



Fire in the Fields:
**Moving Beyond the Damage of Open
Agricultural Burning on Communities, Soil,
and the Cryosphere**

**A CCAC Project Summary Report:
Impacts and Reduction of Open Burning in the Andes, Himalayas – and
Globally**

Co-authors for ICCL:

Pam Pearson, Svante Bodin, Alex Gittelsohn, Stephanie Kinney, Jessica McCarty,
Gail Stevenson, Juliana Albertengo

Inquiries: Gail Stevenson, gail@iccinet.org

INTERNATIONAL CRYOSPHERE
CLIMATE INITIATIVE

This project was supported by the Climate and Clean Air Coalition
to Reduce Short-Lived Climate Pollutants (CCAC)

Fire in the Fields:

Moving Beyond the Damage of Open Agricultural Burning on Communities, Soil, and the Cryosphere

Project Summary Findings: Open Burning in the Andes and Himalayas

I. Introduction

In the Andes prior to the arrival of the Spanish and the introduction of the plow, the practice of burning fields carried a penalty of death because it damaged the soil, the lifeblood of high agricultural yields. In the Himalayas, communities valued stubble as an important resource, gathered after harvest for livestock bedding, food or fuel for the home hearth.

Open burning refers to a common agricultural practice found today throughout the world, including important cryosphere regions such as northern Eurasia, the Andes and the Himalayas. It is the regular and periodic burning of cultivated fields for the purpose of cheaply and quickly removing excess vegetation, including crop residue such as straw, weeds and waste, prior to sowing a new crop. In contrast to the traditional knowledge of the Andes and Himalayas noted above, today's burning is thought by some farmers and most urban dwellers to enrich the soil. In reality, however, burning damages soil and decreases its productive capacity by destroying the humus (organic matter) and soil structure vital to good production, while at the same time destroying a potential resource – the straw. With each successive burn, soils become less fertile and water retentive and prone to erosion, increasing the need for fertilizer, local irrigation and run-off systems. Many farmers are well aware of these impacts but lack the tools and knowledge to adopt alternatives. Nevertheless, alternatives abound--chiefly Conservation Agriculture (CA) practices (broadly defined as practices that keep the soiled covered), but also using straw for fuel, or simply "low-till" practices that incorporate the straw into the earth to enrich the soil.

Although such alternatives have spread throughout the Americas and in some parts of Europe, traditional practices and resistance to change continue to hobble agricultural productivity and, as we now know, accelerate climate change and glacial melt, especially in the Arctic, Andes and Himalayas, through deposition of black carbon on snow and ice regions already under pressure from climate change.

The Climate and Clean Air Coalition (CCAC), founded in 2012, seeks to reduce harmful short-lived climate pollutants (SLCPs) from a variety of sectors, including an Agricultural Initiative that includes efforts to reduce methane from livestock and rice paddies, as well as black carbon (BC) from open burning. The Initiative's Open Burning Component seeks to demonstrate at the local level that changed agricultural practices are feasible and can both successfully reduce climate warming and health-damaging emissions while also increasing soil fertility and soil water retention. Better practices

may even create new markets for agricultural residues formerly burned. In a changing climate, no-burn practices are ideal for improving soil fertility and crop yields, providing adaptation benefits during more frequent extreme weather events. This is achieved both through greater moisture retention in dry periods, as seeding occurs through non-plowed stubble, as well as decreased erosion in the opposite extreme of heavy rains since the remaining stubble holds soil in place. In addition, the UNEP Emissions Gap studies have identified CA as a primary means to meet the two-degree goal, with a consensus that these methods fix more soil carbon than traditional plowing methods.

Conservation agricultural practices re-emerged in the wake of the 1930s Dustbowl in the Great Plains of the United States and repeated droughts of the early 1950s. Today, agricultural experts regard CA cultivation practices as ascendant due to their economic and environmental benefits. However, only recently have these experts begun to appreciate that the open burning commonly practiced with tillage is an accelerant for climate change, especially in delicate cryosphere zones dependent on glacial stability. Within the climate change community, alternative practices to mitigate open burning are even less understood and not as widely recognized as other climate polluting sectors, in part because technological alternatives are not as obvious and because many solutions are not supported by effective policies and enforcement. The CCAC has thus an opportunity to bridge the gap between the SLCP community and the agricultural community, including farmers themselves who have identified climatic changes but do not necessarily know how best to respond to it.

As millions of people depend on glacier melt for access to clean water for drinking and irrigation, glacial deposition of black carbon from open burning can endanger food security and livelihoods. This CCAC work complements others that are working to reduce the impact of agriculture on climate change and vice versa (e.g., Climate Smart Agriculture, <http://www.fao.org/climate-smart-agriculture/en/>), but adds a particular focus on short-lived climate pollutants like BC and the role of the majority of small and medium-sized producers in this regard.

This report summarizes what has been learned until now from CCAC's work on open burning in the Andes and Himalayan cryosphere zones through an 18-month project scoping the scale of the problem in these two regions: the "what, who, when, where and why" of open burning there; identifies the major alternatives applicable to each region; and suggests some low-hanging fruit "catalyst" projects to begin the process of change that may be supported by bilateral donors, private sector foundations, multi-lateral development banks or the CCAC itself. This report also highlights elements of, and lessons learned from, earlier work by its main implementer, the International Cryosphere Climate Initiative (ICCI), with support from the Swedish Ministry of Environment, the Nordic Environment Finance Corporation (NEFCO) and the Oak Foundation of Geneva, Switzerland, and highlights next steps on the global level. These lessons learned include "shovel-ready" programs that can lead to increased awareness among farmers, public sector officials and other stakeholders of the dangers of open burning and the wide availability of more affordable and sustainable agricultural practices.

Rapid change is possible when it responds to farmers' own self-interest. In Poland and the Baltics, widespread open burning was reduced to EU levels in a period of 5 years. However, the effort requires a combination of farmer extension education, political will and financing and, not least, connections with related work by major stakeholders such as FAO, UNEP and the multilateral development banks, as well a regional governmental and farmer interest and support. With sustained effort and good political will, open burning can and will become an exception--a relic of the recent past, bringing the practice of open burning full circle to earlier sustainable and traditional practices, to where it again becomes a waste of valuable resources and an unthinkable crime against the "lifeblood of the soil."

II. Climate Change, SLCPs and Open Burning

Short-lived climate pollutants (SLCPs—methane, black carbon and tropospheric ozone) last in the atmosphere for a few days to several weeks and up to 12 years for methane, which means their abatement can have an almost immediate positive impact on climate and temperature. Open burning is the single largest source of BC emissions globally, producing over one third of such emissions (approximately 2700 Gg or 36%¹). Although set agricultural fires comprise a smaller portion of this figure (10-20%), these agricultural fires are responsible for the vast majority of all open burning because they so often spread and cause forest and field fires. Contrary to popular belief, "natural" causes such as lightening are responsible for a small minority of wildfires, and these primarily at very high polar latitudes. When agricultural fires burn out of control, even with "controlled burning" policies in place, they cause larger forest, peatland, grassland, and pasture wildfires, which then release additional BC, methane, CO, and CO₂ and damage or destroy nearby sensitive ecosystems, habitats and carbon sinks – which in the cryosphere includes ancient peatlands.

Measures aimed at addressing SLCPs have a greater positive impact on slowing warming in the earth's cryosphere, or ice and snow regions. This more positive impact arises from the enhanced influence of BC emissions over the highly reflective surface of ice and snow.

No source (except possibly kerosene lanterns) emits "pure" black carbon, but open burning produces a complex mixture of pollutants that adversely impact both health and climate. Some sources, including open burning, emit high percentages of the more reflective white organic carbon and yellow sulfates often co-emitted with BC. The lighter organic carbon and sulfates reflect the sun's rays and thus can actually cause a cooling effect stronger than the warming effect of BC emitted from that same source. However, black carbon researchers know today that this effect happens only over a surface that is darker to begin with. There is far more certainty about the effect of BC on surface and atmospheric warming over snow and ice. The "cooling" impact is absent over a white and highly reflective surface like ice or snow, such as in the Arctic,

¹ Bond, T.C. and 29 other authors. (2013), Bounding the role of black carbon in the climate system: A scientific assessment. J. Geophys. Res. Atmos. 118, 5380-5552, doi:10.1002/jgrd.50171.

Andes or Himalayas,² thus leaving little doubt as to the negative impact of open burning in cryosphere zones.

While the health impacts are well documented, emissions monitoring and tracking, such as in Chacaltaya, Bolivia, and a new project in Huancayo, Peru, as well as projects by CCAC Partners ICIMOD and EvK2CNR in the Himalayas, only recently have built a more definitive understanding regarding the extent and impact of open burning on local glaciers and water supplies – though some farmers near these glaciers seem well aware of such impacts and are searching for solutions.

In addition to speeding melting through the deposition of BC, and contrary to what many farmers believe, open agricultural burning badly damages soil quality (a non-renewable material) by compacting and destroying the humus and organic matter that make agricultural lands productive. As noted, soil damage from open burning decreases water retention and agricultural yields at a time when agriculture is already under stress from climate change.

The summer 2010 fires in European Russia documented the degree to which smoke from habitual or annual open agricultural burning significantly and negatively impacts human health, with Russia authorities estimating that 25,000 additional deaths occurred that summer in Moscow alone. Recent studies show that 5-10 percent of global air pollution deaths (approximately 250,000 deaths annually) are due to open biomass burning. Lelieveld et al. (2015) note that PM_{2.5} from agricultural sources is the main contributor to premature mortality from air pollution for the eastern U.S., Europe, Russia, and East Asia³. Biomass burning will likely cause a 0.4°K temperature increase in the next 20 years of global climate change⁴. Bond's estimate of ~ 2700 Gg of BC per year due to open burning of biomass is argued to be the most uncertain on sourcing of BC due to lack of scientific analysis⁵. However, the uncertainty points to an underestimation, and some scientists argue that the data understate emissions by at least a factor of 2, and arguably as much as 4, based on ground-level comparison⁶.

Previous work under the Arctic and Nordic Councils has aimed at addressing open burning in Russia beginning in 2010.⁷ This work inspired the current CCAC effort focused on the Himalayas and Andes, in part because of the clear climate impacts from burning in Russia.

² For research about the impact of open burning on the cryosphere, see the joint ICCL/World Bank report, "On Thin Ice: How Cutting Pollution Can Slow Warming and Save Lives," (2013).

³ Lelieveld et al. (2015), The contribution of outdoor air pollution sources to premature mortality on a global scale, *Nature*, 525, 367-371, doi:10.1038/nature15371.

⁴ Jacobson, M. Z. (2014), Effects of biomass burning on climate, accounting for heat and moisture fluxes, black and brown carbon, and cloud absorption effects, *J. Geophys. Res. Atmos.*, 119, 8980–9002, doi:10.1002/2014JD021861.

⁵ Bond, T.C. et al. (2013), Bounding the role of black carbon in the climate system: A scientific assessment. *J. Geophys. Res. Atmos.* 118, 5380-5552, doi:10.1002/jgrd.50171.

⁶ Unger, N. and 6 other authors. (2010), Attribution of climate forcing to economic sectors. *PNAS*. 107, 3382-3387, doi: 10.1073/pnas.0906548107.

⁷ See <http://iccinet.org/open-burning> for greater detail.

As noted, open burning can endanger food security and livelihoods in rural communities that depend on glacial melt for drinking water and irrigation. The loss is most pronounced on small glaciers at low altitude. As in Figure 1 below, land glacier ice has steadily and steeply declined globally since the 1960s, and the Andes and Himalayas regions are no exception.

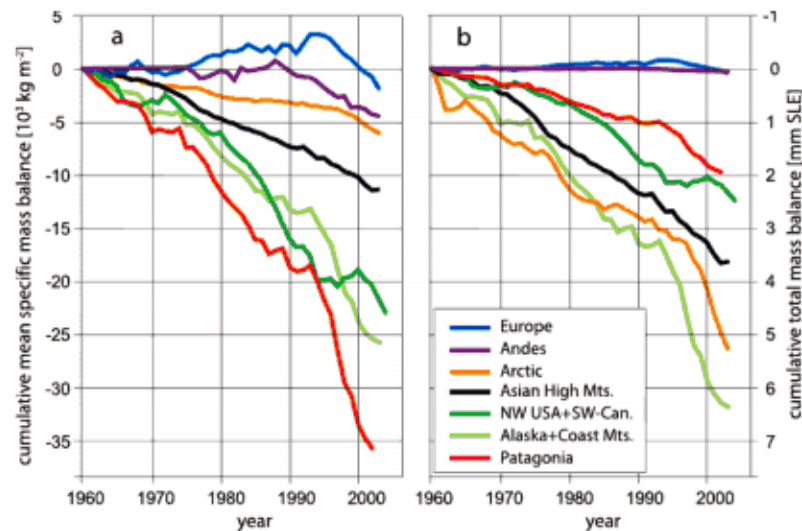


Figure 1: Land Glacier Ice Loss. Figure (a) shows the cumulative mass lost over time. Figure (b) shows the relative contribution of loss in each region to sea-level rise. (Source: IPCC AR4 (2007) based on Dyrgenov and Meyer (2004).)

❖ Andes Region

The Andes, a narrow band along the Pacific coast, are one of the most fragile cryosphere regions, with most glaciers disappearing at rapid and often highly visible rates. The Andes contribute a significant portion of river basin water supply, with up to 35 percent annually from glaciers or snowfall in some of the more arid regions of Peru and Chile⁸. Peru's capital is 70 percent dependent on glacier run-off and managed water, as is Huancayo, the largest city in the central highlands of Peru, which is fed by the dying glacier, Huaytapallana. The small glaciers of the northern Andes play a lesser role in water resources, though they greatly impact delicate, unique, and endemic high mountain ecosystems such as the paramo, puna, and Andean cloud forests. In all regions, however, glaciers can be the most important source of runoff during dry seasons, affecting water availability for irrigation and other uses. Concerns for both drinking water and hydroelectric power already have arisen in La Paz, Lima, and Quito, Ecuador.⁹ The effects can also be felt on Andean valley agriculture¹⁰, including from

⁸ Vergara, W., Deeb, A., Valencia, A., Bradley, R., Francou, B., Zarzar, A., Grünwaldt, A., Haeussling, S. 2007. Economic Impacts of Rapid Glacier Retreat in the Andes. EOS, Transactions American Geophysical Union, 88(25), 261 – 264, doi:10.1029/2007EO250001.

⁹ Buytaert, V. and 5 other authors. 2011, Towards integrated sustainability assessment for energetic use of biomass: A state of the art evaluation of assessment tools. Renewable and Sustainability Energy Reviews. 15, 3918-3933, doi:10.1016/j.rser.2011.07.036.

¹⁰ Stern, N., 2006. The Economic of Climate Change: The Stern Review. London, Cambridge, University Press.

changes in the contribution of melt water supporting regional economies in Argentina and Chile.

Glaciers have retreated in all Andean countries over the last three decades due to atmospheric warming, with a mean decadal increase in temperature of 0.34°C reported for the past 25 years at high elevations, similar to that of polar regions¹¹. A recent extensive survey of climate change impact patterns across the Andes¹² concluded that current glacier retreat over the last three decades is unprecedented since at least the Little Ice Age (1300-1850 C.E.). Although a few glaciers have shown sporadic gains, the trend has been negative over the past 50 years, with slightly more glacial loss in the Andes than other cryosphere regions. This loss nearly quadrupled in scale beginning in the late 1970s through 2010 compared to 1964-1975 (see Figure 1).

Temperatures have increased at a high rate of 0.10°C per decade in the Andes over the last 70 years. Variability in the surface temperature of the Pacific Ocean (related to El Niño Southern Oscillation) also seems to be a large factor governing changes in glaciers, with precipitation playing a lesser role. The higher frequency of El Niño events and changes in its timing and other patterns since the late 1970s, together with a warming troposphere over the tropical Andes, may explain much of the recent dramatic shrinkage of glaciers in South America. While urban dwellers may remain relatively immune to climate changes (for now), it is striking how small agricultural producers in cryosphere zones express concerns about climate change, inevitably pointing to seasonal shifts and longer duration of droughts and other extreme weather events as evidence that something is changing.

❖ **Himalayas Region**

Rapid climate-induced changes in the Himalayan region, the largest cryosphere region and supply of freshwater outside the poles, directly impact the quality of over 1.5 billion human lives. Observed and projected impacts include changes in the annual monsoon on which much local agriculture and food supply depend, as well as the risk of flooding and landslides from extreme weather and glacial lake outbursts. The annual mean temperature across the region has increased by 1.5°C, similar to that seen in the Arctic and Antarctic Peninsula. Despite the complexity of observations, glacial and snow cover decrease has been recorded across almost the entire Himalayan region, and a recent study coordinated by ICIMOD forecasts that glaciers in the Everest region might disappear by 2100. Many glacial lakes have formed or expanded during the rapid melt process in the Eastern and Central Himalayas. These have led to catastrophic floods, so-called glacial lake outbursts (GLOFs), especially in the Tibetan region, with others narrowly averted thus far in Nepal and Bhutan.

The importance of meltwater from Himalayan glaciers and snowpack to human water supplies varies across the region, with the semi-arid areas of western China, Pakistan

¹¹ Herzog et al. 2011. Climate Change and Biodiversity in the Tropical Andes, Inter-American Institute for Global Change Research.

¹² Rabatel, A. et al. 2013. Current State of Glaciers in the Tropical Andes: a Multi-century Perspective on Glacier Evolution and Climate Change. *The Cryosphere*, 7, 81-102.

and Central Asia most clearly dependent on a regular, predictable melt season. This dependency on regular water supply occurs to an even greater extent with the Asian monsoon rains, around which local populations have based their agricultural practices for a millennium. However, even seemingly small changes can have large impacts on human populations in situations of water stress, where changes in timing or just a few percentage points in flow may make the difference between adequate irrigation and crop loss for that season.

III. Burning Patterns in the Andes and Himalayas Regions

Cryosphere regions in the Andes and the Himalayas tend to host tradition-bound, smaller-scale, mixed-crop, village-based crop and livestock grazing systems. Small and medium-sized farmers, who constitute the majority in these regions, tend to grow a variety of crops in order to hedge losses, rotate crop types for soil inputs from the plants (i.e., nitrogen), and diversify production. Burning occurs as a necessary measure to remove excess residue before planting and after harvest, and because there are few alternative uses or markets for this biomass. The choice to burn depends largely on tradition, ease, timing, weather and location, and appropriate tools and practical alternatives provide flexibility on the ground in order to reduce the need for burning overall.

As the initial stage of the CCAC project, burning patterns across South America, Eastern Europe, Central Asia, and South and East Asia were mapped using the Moderate Resolution Imaging Spectroradiometer (MODIS) 1 km Global Fire Location Product (MCD14ML) collection 5 data. This mapping exercise initially covered 16 countries in the Himalayas, narrowing the focus to 9 countries that received detailed annual/monthly mapping for 2003-2013 due to their greater regional climate impact based on the extent of burning and wind patterns. In the Andes, the program covered 10 countries initially with five included in the detailed mapping effort.

The maps were circulated broadly among stakeholders, presented to the CCAC and at the COP-20 meeting in Lima, and made available on a dedicated website. The mapping also formed the core of two regional conferences that brought together stakeholders and experts from these countries and to which all CCAC Partners also were invited. The Himalayan conference took place in conjunction with a CCAC Working Group meeting.

The discussion below notes some general trends, going into detail for certain countries considered for catalyst projects. Regional maps for the Andes and Himalayas, as well as national maps for the individual countries of Bangladesh, Bhutan, Bolivia, Chile, China, Columbia, Ecuador, India, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pakistan and Peru can be examined at <http://openburningcryosphere.org/>, with individual maps for each year 2003-2013 and burning shown by month.

The general conclusions drawn from the maps are that so-called “burning seasons” vary based on several factors: regional conditions related to planting and harvest, type

of crop, and proximity to cover types (i.e., grasslands, forests, and steppe). Grain production in the Northern Hemisphere, for example, is closely associated with fires in spring and summer, while agricultural burning bordering grassland and steppe areas continues through the fall. Infrastructure and topographical conditions (proximity to roads and rivers, for example) also influence how far fires may spread, sometimes creating natural or man-made barriers. General, regional, and country-specific fire patterns indicate that most fires tend to start on or near agricultural lands.

Overall, there is a strong signal of satellite-detected fires during the Southern Hemisphere's spring and summer (October – December) in Bolivia, Chile, and Peru, as well as fall burning during March and April, specifically near the Equator and particularly in Colombia and Ecuador. On average, 14 percent of all detected vegetation fires in South America were agricultural burning, though, as noted above, non-agricultural fires usually originate with fires on agricultural lands -- up to 90 percent by some national estimates.

As a result, the discussion below focuses on total fire amounts, although it should be noted that the high proportion of fires on identified agricultural lands in countries like Ecuador and Pakistan creates the potential to halt almost all BC emissions from open burning. Other countries like Bolivia may also represent the scale of non-crop fires (especially pasture in Bolivia), or sugar cane, which satellite resolution likely quantifies as "grassland" but which likely represents the largest crop burning there.

In Bangladesh, the vast majority of burning occurs pre-monsoon in March and April, with much burning occurring in cropland-dominated areas. Similarly, Bhutan shares the same March and April burn season, but with much less fire.

In northeast China, there is a significant agricultural burning in April and again in October. Along the central coastland, there is significant agricultural burning in June that moves southward towards the South East in the November and December. Both western and southern China experience grassland and agricultural burning throughout much of the year, from April to October.

Agricultural burning occurs throughout northern India in June, October and November. Central and southern India experienced more grassland, forest, and agricultural burning from March to May. Much of the burning in Pakistan is agricultural, with fires common in all months of the year and with 87 percent of BC emissions from all fire activity coming from open agricultural fires (Table 1).

Fires in Mongolia are mainly in steppe grasslands, similar to western China. These occur from May to October with a small number of agricultural fires in May and June. In Nepal, much burning occurs in March through June, with a large amount of burning also along the border in India at the same time.

Fires in Central Asia, specifically Kazakhstan and Kyrgyzstan, are concentrated in July, August, and September, with equal amounts of fire in the arid steppe grasslands and croplands. The picture is complicated because the grassland areas are often contiguous to cropland areas, so both potential agricultural land cover types (pastures and croplands) are sources of open burning.

More detailed analyses were performed on good candidates for potential pilot projects in the Andes and Himalayas Regions (see below). We note, however, the evidence that actual emissions are likely larger by a factor of four because the data below only include observed fires, and various on-the-ground studies have indicated the satellite data under-estimate the amount of actual fire by a factor of four. Actual BC emissions from open burning in Ecuador, for example, may be around 1600 metric tonnes. (To give a sense of scale of the below figures, total BC emissions from all sources in Norway, which has issued a very detailed report, were 5100 metric tonnes in 2011.) The accompanying maps show burning for the last year mapped, 2013, by month. As noted above, annual maps for all 14 countries from 2003-13 are available at: <http://www.openburningcryosphere.org>.

Table 1. Global Fire Emissions Database estimates of average annual CO₂, CH₄, and BC emissions from all fire sources, 1997-2014; all emissions reported in Metric Tonnes.

	BC	CO ₂	CH ₄
Bolivia	41,137	156,022,592	311,368
Chile	1,935	6,377,611	12,847
Ecuador	399	1,423,119	2,597
Peru	2,386	9,506,494	15,143
India	14,537	46,269,411	105,506
Nepal	2,017	4,674,897	7,815
Pakistan	576	11,189	4,287

❖ Andes Region

The ICCI project focused on Bolivia, Chile, Ecuador and Peru, all countries with little or no adaptation of conservation agriculture practices among the majority of farmers. In Peru, CA is virtually unheard of. These countries have experienced rapid rural-to-urban demographic shifts and population growth of all urban areas—large and small—with the utter dependence of urban centers on cryosphere water resources and hydraulic systems and cycles. The cities of La Paz, Quito, Santiago, and Lima, a region of a little more than 16 million people, are directly dependent on the glacial water sources of the Andes for drinking water and hydroelectricity. Most agriculture in this region relies at least in part on glacial or snow runoff for irrigation, especially in summer. Tourism has even been impacted. For example, Bolivia used to boast the world’s highest ski resort, Chacaltaya, which began operating a lift in 1939 and closed its doors for good in 2011.

Emissions from open agricultural burning were estimated using the Global Fire Emissions Database (www.globalfiredata.org), a peer-reviewed science- and ecosystem-based model that relies on satellite observations of fire (Table 1). For the Andean region, open agricultural burning from 1997 to 2014 accounts for an average 3 percent, 25 percent, 37 percent, and 14 percent of BC emissions from all fire types (including deforestation of tropical and temperate forests and grassland burning) in Bolivia, Chile, Ecuador, and Peru, respectively. Average methane emissions from agricultural burning range from 44 percent (Ecuador) to 3 percent (Bolivia) of all methane released from all types of fires. CO₂ emissions from agricultural burning in Chile and Ecuador account for 1/5 to 1/4 of CO₂ emitted from all fire sources.

Chile

Central Chile is the center of agricultural production for the country. Much of Chile falls within the Mediterranean-like climate zone, with winter rainfall and dry summers and autumns. Annual crops are usually planted May through June and harvested in December and January. Crop yields tend to be high due to excellent climatic conditions. Most agricultural soils in Chile come from volcanic ash, which is an outstanding soil but very low in phosphate. As a result, soil acidity is high and phosphate and organic matter levels are low and cation exchange capacity, the ability to hold onto essential nutrients and to prevent soil acidity, is poor.

High crop yields combined with no rainfall in summer/autumn mean that straw decomposes poorly. A large amount of residue accumulates and sits in the fields and farmers usually burn it—even under no-till conditions—as it is not economical to remove by other means. Less than 20 percent of Chile is under no-tillage and Chile is the only country in South America that burns even under no-till. Chilean agriculture generates around five million tons of straw per year with 60,000 ha (25 percent) in the Bio-Bio Region, with the majority of straw coming from wheat fields (79 percent). 27 percent of agricultural fires occurred in the wheat-dominated Bio-Bio Region.

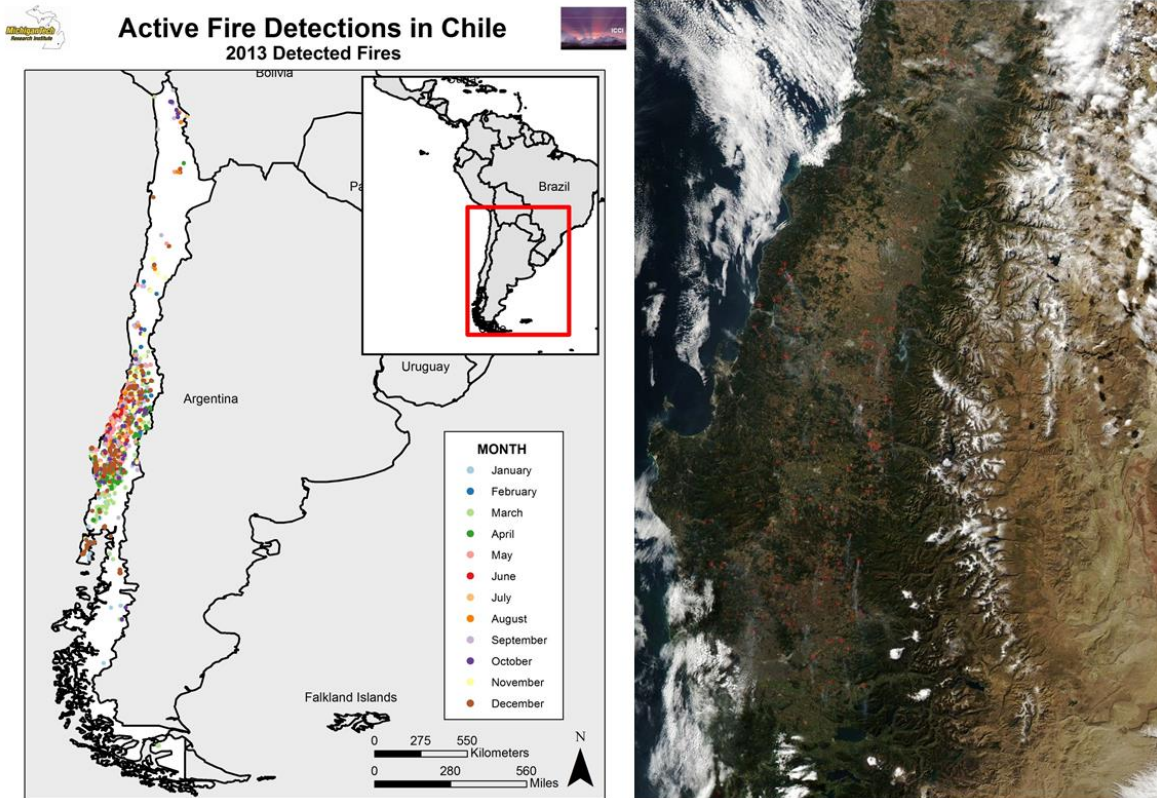
One farm in central Chile, Chequén Farm, has practiced conservation agriculture since the late 1970s. By 1997, after 19 years of continuous no-till, 1 inch (2.54 cm) of topsoil had been added and organic matter content boosted from 1.7 percent to 10.6 percent in the first 5 centimeters of soil. The farm also increased the soil's water-holding capacity by more than 100 percent and improved the soil's cation-exchange capacity from 11 to 26 milli-equivalents per 100 grams of soil.

Despite the many years of successful no-till farming on Chequén Farm and a strong demonstration of bioenergy use of straw by the regional government in Bio-Bio, the system has not expanded beyond the original 100,000 ha. Many farmers still burn straw residues (Figure 2). Despite its remarkable success and international renown, the Chequén Farm remains a "conservation oasis" in the Chilean agricultural landscape. With this viable model already demonstrating long-term results across a variety of indicators, education on best practices and technical assistance will reach out from the Bio-Bio Region to disseminate information on no-burn techniques.

Figure 2. Agricultural burning in Chile as detected by MODIS for 2013 alongside a natural color MODIS image from 7 May 2015 showing agricultural fires in central Chile outlined in red.

Bolivia

The MODIS satellite documents the extent of open agricultural burning in the



agriculture-dominated eastern half of Bolivia (Figure 3). A May 2015 field mission clarified the centrality of the Department of Santa Cruz to any initiative involving open burning because of its size, focus on agriculture, prominent role in the national economy and the quality of its human capital. While well-educated, large producers east of the Altiplano, especially in Santa Cruz, are now significantly practicing or moving towards the best practices of conservation agriculture, smaller producers and large livestock wranglers and producers are not because they are uninformed about CA practices and how best to undertake them. When offered the possibility, however, and allowed to consult among themselves, they demonstrate tremendous interest and will to learn. Small producers now account for the bulk of agricultural and grassland burning in Bolivia. Both groups are also most responsible for burning down forests in order to create new land for cultivation or pasture. Nevertheless, both groups also grasp the essential link between their need for water and the crucial role of the Altiplano glaciers. Both groups volunteered personal observations, anecdotes, and experience with a changing climate during the scoping mission. As noted, many specifically volunteered commentary on changing seasonal patterns, extended droughts and the drying out of their soil, though they were unaware of how their own practices were contributing to the latter.

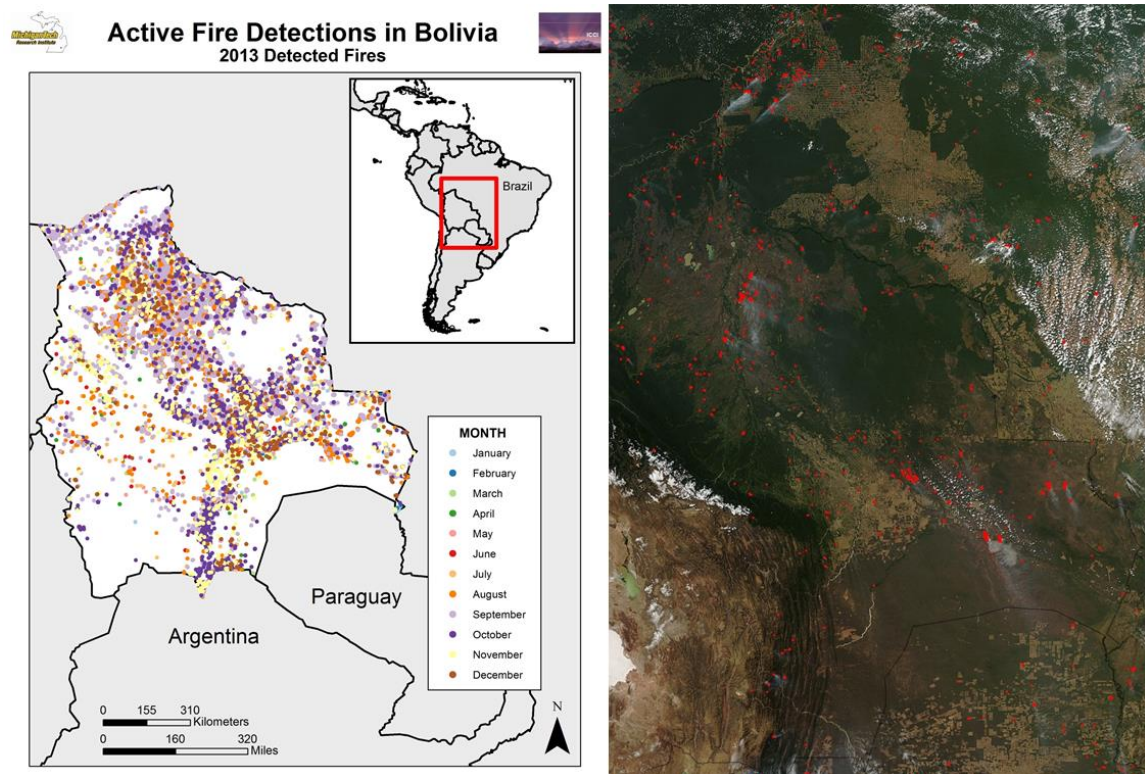


Figure 3. Agricultural burning in Bolivia as detected by MODIS for 2013 alongside a natural color MODIS image from 31 August 2013 showing agricultural fires in central and western Bolivia highlighted in red.

Peru

The February CCAC Regional Andean Conference in Lima focused key attendees on the challenge of “Reducing Agricultural Burning.” The conference highlighted the importance of conservation agriculture practices, which preclude burning. Few participants beyond the speakers were familiar with either the open burning issue or its alternatives. It was clear that CA is least known and least commonly practiced in Peru among all the Andean countries. Yet since that conference, interest in learning more about CA has been greatest in Peru, from the office of the Vice Minister of Agriculture to the science community to the regional government of Junin to local communities in that region. The interest has been great because every level of government and economic planning is painfully aware of the role of glaciers to water management. For example, the head of the National Water Authority (ANA) reports to the Ministry of Agriculture, while ANA itself carries the title of “Guardian of the Glaciers.” ANA co-sponsored the February conference with ICCI. Recently, Peru’s EPA created a new division that also focuses on the conservation of the glacial cryosphere. The issue of glacial loss due to global warming is urgent in Peru, but practical ways to address it are less clear--hence the interest at every level in encouraging better agricultural practices (CA) that enrich the soil, increase yields and pose less threat to the cryosphere.

Ecuador

Agricultural burning is common in the Ecuadorian coastal and central region, where cropland and pasturelands dominate the landscape (Figure 4). Significant burning occurs between September and December, with sporadic agricultural burning detected by the MODIS satellite in every month. Most agricultural burning occurs in central Ecuador, mainly in the provinces Los Ríos, Bolívar, and Cotopaxi, considered an area of influence for the equatorial glaciers of Cotopaxi and Chimborazo volcanoes. The average farm size in Ecuador ranges from 5-20 ha, with extensive managed areas used for pasture and forage. The main crops include rice, sugarcane, maize, soybeans and cacao, as well as many types of fruits and vegetables, making Ecuador a diverse agricultural system with potential for improved agricultural productivity that will impact local economies and food security. Moreover, the implementation of conservation agriculture has been limited to small case studies in Chimborazo Province (funded by USAID) and a white paper on agricultural engineering aspects of conservation agriculture funded by the UN FAO in 2007¹³.

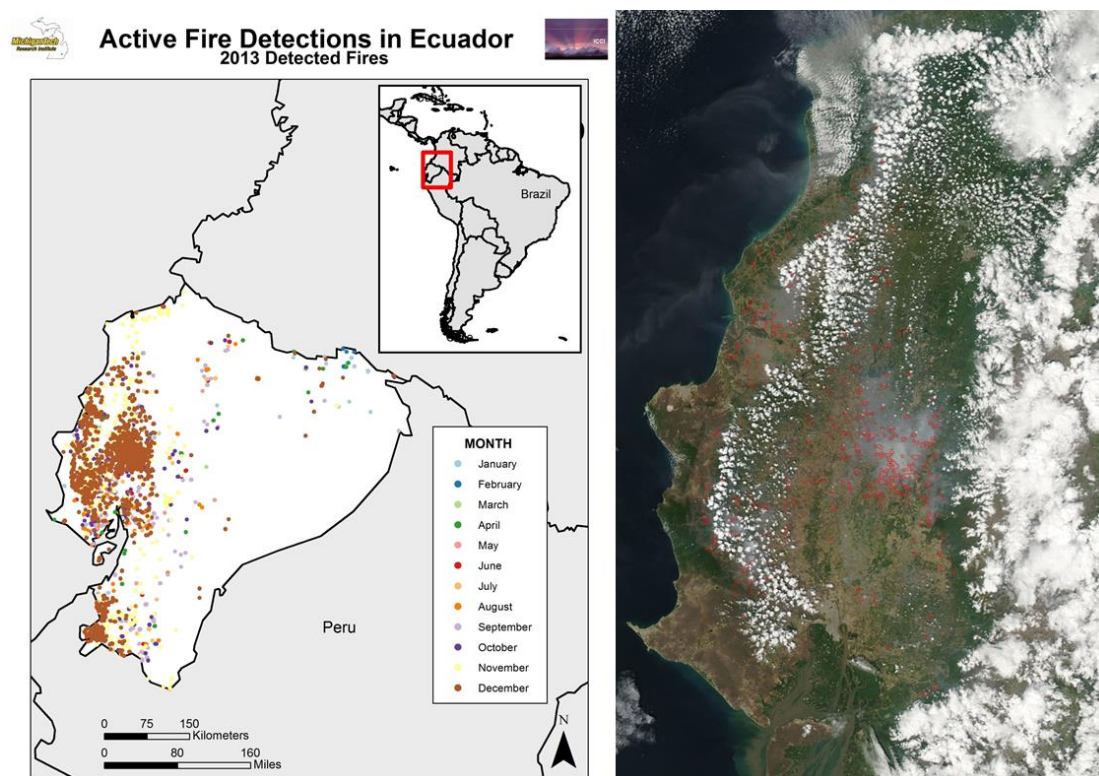


Figure 4. Agricultural burning in Ecuador as detected by MODIS for 2013 alongside a natural color MODIS image from 3 December 2013 showing agricultural fires in central Ecuador highlighted in red.

❖ Himalayas Region

The MODIS satellite data analysis and the assessment discussed at the scoping conference in Kathmandu in February 2015 revealed some systemic features of open agricultural burning in the countries surrounding the Himalayas. One striking feature was the massive November burning in the Indian Punjab. Globally, burning patterns differ from year to year based on crop and weather conditions, but this signal occurred

¹³ Friedrich, T. 2007. El Papel de la Ingenieria Agricola en el desarrollo de la Agricultura de Conservacion. URL: http://www.fao.org/ag/ca/CA-Publications/Ingenieria_y_AC_2007.pdf.

strongly in all 10 years mapped (2003-2013). Practically all farmers seem to burn rice stubble during November. There is also a peak of wheat stubble burning in late May. The same situation could also be observed in the Punjab region of Pakistan and the flatlands of southern Nepal, all part of the Indo-Gangetic Plain. Since these regions are so close to the Himalayas, they are likely to significantly affect the melting of glaciers due to BC emissions originating from agricultural burning transported up along the valleys and hillsides.

Analysis of what is being burned and for what reason revealed a similar pattern. Farmers practice a rice-wheat crop rotation system where rice is planted in early June and wheat in November. Data reveal a substantial increase in burning activities over the last 10 to 15 years, likely due to the introduction of combine harvesters. Combines do not spread straw and chaff uniformly behind the machine, making it difficult to plant the next crop without burning the straw left over from the previous crop. Since the time window is short, there is little opportunity for tillage or other residue management practices. It is also difficult to employ seasonal farm workers to prepare the land from harvest of one crop to planting of the next. Average farm size in the Indian Punjab is 4 ha, in the Pakistan part of Punjab about 2 ha, and in southern Nepal about 1 ha. Only India has a general ban on open burning of agricultural residues, but the ban is not enforced and farmers pay little or no attention to it. Similarities in the cropping system and farming practices leave room for considerable synergies among the three countries.

India

Open agricultural burning in India occurs most often in April through May and again in October and November. Agricultural burning is so common in India that observations from MODIS satellite data outline entire states, i.e., Punjab state in northwest India along the border with Pakistan (see region in yellow – November -- in Figure 5, below, which shows the most consistent pattern of year-on-year burning mapped in the entire project). Burning is most pronounced in Punjab, western Uttar Pradesh and Haryana, where the largest emissions of BC can also be found. These three states form the northwestern part of the Indo-Gangetic plain, where most burning is coupled with the rice-wheat crop rotation system. Further south, burning is associated with other crops like sugar cane and stovers of oil seed crops (mustard) in December; however, it is notable that open burning of these residues is less as these are valued fuels for cooking and mulch. The reasons for burning are similar across this region and similar to what is prevalent in both the Pakistani Punjab and southern Nepal. Small and medium size farmers hand-harvested until about 15 to 20 years ago, so little burning took place. With the introduction and popularity of harvesting combines, high stubble was left in the field and hand sowing was no longer possible. The only option for a majority of farmers given the narrow window of timing to plant in November has been to burn and clear the fields for immediate sowing.

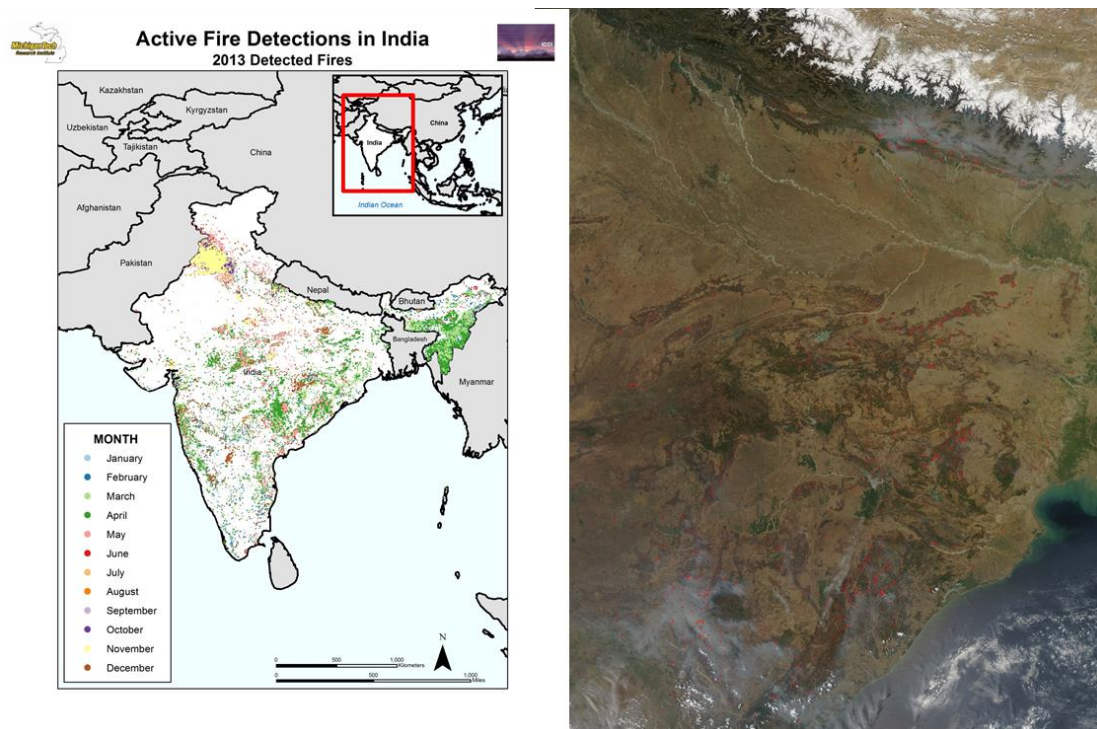


Figure 5. Agricultural burning in India as detected by MODIS for 2013 alongside a natural color MODIS image from 6 April 2013 showing agricultural fires in northeast India and Nepal highlighted in red.

Nepal

Burning is widespread in southern Nepal, with the same rice-wheat cropping system as Punjab and the rest of the Indo-Gangetic Plain (Figure 6). Agriculture in Nepal faces many problems. Young people are increasingly leaving the farm for Kathmandu or work in the Middle East. Traditional manual farming practices have been replaced by mechanized agriculture in the southern flatlands. Harvesting is generally completed by using combines offered by a variety of private sector service providers. As with India and Pakistan, straw and chaff are unevenly spread behind the combine and also leave high stubble, thus making direct seeding or hand sowing non-viable. Tillage to incorporate straw into the soil and allow for proper planting is expensive and time-consuming so burning straw looks like the only realistic option for most farmers. It is also commonly believed that burned residue is a good fertilizer for the next crop and that it kills pests and drives away other insects and mosquitoes. There is little knowledge of other farming methods like direct seeding as alternatives to burning and the benefits that can be gained from changed practices. Because of Nepal's small size, the map below includes regions immediately around Nepal as these may also represent sources of wildfires or with air quality impact within Nepal.

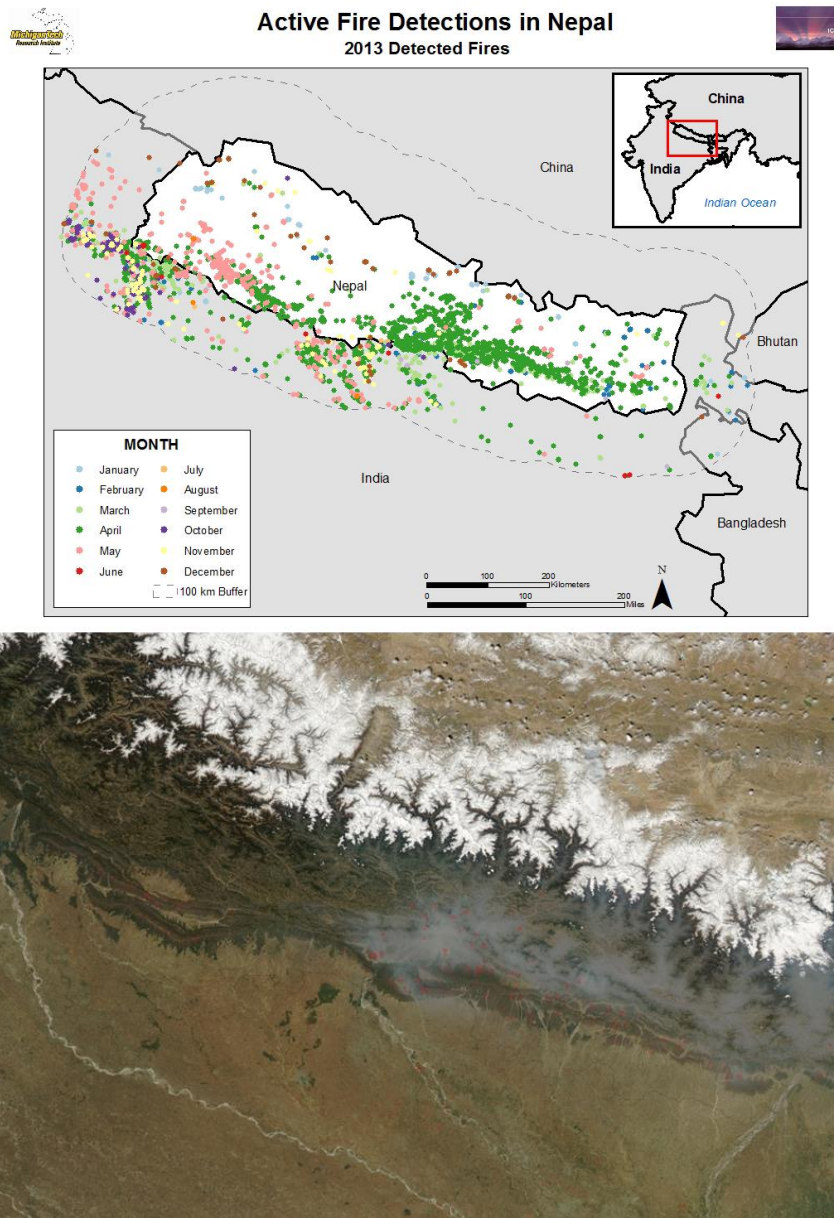


Figure 6. Agricultural burning in Nepal as detected by MODIS for 2013 alongside a natural color MODIS image from 6 April 2013 showing agricultural fires in Nepal and northeast India outlined in red.

Pakistan

The Punjab region around Lahore has burn rates of almost 100 percent (Figure 7), which directly affects the Himalayan cryosphere. The relationship between mechanical harvesting and burning in Pakistani Punjab is similar to the Indian Punjab. The number of combine harvesters in Pakistan increased from about 100 in 1994 to about 6,000 in 2004, after which the number has remained stable. At the same time, other regions in Pakistan have both strong conservation agriculture expertise, with substantial involvement by a number of donors in the agricultural sector that could be directly leveraged to support a transition to these practices in the target region, as well as strong academic knowledge and institutional partners.

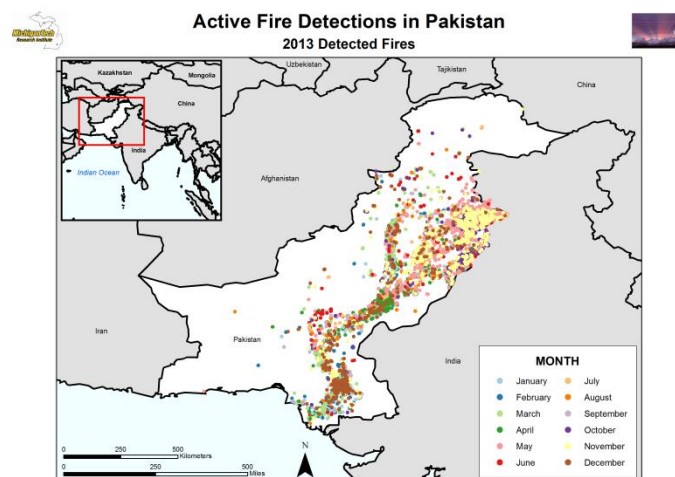


Figure 7. Agricultural burning in Pakistan as detected by MODIS for 2013.

IV. Alternatives to Open Burning

This report focuses on solid and sustainable alternatives to annual burning, many of which have been adopted worldwide. It advocates for conservation agriculture, which can be broadly defined as practices that seek to keep the soil unbroken while also maintaining vegetation coverage via crop rotation and agricultural residues. New crops are then directly sown into this protective vegetation cover. These measures all reduce the need to burn as all residues are saved for the next crop seeding. CA is only one of several possible approaches but it is deemed the most appropriate in the target regions.

Alternatives to agricultural burning fall into the following categories:

- **Use in bioenergy** (often through conversion of stubble to pellets): Stubble is gathered for biomass burning for heating and biofuel. This method is widely practiced in other regions of the world and depends upon the development of local/national markets, which are for all intents and purposes non-existent in the Andean and Himalayan cryosphere zones, but may be available in nearby regions like the Indo-Gangetic plain.
- **Livestock feed and/or bedding:** Similar to bioenergy, straw is gathered for use and, where appropriate, used as cattle feed and bedding for swine, poultry, and cattle. This alternative assumes the farmer also has livestock as part of the holdings and that such practices have been introduced and encouraged or that there are nearby livestock facilities to which they can sell the straw, i.e., there is a demand for livestock feed beyond the naturally occurring grasslands and pastures.
- **Conservation (reduced/minimal) tillage:** A technique that leaves at least 30 percent of crop residue on the soil surface, facilitating planting and increasing nitrogen in the soil, while also reducing the need for fertilizer, and eventually

decreasing the need for pesticide/herbicides by the mulching effect and by creating natural predators.

- **Clearing crop waste using improved machinery:** Combines, dedicated choppers or simply tractors with improved plows can better enable stubble to be incorporated into the soil. This alternative requires that farmers have access to the appropriate machinery and fuel as well as the capital to pay for this alternative.

The use of agricultural residues for energy requires refineries, transportation and a distribution network. A bioenergy infrastructure does not currently exist or is not well developed in the target regions, although it is growing in some other regions, particularly in Europe. Alternative agricultural uses such as bedding and fodder require livestock and, again, the target regions rely on natural grasslands and pastures for animal feedstock, but these grasslands are also subject to annual open burning. None of the target regions has a well-developed agricultural infrastructure, services or markets. Better, more appropriate technology, tools and machinery represent the closest and easiest steps to incorporate into traditional farming practices, although they may not guarantee a barrier against burning in years where the harvest is unusually good, thus resulting in excess stubble.

Conservation agriculture does not usually require large-scale investment where infrastructure and markets are lacking or inadequately developed. CA is well-suited to small- and medium-sized fields with a complex cropping calendar and multi-crop systems. CA provides the co-benefits of improved yields and farm economies, and improved soil health and quality and water management, in addition to climate benefits.

A robust and flexible approach that embraces local input and expertise, together with the diversity of cultural dynamics and practices, climatic conditions, landscapes, and soil diversity, is most effective in addressing open agricultural burning. Such an interactive approach with villages and communities attacks the problem on a practical level immediately, while at the same time informing scientific research and institutional and national policy change. Ongoing work, either as part of the CCAC Agriculture Initiative or others, should continue to explore available no-burn alternatives in a manner consistent with local needs and rural development, while producing measurable results and contributing to scientific research in this burgeoning field, as well as examples of success with which to encourage policy makers in capital cities, who may be distant from rural realities.

Direct Seeding

Direct seeding (also called “no-till”) is defined as planting directly into the standing and undisturbed stubble of the previous crop, and farmers on millions of hectares around the world have transitioned to this technology. As most farms tend to replace machinery on a 5-10 year cycle, timely education and extension services promoting this transition can allow for rapid change.

The key to successful direct seeding is to cut crop stubble fairly short at harvest and chop and spread straw as chaff as it passes through and out of the combine. As mentioned above, combines used in India, Pakistan, and Nepal are not equipped to chop and spread residue. Instead, they dump straw and chaff in a windrow behind the combine, making it virtually impossible to successfully direct seed the next crop. In India, recent technology has developed a system that can be attached to existing combines for uniform spreading of the chaffed straw and it costs about INR 30,000.

The second important component of successful direct seeding is a seed drill that can achieve excellent plant stands. Although a few direct-seed drills are manufactured in India and Pakistan, an early analysis showed that these drills are of low quality. Some experiments have been carried out with direct seeding but, due to the crudeness of the drills and combines used, the results are not indicative of the true potential of direct seeding if the proper equipment were available. In the Andes, a low-cost, hand direct seeder (*matraca*) exists, but since CA is little known and less practiced, the *matraca* languishes unused.

In the Himalayas, many smallholder farmers do not own combines but instead harvest rice and wheat with custom harvest crews that travel from farm to farm throughout the region. This makes the introduction of new equipment more practical to deploy as a model that could be adapted to other cryosphere regions, as one team covers multiple regions and farms. Another model that resonates well with Andean *comunidades* is community ownership and maintenance of a single machine used according to a schedule. As much of comunidad life is communitarian, a community decision to adopt of CA practices would be required. The result and benefit is that word of one successful community process quickly travels to all communities nearby and engagement spreads. Seeding the process with three or four communities is even better.

The analysis made during CCAC activities in the Himalayas shows that the combine harvesters and seed drills used throughout the region were not suitable for successful direct seeding in the rice-wheat cropping system, but have been improved over the last few years to the level where they may be a viable alternative to burning. Alternatively, relatively small combine harvesters or drills manufactured in Europe could be acquired or further development could benefit from contacts with overseas producers. There are numerous types and models of direct-seed drills available that could be successfully used. Successful demonstration of direct seeding will also likely stimulate private sector entrepreneurs to procure a properly-equipped seed drill and combine to offer contract services to farmers.

As mentioned, a general feature in all countries is small farm size and weak or lacking infrastructure. Extension services exist but farmers are reported to not fully trust the advice given by extension service staff, whom they do not see as dependent on yields for their livelihood. There are no real farmers' organizations for less educated small and medium-sized farmers. However, the village communities play an important role as education centers in rural areas.

The clear benefits of CA have helped its practices spread relatively rapidly throughout the Western Hemisphere, including in countries such as Brazil, Argentina and Paraguay. However, conservation practices are little known and less practiced in South America's most vulnerable cryosphere regions in Bolivia, Ecuador and Peru. Basic concepts of conservation agriculture have not been transferred to the Andean countries. Peru's first Spanish-language textbook on CA was just published last spring and is only now fighting its way into university curriculums. Similarly, conservation agriculture has had limited adoption or knowledge transfer in the Himalayan cryosphere, especially Nepal, Pakistan, and, to a lesser extent, India.

V. Next Steps: Catalyst Projects

The 2010 UNEP/WMO Assessment that formed the basis for the formation of the CCAC considered banning the open burning of agricultural waste as one of its mitigation measures.¹⁴ While such a moratorium is ideal, farmers themselves, local authorities and national governments must first be convinced that feasible and affordable alternatives are available and that farmers benefit from adopting them. Any mitigation effort must begin with changing individual farming community practices, along with providing accurate information about the adverse impact of burning and the existence of other options.

The feasibility and acceptability of different mitigation approaches depends on local conditions and perceptions. This is why the Open Burning component aims to take local considerations into account in designing and implementing catalyst projects to demonstrate that better practices work and carry not only social but also individual farmer benefits. Only then will more national and global efforts become possible and successful, with farmers themselves becoming advocates and ambassadors for change, organically spreading change by example, as can be seen in recent projects in the Chiquitania dry forest zones of Bolivia.

Successful implementation examples help demonstrate the validity of conservation agriculture practices and help catalyze ever-larger BC reductions from open burning. Key stakeholders in catalyst countries will recognize the opportunity to achieve both economic and societal benefits by scaling up these practices regionally and nationally. Broader implementation alternatives will reduce BC emissions on larger scales, with concomitant climate, air quality, health, agricultural, and economic benefits, leveraging the political will of the Climate and Clean Air Coalition (CCAC) partners and others.

Awareness of open burning as main contributor to SLCPs is only the first step—the goal is widespread implementation of CA practices that will have a measurable impact both on open burning practices and on emissions that reach the cryosphere.

¹⁴ United Nations Environment Programme and World Meteorological Organization (2011). Integrated Assessment of Black Carbon and Tropospheric Ozone. United Nations Environment Programme: Nairobi.

Based on the mapping and the results of the two regional conferences (also reported on the www.openburningcryosphere.org web page), further discussions took place to determine the best candidates for potential demonstration or “catalyst” projects, engaging both national stakeholders and CCAC Partners in this work, with design occurring both virtually and through expert missions to the two regions. Out of the initial wide net of 26 countries first mapped, the work has narrowed down potential catalyst projects to six where there is 1) extensive burning with strong local or regional cryosphere impact; 2) strong and engaged local partners willing to commit to project work, including in-kind support; 3) local and/or national government support and commitment; and 4) the potential to serve as models for local, national, regional and, indeed, global scale-up.

These six “catalyst” nations are outlined in Table 2 below. It is important to note that these particular countries and projects are not meant to be exclusive. “Catalyst” projects in additional countries, both within these regions and elsewhere, can help spur the transition to more climate- and-health-friendly alternatives that, most importantly, better secure yields and food security, resulting in permanent change.

Recommendations for Action Summary

Table 2

Country	Who	What	Where	Why	Alternatives	Importance of Burning / Opportunities
Bolivia	Small farmers	Crop residue. Sugarcane (pre harvest and residue). Forests.	Santa Cruz region mainly.	Cultural paradigm. Lack of mechanization and consciousness about soil properties.	Conservation Agriculture. Mechanization for sugarcane harvest. Increase production in already existing areas so as not to continue deforesting to increase total production.	High / High
Peru	Small farmers	Grasslands. Crops	Huancayo, Huaytapallana.	Cultural paradigm. Lack of mechanization and consciousness about soil properties.	Conservation Agriculture, Mechanization, Integration, Cattle management practices.	High / High
Ecuador	Small farmers	Grasslands, pasture. Crops	Equatorial coastal and central region.	Cultural paradigm. Lack of mechanization and consciousness about soil properties.	Conservation Agriculture, Infrastructure integration, Cattle management practices,	Medium / High

					Mechanization.	
India	All farms (small to large)	Wheat and rice residue.	Punjab region	Cultural paradigm. Lack of consciousness about soil properties and alternatives	Direct seeding, Integration Mechanization, Bioenergy. Improved drills	High / High
Pakistan	All farms (small to large)	Wheat and rice residue.	Punjab region	Cultural paradigm. Lack of mechanization and awareness of alternatives	Conservation agriculture, Infrastructure integration, improved drills	High / High
Nepal	Small to medium farmers	Wheat and rice residue.	Lumbini	Human capital shifts. Lack of mechanization, extension, and consciousness.	Conservation agriculture, infrastructure integration, mechanization, improved drills	High / Medium

Country-specific Opportunities

Bolivia

The Santa Cruz region of Bolivia offers immediate opportunities for advancing the knowledge and diffusion of best agricultural practices among small producers (10-40 ha) of soy, corn, rice and sugar cane, as well as among livestock producers. Appropriate community-level tools and technology are most suitable given the diversity of crops and large numbers of small producers. Efforts to promote agricultural innovation and best practices, especially among small producers, is a very high priority of the central government in La Paz, something not lost on those closest to the ground realities in Santa Cruz.

Peru

A May field mission to Peru documented clear opportunities for pilot projects in the region of Junin, near its principal city of Huancayo, and also in the private sector-dominated region of Cañete, closer to the coast. The small agrarian and livestock-based communities of the Altiplano region around Huancayo are anxious to participate in any pilot project. These communities are dependent upon water from the Huaytapallana Glacier, which is melting rapidly, with calvings increasing from 7 to 14 a day in the last five years. One farmer-led community (Acopalco) has already prohibited burning of cultivated fields and grasslands with good results, but all communities would need best practices education, technical assistance and tools in order to build on Acopalco's example. Local pasturelands are further threatened by the rapid invasion of an aggressive cultivar (*maca*) that is being encouraged by foreign investors but that is rapidly exhausting local soil and grassland fertility as it is always burned.

Ecuador

In Ecuador there is strong support from NGO, academic, and governmental development of community-level approaches to address agricultural burning. The international NGO Heifer Ecuador (<http://www.heifer-ecuador.org/>) works extensively with smallholder farmers. Three national federal agencies, including Instituto Nacional de Investigaciones Agropecuarias (INIAP; <http://www.iniap.gob.ec/web/>), the Ministerio de Agricultura, Ganaderia Acuacultura y Pesca (MAGAP; <http://www.agricultura.gob.ec/>), and the Ministerio de Ambiente (MAE; <http://www.ambiente.gob.ec/>) have expressed interest in researching and adopting sustainable non-burning practices as well as the development of non-burning farm prototypes. Other international institutes like the Pinchot Institute for Conservation (<http://www.pinchot.org>), could be engaged further to relate to their ongoing agriculture and conservation work. The Universidad Técnica de Cotopaxi has been an enthusiastic potential partner, with capabilities to assist with in-country ground-truthing as well as to potentially continue developed satellite data and ground monitoring. This group is highly trained in satellite data analysis, GIS, field data collection, environmental engineering and ecology, with access to computing facilities and labs.

India

India has introduced a ban on open burning. The ban has not been enforced and since farmers see no alternatives, the ban has had no effect in reducing burning.

Punjab is the richest agricultural region in India and accounts for about 40 percent of India's wheat and rice production. It has a comparatively well-developed infrastructure compared to the other countries and several research institutions in agriculture, air pollution monitoring, and development of new renewable energy sources, such as the use of straw combined with pyrolysis technology.

The Punjab Agricultural Management & Extension Training Institute (PAMETI), Department of Agriculture, Government of Punjab has offered to host the implementation of the project in there. PAMETI is located at Punjab Agricultural University Campus, Ludhiana. There is also an opportunity for establishing a national monitoring program in Mohali at the Indian Institute of Science Education & Research. The university hosts ongoing work to improve extension services in order to better work with farmers, including moving them from traditional beliefs and practices to non-burning, higher yield, no-till, direct seeding practices. In Mohali, the Indian Institute of Science Education and Research is in an excellent position to provide ground-truth monitoring of BC emissions as part of its air pollution program.

Indian Punjab has also tried a subsidy system for equipment purchase, but without any related education and demonstration of successful alternatives it showed little real success and the system was discarded. In 2009, 92 farmers in Punjab were invited to and supported in trying the so-called Happy Seeder, a mechanical seeder designed to be mounted on a tractor to provide drilling and direct seeding after a combine. The study showed that the overall costs were comparable to those of burning or slightly less but the difference was not so large as to be sufficiently convincing to lead to large scale adoption to replace burning. However, since then the Happy Seeder has been improved and a chopper has been added to shred the straw before drilling. New cost calculations have shown a considerable improvement over the first study in 2009. The improved Happy Seeder costs about USD2,500.

Independent observers see opportunities for further improving the Happy Seeder and the combines at relatively low costs. With the advent of the improved Happy Seeder, the basic problem is not technology, but rather changing attitudes and behavior. (Nepal and Pakistan are lagging behind in the adoption of the Happy Seeder, but there is a trend to a larger extent to adopt direct seeding practices in Nepal.)

Nepal

A prime region for a catalyst project is Lumbini, e.g., Rupandehi and Kapilbastu districts in southern Nepal. ICIMOD is planning an air pollution monitoring station in Lumbini that can contribute ground-truthing to project monitoring. The Nepal Agricultural Research Council also has a National Wheat Improvement Research Center located in the Lumbini zone and

has showed a strong interest in cooperating and implementing the project in the Lumbini region. There is also strong interest from various bodies in Nepal to address open burning but weak government support in terms of extension services and other infrastructure. The April 2015 earthquake in Nepal slowed work in the capital but had less impact in the above regions to the south of Kathmandu and work beginning in 2016 should still be feasible. CIMMYT (<http://www.cimmyt.org/en/>), with offices in Nepal and Pakistan, has a strong interest in the project and finds it aligns well with its own policies.

Pakistan

CIMMYT in Pakistan has committed to this work, and would be a useful partner and home for activities in Pakistan. In addition, there is strong cooperation with the Pakistan Agricultural Research Council (PARC) that would contribute to setting up a project in Pakistan. PARC is ready to become a partner in implementing such a project and is working to demonstrate the advantages of improved combines and seeders. It has recently developed a prototype seeder, the PAK seeder, which was used in demonstration activities in Lahore district at Daska and Gujranwala. PARC's experiences will be a valuable input to the implementation of the pilot project in Pakistan. The FAO national office in Pakistan has several operative projects in Pakistan and has also offered to participate in implementing a project on mitigating open burning in Pakistan.

VI. Scale-up: Implementing Viable and Sustainable Change

Based on our initial exploratory activities in the Andes and Himalayas, as well as ongoing activities in Russia, it seems clear that any program to address open burning would need to take the following realities into account:

- Farmers' main concerns are improving yields and fertility and maintaining financial sustainability at a time of highly uncertain economic and, at times, political stability.
- The hunger for new and more productive methods is a strong motivating factor, and many farmers would welcome new and stronger ties with Nordic, European and Americas farming counterparts in Argentina, Brazil, Mexico and the U.S.
- Farming community and organizational concerns also include protecting infrastructure and human health.
- Administrative and/or legislative sanctions, if they exist, have little impact because they are minimal, unenforced, and/or ignored--in part because farmers see little economic benefit to themselves at a time of unusual stress. Knowledge that burning harms their greatest resource (soil) along with identifying these methods as normative elsewhere in their region (Brazil and Argentina, for example) may shift this balance rather quickly and significantly towards support for such bans.
- Farmers need access, including potentially financial assistance, to appropriate equipment, although such financing is not a universal barrier and due to the greater crop yields, an issue of initial transition only. There are almost no instances of regions that have adopted conservation agriculture techniques returning

traditional methods for this very reason. Farmers simply save money through higher yields and lower costs for fertilizers and fuel.

- Climate concerns are secondary, though farmers are aware of and increasingly concerned by a changing and less reliable climate pattern. Indeed, winters and summers have become drier and hotter in recent years, which mean the advantage of no-till, low-till, and/or direct seeding practices that conserve moisture through maintaining stubble cover may increase the desire to transition.

Rapid change is possible. Programs to drastically reduce open burning have met with success in recent years. Poland's accession to the EU mandated that it reduce burning to substantially lower EU levels, which it did in 5 years. The Baltic countries also managed to do the same within 5-10 years. Agricultural burning in Krasnodar in Russia has diminished by 21 percent since the introduction of stricter legislation and enforcement in early 2014 as a result of the open burning project there. As climate change progresses, however, farms of all size across all regions are experimenting with various crop combinations and sequences. Legislative carrots and sticks are essential to support behavioral change, as is eliminating perverse incentives and widely-spread misinformation. These needs and cautions point to a multi-pronged approach consisting of:

- Education and information, including exchange of best practice and dissemination of information across all stakeholders—farmers, the public, scientists, officialdom and others;
- Introduction of financially sustainable and culturally appropriate alternative technologies;
- Support from local authorities (at least passive) and farmer organizations, and, ideally;
- The introduction of stricter legislative sanctions and official commitment to make them stick; and, if necessary,
- A financing mechanism to support purchase of more appropriate tools and technology than are currently available.

Both regions offer a number of potentially active (or even new) CCAC Partners. Both also offer clear climate benefits due to their proximity to important cryosphere regions, in addition to proven health and infrastructure protection co-benefits. The Open Burning Component chose these initial regions to avoid any potential controversy about climate impacts, given that crop and health impacts are clear. We note that the Arctic is also important in this sense, and no-burn policies and/or bilateral programs to address burning have existed there (Russia) for several years, supported by Nordic countries and private foundations and implemented by CCAC partners Bellona and ICCI. Using these existing Arctic efforts as a model for new CCAC work in regions where no one else currently is addressing open agricultural burning provides true value-added for the Coalition.

Each current or future catalyst project will have in common three “legs” identified as necessary for success:

- (1) **Farmer Outreach and Education** conducted through study tours, Field Days to demonstrate methods, and production of local-language educational materials, including information on the negative impacts of burning on soils and crop yields as well as air quality, health and nearby water resources from glaciers/snowpack; country-and crop-appropriate alternatives; and how to integrate these practices in a holistic approach to improved agricultural methods and adaptation.
- (2) **Demonstrating Impact** through continued satellite and on-the-ground monitoring and evaluation of fires and related pollution emissions, including where possible direct BC monitoring on nearby snow and glaciers.
- (3) **Policy Support** to local and national authorities, conveying measures and regulations used successfully elsewhere, from subsidies for alternative equipment to regulation of burning.

Each leg is critical to ensuring that the project achieves sustainable and scaled-up change. Eventual global scale-up will explore policies, financial mechanisms, and other approaches to incentivize and motivate farmers to adopt no-burn practices. An important element to open burning as an SLCP source is that the measures to address it – in particular, CA – are not only cost-effective, but ultimately economically beneficial to the farmer. This is one reason why these practices have already spread in other countries.

The CCAC's unique position allows it to connect open burning, climate, air quality and agricultural yields, demonstrating these alternatives across a variety of crop systems and national realities. Because of these strong economic co-benefits, it is not anticipated that further CCAC financing would be required, as open burning and its alternatives join the climate, agriculture and development financing "mainstreams" as a win-win solution for the individual farmer, food security, climate and air quality. In doing so, it will ensure that the catalyst projects are sustained well beyond the end of the CCAC investment.

Rapid change and emissions reductions are possible, especially when these correspond to farmers' needs and economic well-being. Whole regions have already converted to no-burn methods, often over startlingly brief periods, as in Poland and parts of Argentina. The CCAC be the catalyst for transition in regions where climate impacts from open burning – in near-cryosphere regions where combinations of wind and weather take black carbon directly to glacier and snowpack – are greatest. The effort requires a combination of farmer education and incentives with political will and measures and, not least, connections with related agriculture and climate work by global actors such as FAO, UNEP and the multilateral development banks, in partnership with the CCAC.

With these ingredients, open burning can and will become a relic of the past.