitigation, measurement of both avoided emissions, and monitoring for compliance can be achieved in an unusually reliable, real-time, cost-effective manner through use of the new VIIRS satellite technologies and algorithms. Avoided emissions also include an unusually broad array of greenhouse gases, including CO2, methane and N2O; as well as black carbon, VOC and PM2.5 (as co-benefits). Additional avoided environmental impacts and co-benefits under the GCF definition include avoided erosion, water pollution, eutrophication and flooding from more brittle burned soils.

 GCF-defined adaptation benefits include enhanced resilience to extreme weather events (both extreme rain and droughts, due to higher organic matter in soils); and lower water use for irrigation (where appropriate), again due to more organic-rich soils with higher water retention. Economic co-benefits include lower costs for the farmer from lower fertilizer and petrol use (for alternatives that involve incorporation or no-till), and/or additional income from alternative straw use and sale (where applicable markets exist), with the GCF financing making technologies to realize these alternatives and provide education/training for their use.

 Necessary pre-conditions for a successful GCF application however present some barriers. In particular, support from both the national Agriculture Ministry and Finance Ministry (which is usually the GCF National Designated Entity, or NDA, as denominated in the UN Framework Convention on Climate Change, UNFCCC), as well as the Environment Ministry is needed.

 Basic mapping of burning patterns and identification of main burned crops and sectors, as well as alternatives to burning specific to that crop and environment, could serve as an implementation plan for transition to fire-free agriculture. Such a plan would also comprise an important intermediate step in support of future GCF funding applications is also a pre-condition.

**VI. Conclusions and Recommendations**

Open burning in agriculture is an issue in many countries in the UN-ECE region, as well as at global level. Substantial and clear evidences exist that open burning in agriculture has negative impact on the soil organic characteristics reducing the soil fertility and ultimately reducing the yield of the field. Moreover, the pollutant emissions generated by open burning contribute to worsen the level of air pollution and have adverse impact on climate change, with harmful effects on the human health and the environment, at global level.

Alternative methods, practices and technologies exist to avoid the open burning and its negative effects. The advantages of adopting the fire-free practices, illustrated in this guidance, are demonstrated by various successful experiences in several countries, within the UN-ECE region. The transition from open burning to fire-free methods is proven to be successful and cost-effective when based upon three main pillars: a) mapping and monitoring to define the problem, b) education and training of the farmers, c) developing regulations and financial support. Awareness raising, training and dissemination of relevant information on the fire-free methods are essential to achieve the required sensitivity on this issue, among the concerned stakeholders.

The use of the present guidance is recommended to the Parties to the Air Convention, although on voluntary basis. The implementation of the practices, methods, approaches, technical instruments, depicted in this guidance, may significantly contribute to reduce the air pollution from residue burning in agriculture, and its negative impact on human health and the environment, within the UN-ECE region and beyond.

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